J. Print Media Technol. Res.
Vol. V – No. 4 (267–350)
December 2016

4-2016

ISSN 2414-6250 (Online)
CODEN JPMTBI
UDC 665

Journal of Print and Media Technology Research

Scientific contents

ISSN 2414-6250

Editor-in-Chief Gorazd Golob (Ljubljana)

Published by iarigai The International Association of Research Organizations for the Information, Media and Graphic Arts Industries

www.iarigai.org

J. Print Media Technol. Res.
5(2016)4, 267–350
September 2016

No. 4-2016
ISSN 2414-6250 (Online)
available also as (on demand) print
publication ISSN 2223-8905 (Print)
CODEN: JPMTBI

Journal of Print and Media Technology Research

A peer-reviewed quarterly

PUBLISHED BY

The International Association of Research Organizations
for the Information, Media and Graphic Arts Industries

Magdalenenstrasse 2, D-64288 Darmstadt, Germany
http://www.iarigai.org E-mail: journal@iarigai.org

A mission statement

To meet the need for a high quality scientific publishing in its research fields of interest, the International Association of Research Organizations for the Information, Media and Graphic Arts Industries (iarigai) publishes the peer reviewed quarterly Journal of Print and Media Technology Research.

The Journal is fostering multidisciplinary research and scholarly discussion on scientific and technical issues in the field of graphic arts and media communication, thereby advancing scientific research, knowledge creation and industry development. Its aim is to be the leading international scientific periodical in the field, offering publishing opportunities and serving as a forum for knowledge exchange between all those scientist and researchers interested in contributing to or benefiting from research in the related fields.

By regularly publishing peer-reviewed high quality research articles, position papers, survey and case studies, the Journal will consistently promote original research, networking, international collaboration and the exchange of ideas and know how. Editors will also consider for publication review articles, topical and professional communications, as well as opinions and reflections of interest to the readers. The Journal will also provide multidisciplinary discussion on research issues within the field and on the effects of new scientific and technical development on society, industry and the individual. Thus, it will serve the entire research community, as well as the global graphic arts and media industry.

The Journal will cover fundamental and applied aspects of at least, but not limited to the following fields of research:

Printing technology and related processes

- ◇ Conventional and special printing
- ◇ Packaging
- ◇ Printed fuel cells and other printed functionality
- ◇ Printing on biomaterials
- ◇ Textile and fabric printing
- ◇ Materials science
- ◇ Process control

Premedia technology and processes

- ◇ Color management and color reproduction
- ◇ Image and reproduction quality
- ◇ Image carriers (physical and virtual)
- ◇ Workflow management
- ◇ Content management

Emerging media and future trends

- ◇ Media industry developments
- ◇ Developing media communication value system
- ◇ Online and mobile media development
- ◇ Cross-media publishing

Social impacts

- ◇ Environmental issues and sustainability
- ◇ Consumer perception and media use
- ◇ Social trends and their impact on media

Submissions to the Journal

Submission details and guidelines for authors can be found on the inside back cover of this issue, as well as downloaded from http:// www.iarigai.org/publications/journal.

Subscriptions

http:// www.iarigai.org/publications/journal/order
or send your request to office@iarigai.org.

✉ Contact the Editorial office: journal@iarigai.org

Journal of Print and Media Technology Research

4-2016

December 2016

J. Print Media Technol. Res. 5(2016)4, 267–350

Journal of Print and Media Technology Research is listed in:

Index Copernicus International

PiraBase (by Smithers Pira)

Paperbase (by Innventia and Centre Technique du Papier)

NSD – Norwegian Register for Scientific Journals, Series and Publishers

ARRS, Slovenian Research Agency – List of Scientific Journals
(not included in the foreign bibliographic databases)

Printed in Slovenia by Collegium Graphicum, d. o. o. Ljubljana

Contents

A letter from the Editor

Gorazd Golob
Editor-in-Chief
E-mail: gorazd.golob@jpmtr.org
journal@iarigai.org

In the present 4th issue of the Journal in 2016, two papers from 3D printing technology research field appears for the first time, both submitted by the same research group. This relatively new area represents one of the promising directions of manufacturing technology development in general, but also in the field of printing. The use of 3D printing, also called rapid prototyping or additive manufacturing technologies, rapidly grows in many areas. First research, patents and solutions already appeared in the 1980's and today 3D printing is present in a form of a simple output device at homes and elementary schools for rendering of 3D models, useful items, toys and other objects; or as hi-tech professional research and production equipment, using dedicated materials and technical solutions, and being imposed in almost all areas of human activity. In published two papers the research results presents the appropriateness of the use of 3D printing in medicine, where advanced printed polymeric materials can potentially replace bones and thus displace dominant metal implants. Preliminary clinical trials and first implementations were already realised and are reported in quoted papers, but certainly in this area much more room for improvement and innovations is open. Depending on the intended end use in human bodies, the cooperation of various medical, scientific and other disciplines is indispensable and the respect of highly positioned ethical codes and other rules must be observed by all participants. The authors of the articles published are aware of this and commitments are respected. I hope that in the future we can expect more contributions from this field, along with the research reports of 3D printing in other areas.

Excellent overview of news, publications and events on this subject, in addition to other innovations, was once again prepared by the Associate Editor Markéta Držková (marketa drzkova@jpmtr.org). I would especially like to mention an overview of news in the field of color and lighting, which covers the activities of the CIE, and the contribution of Ghent Workgroup in the development, utilization and standardization of PDF file format. Summaries of the content of three high-profile doctoral theses show the achievements in the field of modern printing technology and prepress, new approaches to the treatment and evaluation of digitized images, and new materials and their application in the field of printed electronics.

The third paper is published on the media, or more precisely, the scope and role of gender in the print media. The topic is certainly interesting, although falling in the border area of our interest covering research on the social role of the media, rather than the technology itself. However, this is to complement and continuation of themes that were discussed in the JPMTR Special Issue: Audience, design, technology and business factors and new media innovation published in Summer 2016.
In the fourth article, authors deal with the theoretical basis of the links between medieval scribe and modern book graphic designers, notably by presenting and justifying the idea of the "systematization" and "automation" process of graphic design, of course by keeping the creative role of the process. Programming of the proposed functional model is only implied, however its realization would mean yet another evolutionary step forward in the field of book design and also in general press and media field.

The five-year period of the current format of the Journal, designed especially for the printed edition, is coming to an end and in 2017 we will experience some changes, using primarily online publication. I hope and I wish to continue our mission with the support of the iarigai – our publisher, and contributions of the authors, reviewers, editors, subscribers, and, of course, the readers – end users. Invitation to participate is continously open, so I invite you to participate with your contributions in the field of conventional printing technologies, digital printing, printed electronics, packaging, color reproduction, media developement, the social impact of media, materials, 3D printing and all other areas that gather and connect us to the Print and Media Technology Research.

Ljubljana, December 2016

JPMTR 088 | 1608
DOI 10.14622/JPMTR-1608
UDC 620.1|531-3:678.5

Research paper
Received: 2016-08-11
Accepted: 2016-12-16

Mechanical properties of 3D printed polymers

Azem Yahamed[1], Pavel Ikonomov[2], Paul D. Fleming[1], Alexandra Pekarovicova[1], Peter Gustafson[3], Arz Qwam Alden[3] and Saif Alrafeek[3]

[1] Department of Chemical and Paper Engineering, Western Michigan University, Kalamazoo, MI 49008

[2] Department of Engineering Design Manufacturing, and Management Systems, Western Michigan University, Kalamazoo, MI 49008

[3] Department of Mechanical Engineering, Western Michigan University, Kalamazoo, MI 49008

E-mails: azemkhalifa.yahamed@wmich.edu
pavel.ikonomov@wmich.edu
dan.fleming@wmich.edu
a.pekarovicova@wmich.edu

Abstract

Polymeric bone implants are used in many medical applications. To create bone structures from plastics that can match the real bones, the structure and mechanical properties must be tested to make sure they can sustain loads comparable to the original. Also, it is very important to use proper materials that provide biocompatibility. In this work, the mechanical properties of 3D printed samples of thermoplastic materials that can be used for 3D printing of human bone structure substitutes were tested. The thermoplastics that were printed using 3D printing are acrylonitrile butadiene styrene (ABS), Digital ABS™, polylactic acid (PLA), polyetherimide ULTEM 9085 and polyamide PA 2200. The samples of ABS and PLA were printed using fused deposition modeling technology (FDM), Digital ABS™ was printed using PolyJet™ technology, and ULTEM 9085 and PA 2200 were printed using selective laser sintering (SLS). Compression tests showed that PLA and Digital ABS™ create anisotropic 3D printed structures, because they exhibited different stress vs. strain properties in different directions. The samples made from ABS, ULTEM9085 and PA2200 have the same shape of stress-strain curves in different printing directions, but different slopes, which shows that these printed structures are also anisotropic. Differential scanning calorimetry was used to acquire the thermal analysis profile of these polymers. The thermal analysis results of these polymers indicate that ABS and ULTEM9085 are amorphous while PLA is partially crystalline and PA2200 is completely crystalline.

Keywords: polymeric material, fused deposition modeling, bone structure, 3D model, selective laser sintering

1. Introduction

The goal of this work is to design and build bone structures from biocompatible plastic materials and investigate their mechanical properties. We studied and tested several biocompatible materials to investigate the possibility of their use in bone structures by using three-dimensional (3D) printing. Replicating of the bone structures is a complex process of imaging, design and fabrication of replacement tissue, which has been the subject of several studies in recent years.

1.1 Building bone structures

Initially, image slices of bones according to digital imaging and communications in medicine (DICOM) standard are acquired using magnetic resonance imaging (MRI) or computed tomography (CT) scans from actual body organs. Next, 3D modeling software is used to produce a new part or the model of the missing bone structure. The 3D model is then imported into 3D printing software for building the substitute bone structure (Leukers et al., 2005). Recently, there have been many successful attempts to 3D print items for human bone substitutes, using 3D printing technology (Ehrenberg, 2013a; 2013b).

1.2 Thermoplastics

Thermoplastics have been used successfully as replacements for certain metals for many years in manufacturing and have been used widely in medical applications

(Jia and Kagan, 2001; Lasprilla et al., 2012). In applying these materials, 3D printing has a significant role, providing high performance, cost efficiency and enhanced resistance to environmental conditions. The low melting temperature used in 3D printing is considered an advantage of the technology to create high quality parts for manufacturing and in medical applications, also allowing precise manufacturing for replacement of tissue, specifically bone structures.

1.3 Fused Deposition Modeling

Fused Deposition Modeling (FDM) is a method widely used to produce 3D printed items from thermoplastics (Ahn et al., 2002; Materialise, 2016a). The first step is to create a 3D model and then convert it to STL (stereolithography) file format to produce the 3D object. This format has some advantages and disadvantages. The advantage of STL format is that it facilitates the geometry of the object by reducing it to its initial components and it can maintain and adjust the geometry of 3D model such as shape and size. The disadvantage of STL format is that the object loses some of its resolution because it uses only triangles to represent the complex geometry. Once the STL file format is imported to the 3D printing software to be prepared for 3D printing, it is sliced into numerous thin slices that become layers during the 3D printing process.

These layers define the two-dimensional planes that the 3D printing process will produce to build the 3D object. When created, the layers are stacked upon one another, thus creating a 3D object directly from the original design. It is obvious that the thinner the layer is, and higher the precision is of the 2D movement, the higher is the precision that can be carried out for an item (Hutmacher, 2000). The working mechanism of the FDM technique is that it takes a plastic filament from a coil and drives it through an extruder. The plastic is heated and melted by the heat extrusion nozzle, the molten filament flows through the nozzles, and is deposited on the building plate to form a layer. The heads move on the X-Y axes to follow a predefined path to form a specific shape on each layer. Then, the platform moves vertically in the Z direction to produce the next layer (Hutmacher, 2000). Three-dimensional printing with thermoplastics is one of the most common methods to create 3D structures in both medical and industrial fields (Fischer, 2011).

1.4 Selective Laser Sintering

Selective Laser Sintering (SLS) is another rapid prototyping process that can manufacture 3D structures directly from 3D models. Applying laser sintering technology, objects are built layer by layer (Materialise, 2016b). The method uses a high-power laser to fuse tiny particles of powders, such as plastic, metal, ceramic and glass, into a structure that has a desired 3D form. The principle of SLS process is that a thin layer of powder is distributed and leveled by a roller above the flat surface. Then, a laser beam follows a defined profile on the layer and melts the powder that bonds together. To make room for the new layer of powder, the piston in the cylinder shifts down by one layer thickness.

Next, the powder supply piston goes up to provide a fresh amount of powder for the subsequent layer. The powder is distributed again on the flat surface. The laser repeats the same process as on the first layer. This process repeats layer by layer until the entire object is built. The SLS technique is capable of producing objects from an extensive variety of powder materials. These materials can contain polymers, such as nylon or polystyrene, or metals, such as steel, titanium, alloy mixtures and green sand. In addition, materials that can be used are polyamide, glass filled polyamide and alumide, a combination of aluminum and polyamide (Materialise, 2016b; Palermo, 2013).

For medical purposes, SLS has been used for making bone tissue engineering builds for sites, such as temporomandibular joint using polycaprolactone, since it provides a technique to build scaffolds to match the anatomical geometry of periodontal structures. The method allows building scaffolds with complicated inner and outer structures (Williams et al., 2005).

1.5 Stereolithography

Stereolithography is a developed process using a container of liquid UV-curable monomer and a UV laser to construct layers. For each layer, the laser ray draws a cross-section of the part model on the surface of the liquid resin. When the resin is cured by the laser beam it solidifies; after movement in the X-Y direction following the layer pattern, the layer of the model is created and bonds to the lower layer. When the laser ray hits the surface of the liquid monomer, the photopolymer is created, which rapidly hardens. After one layer is totally drawn, the stage is lowered one step down into the container and the second layer will be sketched on top of the first. The material bonds every layer to the prior one, repeating the process over-and-over again till it builds the entire shape of the 3D part. Stereolithography is a fast method that has a high level of precision and good finishing properties (Materialise, 2016c).

1.6 PolyJet technology

PolyJet™ technology (Stratasys, 2016a) is a manufacturing process that can produce smooth, exact parts with a layer resolution of 16 µm and precision of 0.1 mm height. The process can produce thin walls and complex geometric shapes with many materials. PolyJet 3D printing jets layers of curable liquid photopolymer onto a build substrate, which is like inkjet printing that fires drops of ink onto paper. The build preparation software automatically estimates the placement of photopolymers and support material from a 3D CAD file. The 3D printer jets and directly UV-cures small drops of liquid prepolymer. The adherent layers gather on the build substrate to generate an accurate 3D model. The 3D printer jets a removable gel like support material when the complex shapes are in need for support. Then, the support material can be removed easily by the operator's hand or flushing with water. PolyJet 3D printing technology can offer several advantages for rapid prototyping. The technology can make smooth detailed prototypes, produce complex shapes, complicated details and smooth surfaces. In addition, it can combine color and various material properties into one model with the best material versatility obtainable.

2. Methods

2.1 Three-dimensional printing of test samples

We used SolidWorks software to design and create 3D models for tensile test, compressive test and bending test samples with specific dimensions according to the MTS published standards (MTS, 2014; 2015a). Then, using 3D printing technology five different 3D printed samples of polymeric materials were printed, with five replicates for each sample for each test: acrylonitrile butadiene styrene (ABS) (Test Standard Labs, 2016), polylactic acid (PLA) (MakeItFrom, 2015), polyetherimide ULTEM9085 (Stratasys, 2016b), polyamide PA2200 (EOS, 2015), and Digital ABS™, an acrylic photopolymer, (Stratasys, 2016c). Although ABS is not biocompatible material, it is used as a reference for comparison with other polymers. Polylactic acid is a biopolymeric material that can be used in the human body. The polymer has great biocompatibility and mechanical properties, and, because of these features, is widely used in tissue engineering (Lasprilla et al., 2012). A study was performed to evaluate the biocompatibility of the prepared polyetherimide (PEI) by using osteoblast cell line MG63. The results of the research by Tao and Young (2006) showed the PEI was helpful as a tissue engineering scaffold for bone regeneration. PA2200 is biocompatible and it can be used in several medical applications. For instance, compressed structures for scaffold supporting, soft tissue and osseous augmentation are used in neural implants (Stoia, Vigaru and Rusu, 2015).

Selected mechanical and physical properties of these materials are shown in Table 1.

To make 3D printing objects, 3D models need to be created in advance; 3D slicer and OsiriX software were used to design 3D models that were then converted to STL format for 3D printing. The sample size and dimensions can be controlled as needed. Parameters of 3D printing, such as temperature, extruder speed, infill percentage (100–0 % volume), temperature of the heated plate and resolution can be also controlled. Figure 1 shows the 3D printer running while printing the test sample.

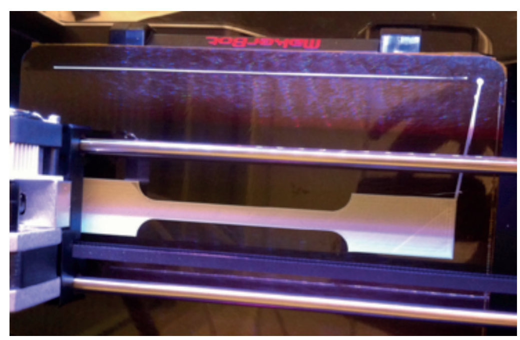


Figure 1: 3D printing tensile test sample on MakerBot

2.2 Testing mechanical properties of 3D printed samples using MTS test system

After printing 3D samples for tensile tests, compression tests and bending tests, we tested the samples using MTS Bionix Servohydraulic Test Systems Model 370.02. The force capacity of the device is 25 kN and it is used to determine the quasistatic mechanical proper-

Table 1: Selected properties of polymeric materials from the material safety data sheets (MSDS)

Material	Tensile strength (MPa)	Young modulus (MPa)	Melting point (°C)
ABS	44.8	2 250	100*
PLA	57.8	3 500	160
ULTEM9085	71.6	2 200	186
PA2200	48.0	1 700	172–180
Digital ABS™	60.0	2 600–3 000	47–53*

* Melting temperature is replaced by the glass transition temperature (*Tg*) for ABS and Digital ABS™, since these materials cannot be crystallized.

ties for a number of biomaterials. The axial alignments of the system are intended to achieve precise tension, compression and bending tests as well as fatigue and fracture studies. Also, they are used to test durability properties of components such as hip, knee and spine implants (MTS, 2015b).

The tested samples were designed according to the MTS standards with specific dimensions for all mechanical property tests. We tested the 3D printed samples at 0.2 mm/s speed of the MTS machine at room temperature.

2.3 Creating of 3D bone structure model using OsiriX

OsiriX is a free open-source software used to create 3D models of human organs from CT, MRI and ultrasound scans. These provide high quality images used for different medical applications including surgeries. To create 3D models for 3D printing bone structures, DICOM images from CT and MRI were acquired by obtaining information from actual patients (Ikonomov and Yahamed, 2014).

For creating 3D models, there are several steps required. The initial step is that the region of interest (ROI) must be selected on each image. After that, the segmentation should be performed to separate the borders of the organ. An example of using OsiriX to make the 3D model is shown in Figure 2. OsiriX enables to view, approximate, read and post process the images, with the techniques for 2D imaging, database, and 3D models.

Figure 2 illustrates the collection of images used to describe the ROI and segmentation, (highlighted in green color), to create the 3D model. Once the segmentation is finished through all the slides, the volumization is carried out to create the final 3D shape. As shown in Figure 3, the 3D model is visualized by OsiriX. Then the model is exported to 3D format, which is STL in our case, to be printed by a 3D printer. The mechanical properties of the 3D printed samples can be tested, once the samples for the MTS test machine are printed at ambient temperature.

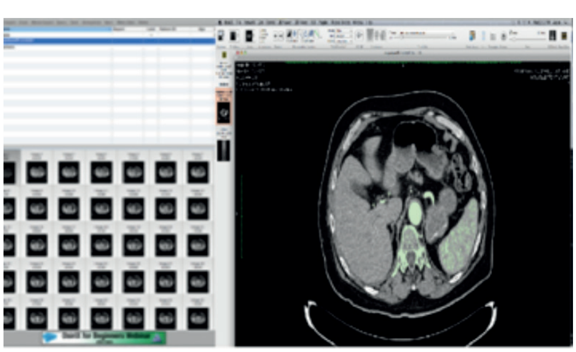


Figure 2: Region of interest and segmentation in OsiriX

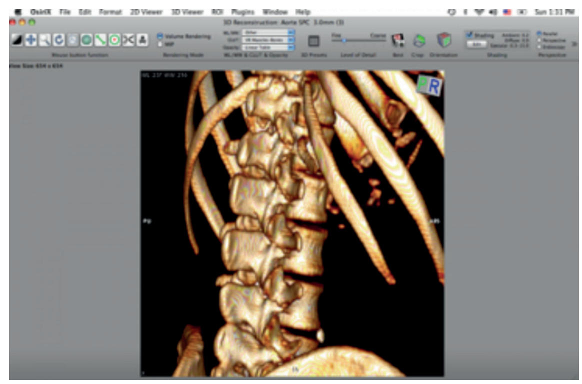


Figure 3: 3D model created after segmentation in OsiriX

2.4 Cleaning 3D model using MeshLab

Before 3D printing, the mesh model needs to be cleaned and smoothened. We used MeshLab software for cleaning of the mesh, which means removing all the tiny geometrical irregularities that may be found in shell meshes. Common problems that usually occur in the model are duplicated vertices, unreferenced null faces, self-intersecting faces, non-manifold faces and small holes. For filling holes, we use the hole filler tool that allows us to select holes and edit them in different ways. The basic filling algorithm uses a technique that inserts a face between the two adjacent border edges. This algorithm selects every time the best pair of adjacent border edges into the hole. Then smoothing of the model is performed, as shown in Figure 4 (Yahamed, Ikonomov and Fleming, 2014). A bone structure sample was printed to test the accuracy of the 3D printer as shown in Figure 5. For that, 3D models were exported to STL format to be printed by the 3D printer (MakerBot replicator 2X).

2.5 Thermal analysis by Differential Scanning Calorimetry

Differential Scanning Calorimetry (DSC) was used to investigate the amorphous and crystalline behavior of these polymers. This tool is important in thermal analysis to investigate how the enthalpy of materials is changed by temperature. A sample with known weight is heated or cooled and the changes in its heat capacity are tracked as changes in the heat flow. This can detect transitions, such as glass transition temperatures and melting temperatures (Pekarovicova, Chovancova-Lovell and Fleming, 2006). Test samples of 0.045 g for all polymers were used. For the first cycle, the sample was held for 1 min at 35 °C, then it was heated from 35 °C to 260 °C at 10 °C/min. After that, it was held for 1 min at 260 °C and cooled from 260 °C to 35 °C at 60 °C/min. The same steps were repeated for the second cycle for all the samples. These analyses indicate how the polymers behave after reheating and recooling.

Figure 4: 3D model of vertebra cleaned by MeshLab software

Figure 5: 3D printed bone vertebra structure

3. Results and discussion

3.1 Tensile strength tests

Five different polymeric materials were printed and tested using the MTS machine. The FDM technique was used to print ABS, PLA and ULTEM9085 polymeric materials (see Table 1 for selected properties). The SLS method was used to print one polymeric material PA2200. PolyJet Technology was used to print Digital ABS™. Five samples were printed for each material. All the samples were printed as a solid at 100 % of infill. We used an MTS machine to test the tensile strength, compression and bending of the 3D printed polymeric specimens. Specific equations were used to calculate stress and strain for each test. Figure 6 shows the stress-strain curves of the materials, calculated by least squares regression of the experimental data using a quadratic polynomial at 100 % infill and the MTS machine speed of 0.2 mm/s at room temperature for tensile test.

The equation regressed to the stress-strain data is of the form

$$\sigma = E\varepsilon + F\varepsilon^2 \qquad [1]$$

where σ is the stress, ε is the strain and E is Young's modulus. The coefficient of the squared term, F is negative for convex curves and positive for concave curves (Boyd and Vanderberghe, 2004; Weisstein, 2016). The fits were regressed in Minitab™ with no intercept. Comparison of measured and fit data are given in the Appendix.

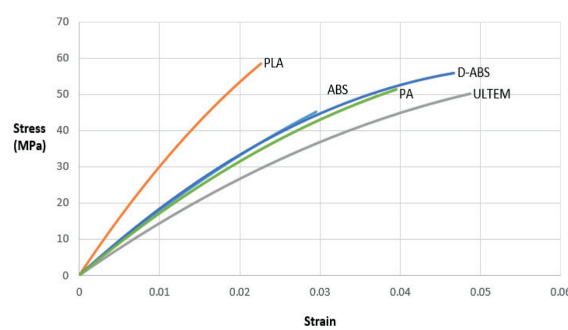


Figure 6: Tensile stress-strain calculated from least squares fit to tensile data for the materials

The shapes of stress-strain curves pinpoint brittle structures, which do not exhibit any dramatic change in elongation prior to rupture. Beer et al. (2012) reported that brittle material ruptures without any obvious prior change in the rate of elongation.

Table 2 shows the results of the tensile strength and Young's modulus after testing with the MTS machine. By making a comparison between the results of the tensile strength of 3D printed samples, and the values of the material safety data sheet (MSDS) from the manufacturer, both measured tensile strength and Young's modulus values were slightly less than the ones provided by the manufacturer, which was most likely due to repeated heating and extrusion of the tested polymeric samples. For PA2200 that was printed by SLS they were indistinguishable from the values obtained from the manufacturer.

Table 2: The values and standard deviations of tensile strength and Young's modulus of the polymers at 100 % infill after testing with MTS machine

Material	Tensile strength (MPa)	SD (MPa)	Young's modulus (MPa)	SD (MPa)
ABS	44.0	2.0	1 925	29
PLA	57.0	2.0	3 333	18
ULTEM9085	49.7	0.6	1 540	3
PA2200	49.7	0.7	1 699	12
Digital ABS™	55.0	3.0	2 013	12

From Table 2, PLA has the highest values for both Young's modulus and tensile strength. After that, Digital ABS™ has the second highest values for both Young's modulus and tensile strength. On the other hand ULTEM9085 has the lowest value for Young's modulus and ABS has the lowest value for tensile strength. Cortical bones have a compressive strength in the range of 131–224 MPa, and a Young's modulus ranging from 17 000–20 000 MPa, while compressive strength and Young's modulus for trabecular bones are 5–10 MPa and 50–100 MPa, respectively (Razak, Sharif and Raman, 2012). The strength and modulus of the polymers are less than the criteria of the compact bone, but they exceed the criteria of the trabecular bone.

Table 3 shows the breaking energy per unit mass and energy per unit mass absorbed per unit strain for the polymers at 100 % infill. Here, PA2200 has the highest values for both tensile breaking energy per unit mass and energy per unit mass absorbed for unit strain (121 kJ/kg and 3951 kJ/kg), respectively.

3.2 Compressive tests

Figures 7 and 8 show the stress-strain curves calculated (from least square fits to compression stress-strain data, using equation similar to Equation 1) at 100 % infill for compression tests in X and Z directions accordingly, while Figure 9 shows the stress-strain curves and calculated (from regression fits to equation similar to Equation 1) at 100 % infill for bending tests. The comparison of fits to raw data are given in the Appendix.

Compression tests give information about the compressive properties of the material of interest. The specimen dimensions were printed according to the standard, and they can be either blocks or cylinders for this test – in our case we made them blocks with the specific dimensions according to ASTM D695 (ASTM International, 2015a). The compressive test properties explain the performance of the material when it is compressed under a load that is relatively low and uniform. The equations used to calculate stress and strain for compressive tests are the same as for tensile tests.

Figures 7 and 8 show the relation between stress vs. strain and the fitted points of the samples for each material. For ABS polymer, the curves appear convex as in Figure 7, when the material was printed horizontally along the X axis, and in Figure 8 when it was printed vertically in the Z axis, but the slopes are not the same in both printing directions. This indicates that this material creates anisotropic 3D printed structures, because it has different slopes in different printing directions. Table 4 shows the values of the compressive strength and compressive modulus for selected materials from MSDS.

For PLA, when it was printed along the X axis, the curve appears convex, while it appears concave when it was printed perpendicularly along the Z axis. This indicates that PLA created anisotropic 3D printed structures, since it has different behavior in different printing directions.

Table 3: Density and the values and standard deviations of breaking energy per unit mass and energy per unit mass absorbed per unit strain for the polymers at 100 % infill

Material	Density (kg/m^3)	Breaking energy per unit mass (kJ/kg)	SD (kJ/kg)	Energy per unit mass absorbed per unit strain (kJ/kg)	SD (kJ/kg)
ABS	1.04×10^3	42.0	2.0	1 851	28
PLA	1.25×10^3	46.0	2.0	2 666	14
ULTEM9085	1.34×10^3	37.3	0.4	1 149	2
PA2200	0.43×10^3	121.0	2.0	3 951	28
Digital ABS™	1.18×10^3	47.0	3.0	1 706	10

Table 4: Compressive strength and compressive modulus for selected materials from MSDS

Material	Compressive strength (MPa)	Compressive modulus (MPa)
ABS	65	2 500
PLA	80	4 000
ULTEM9085	104	1 930
PA2200	58	1 500
Digital ABS™	110	2 200

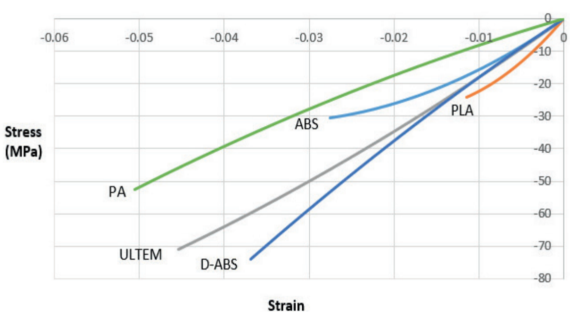


Figure 7: Compressive stress-strain calculated from fits at 100 % infill for the materials in X direction

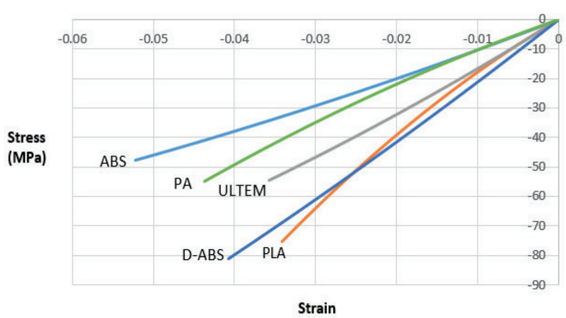


Figure 8: Compressive stress-strain calculated from fits at 100 % infill for the materials in Z direction

The same behavior was found with Digital ABS™, which was printed by using PolyJet™ technology. When it was printed along the X axis, the curve appears concave, while it appears convex when it was printed vertically along the Z axis. This indicates Digital ABS™ also creates anisotropic 3D printed structures.

The rest of the materials showed the same behavior in both directions (Figures 7 and 8). For ULTEM9085 the curves were convex, while for PA2200 the curves were concave in both printing directions; but the slopes are different in both printing directions for both materials. This is an indicator that ULTEM9085 and PA2200 also form anisotropic 3D printed structures. All of these materials have in common that they are thermoplastic polymers, which means that they form linear polymeric chains, thus it can be expected, that the strength is highest in the direction of polymeric chains, and in other directions the strength will be lower.

Table 5 shows the results of compressive strength and compressive modulus after testing with the MTS machine. The table shows the results of the polymeric samples that were printed at 100 % of infill along both directions X and Z for compression tests. It is obvious that the values of the compressive modulus and compressive strength of the tested samples are lower than the original values from the MSDS (Table 4). It was found that for compressive modulus the values of the concave figures are less than the values of the convex figures regardless the printing direction, but if the figures have the same shape in both printing directions, then the values of the compressive modulus of the samples that were printed vertically along the Z axis are less than the ones that were printed horizontally along the X axis and vice versa for the compressive strength.

From Table 5, PLA has the highest compressive modulus in the X direction and the second highest compressive strength in the Z direction. Digital ABS™ has

Table 5: The values and standard deviations of compressive strength and compressive modulus after testing with MTS machine

Material	Print Direction	Compressive strength (MPa)	SD (MPa)	Compressive modulus (MPa)	SD (MPa)
ABS	X	30.0	2.00	1 839	12
ABS	Z	45.0	7.00	1 055	20
PLA	X	24.7	0.60	3 077	29
PLA	Z	74.8	0.30	1 610	28
ULTEM9085	X	70.0	0.05	1 870	13
ULTEM9085	Z	55.0	0.05	1 721	10
PA2200	X	51.9	0.20	1 175	23
PA2200	Z	54.9	0.20	1 064	24
Digital ABS™	X	75.0	5.00	2 157	20
Digital ABS™	Z	80.0	0.04	1 729	20

Table 6: The values and standard deviations of compressive breaking energy per unit mass and compressive energy per unit mass absorbed per unit strain for the polymers at 100 % infill

Material	Print Direction	Breaking energy per unit mass (kJ/kg)	SD (kJ/kg)	Energy per unit mass absorbed per unit strain (kJ/kg)	SD (kJ/kg)
ABS	X	29.0	2.00	1 768	11
ABS	Z	43.0	7.00	1 014	19
PLA	X	19.8	0.50	2 462	22
PLA	Z	59.8	0.20	1 288	21
ULTEM9085	X	52.2	0.04	1 396	10
ULTEM9085	Z	41.0	0.04	1 284	7
PA2200	X	120.7	0.50	2 733	51
PA2200	Z	127.7	0.50	2 474	53
Digital ABS™	X	64.0	4.00	1 828	17
Digital ABS™	Z	67.8	0.03	1 465	17

the highest compressive strength in the Z direction and the second highest compressive modulus in the X direction. On the other hand PA2200 has the lowest compressive modulus in the X direction and ABS has the lowest compressive modulus in the Z direction. The compressive modulus values of human trabecular bones range from 1 MPa to 5000 MPa, with strength values ranging from 0.10 MPa to 27.3 MPa (Williams et al., 2005). The polymers show compressive modulus values ranging from 1175 MPa to 3077 MPa when they were printed horizontally along the X axis and from 1055 MPa to 1729 MPa when they were printed vertically along the Z axis. The compressive strength values of the polymers range from 25 MPa to 75 MPa for the samples that were printed along the X axis and from 45 MPa to 80 MPa for the ones that were printed along the Z direction. The compressive modulus values fall within the range of human trabecular bone, while the compressive strength values exceed the range of human trabecular bones.

Table 6 shows the compressive breaking energy per unit mass and compressive energy per unit mass absorbed per unit strain for the polymers at 100 % infill. Here, PA2200 has the highest values for compressive breaking energy per unit mass and compressive energy per unit mass per unit strain in both printing directions X and Z.

3.3 Bending tests

Bending tests measure the force required to bend a beam under three-point loading conditions. The purpose of this test is to select materials for parts that support loads without bending. The flexural modulus indicates the stiffness of material when bent. The load is applied to the center generating three-point bending at a given rate. The test results are the support span, loading rate, and the determined deflection. They all are based on the specimen thickness and are defined by ASTM D790 (ASTM International, 2015b). The equations used to calculate bending stress and bending strain are different from those used to calculate stress and strain for tensile and compressive tests. Figure 9 shows clearly the convex shape of bending stress-strain curves for all materials except Digital ABS™, which appears concave. Table 7 shows the flexural strength and flexural modulus of the selected materials from their MSDS.

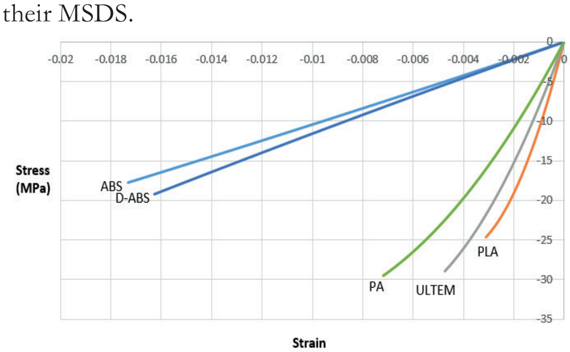


Figure 9: Stress-strain calculated from fit to bending data at 100 % infill for the material

Table 7: Flexural strength and flexural modulus for selected materials from MSDS

Material	Flexural strength (MPa)	Flexural modulus (MPa)
ABS	69	2 300
PLA	80	4 000
ULTEM9085	115	2 500
PA2200	58	1 500
Digital ABS™	66	1 700–2 200

Table 8: The values and standard deviations of flexural strength and flexural modulus after testing with MTS machine

Material	Flexural strength (MPa)	SD (MPa)	Flexural modulus (MPa)	SD (MPa)
ABS	17.6	0.9	1 063	16
PLA	25.0	2.0	2 627	20
ULTEM9085	30.0	1.0	2 049	20
PA2200	29.9	0.1	1 490	30
Digital ABS™	20.0	5.0	1 120	8

Table 9: The values an standard deviations of flexural breaking energy per unit mass and flexural energy per unit mass absorbed per unit strain for the polymers at 100 % infill

Material	Density (kg/m^3)	Breaking energy per unit mass (kJ/kg)	SD (kJ/kg)	Energy per unit mass absorbed per unit strain (kJ/kg)	SD (kJ/kg)
ABS	1.04×10^3	16.9	0.9	1 022	15
PLA	1.25×10^3	20.0	2.0	2 102	16
ULTEM9085	1.34×10^3	22.4	0.7	1 529	15
PA2200	0.43×10^3	69.8	0.2	3 465	69
Digital ABS™	1.18×10^3	17.0	4.0	949	7

Table 8 shows the results of the flexural strength and flexural modulus after testing with MTS machine. The values of the flexural modulus and flexural strength in Table 8 after testing with MTS machine are more or less decreased comparing to the values of the flexural modulus obtained from MSDS in Table 7. In Table 8 PLA has the highest flexural modulus value, after that ULTEM9085 is the second highest value and PA2200 is the third.

Table 9 shows the flexural breaking energy per unit mass and flexural energy per unit mass absorbed per unit strain for the polymers at 100 % infill. Here, PA2200 has the highest flexural breaking energy and flexural energy per unit mass absorbed at unit strain (69.8 kJ/kg and 3 465 kJ/kg), respectively. As before, these represent energies per unit mass absorbed before failure or per unit strain.

3.4 Compressive tests for ABS cubes

We designed a cube with 1 inch (25.4 mm) sides using SolidWorks for compression tests and printed several specimens of ABS using MakerBot replicator 2X as a solid at 100 % of infill. The cubes were tested in different directions X, Y, and Z at two different speeds, 0.2 mm/s and 0.05 mm/s. We tested two sets of cubes, each set containing six cubes, and each couple was tested in a different direction. After testing them with the MTS machine, we obtained two different strain regions for all the cubes – the low strain region and high strain region. The results of compressive strength and compressive modulus for low strain and high strain regions were compared with the results of the compression tests of the standard samples with the specific dimensions according to ASTM D695. The results of high strain region of ABS cubes approximately match the results of the samples having dimensions according to the standard, while the results of low strain region never match. Figure 10 shows the stress-strain curves calculated from least squares fit to compression data for ABS cubes at 100 % for the high strain region at a speed of 0.2 mm/s on the MTS machine.

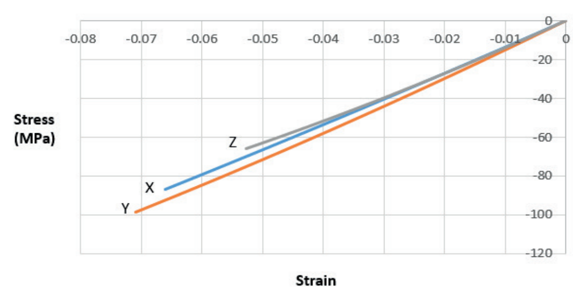


Figure 10: ABS cubes stress-strain calculated from fit at 100 % infill for high strain in X, Y, Z directions for compression speed of 0.2 mm/s

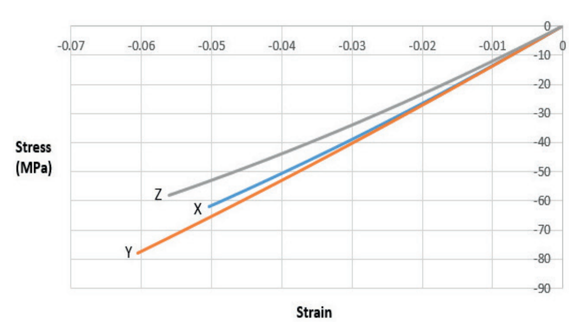


Figure 11: ABS cubes stress-strain calculated from fit at 100 % infill for high strain in X, Y, Z for compression speed of 0.05 mm/s

Table 10: The values and standard deviations of compressive strength and compressive modulus for ABS cubes for low strain region

Print Direction	Speed (mm/s)	Compressive strength (MPa)	SD (MPa)	Compressive modulus (MPa)	SD (MPa)
X	0.20	5.0	1.0	260	8
Y	0.20	6.7	0.7	248	3
Z	0.20	4.5	0.9	330	9
X	0.05	5.0	2.0	284	11
Y	0.05	5.5	0.7	206	3
Z	0.05	3.9	0.3	236	7

Table 11: The values and standard deviations of compressive strength and compressive modulus for ABS cubes for high strain region

Print Direction	Speed (mm/s)	Compressive strength (MPa)	SD (MPa)	Compressive modulus (MPa)	SD (MPa)
X	0.20	70	16.0	1 375	6
Y	0.20	90	9.0	1 373	7
Z	0.20	61	6.0	1 427	4
X	0.05	60	2.0	1 393	3
Y	0.05	70	8.0	1 396	9
Z	0.05	56	0.1	1 241	7

Figure 11 shows the stress-strain curves calculated from least squares fit to compression data for ABS cubes at 100 % infill for the high strain region at a speed of 0.05 mm/s on the MTS machine.

Tables 10 and 11 show the results of compressive strength and compressive modulus for both regions of strain (low and high, respectively) for ABS cubes when they were tested in different directions X, Y, and Z at two different speeds. The low strain moduli for the X and Y directions are indistinguishable. This should be expected based on how the MakerBot prints each layer in the X and Y directions.

3.5 Thermal analysis

To better understand melting, solidification and leveling of these thermoplastics, differential scanning calorimetry (DSC) was done. It is important to understand material behavior under the influence of thermal loads.

Thermal analysis provides important information of use to engineers and designers.

The results of thermal analysis for ABS by using DSC are shown in Figure 12. We heated the sample and then cooled it consecutively for two cycles. Figure 12 shows the behavior of ABS during the first and second cycle. A small exothermic peak appeared around 50 °C, but the graph in general indicates that ABS is an amorphous polymer.

Consequently, the thermal analysis results of PLA, ULTEM9085 and PA2200 were obtained by following the same steps using the DSC under the same conditions.

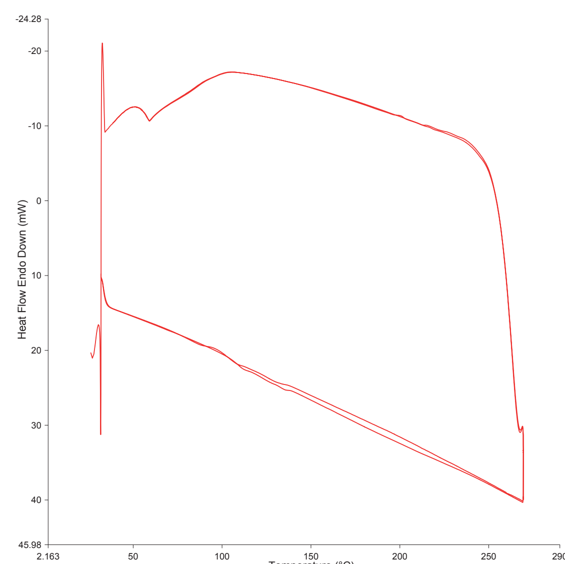


Figure 12: Thermal analysis of ABS

PLA thermal analysis, as plotted in Figure 13, shows that there are two small endothermic peaks. The first peak appeared around 60 °C, which is the *Tg* for the polymer during the first cycle while the second peak was around 160 °C, which is the melting point (*Tm*) of PLA for both cycles. This indicates the polymer is partially crystalline.

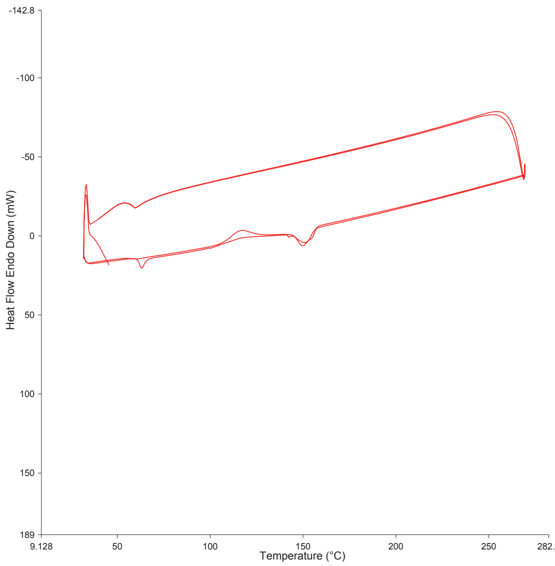


Figure 13: Thermal Analysis of PLA

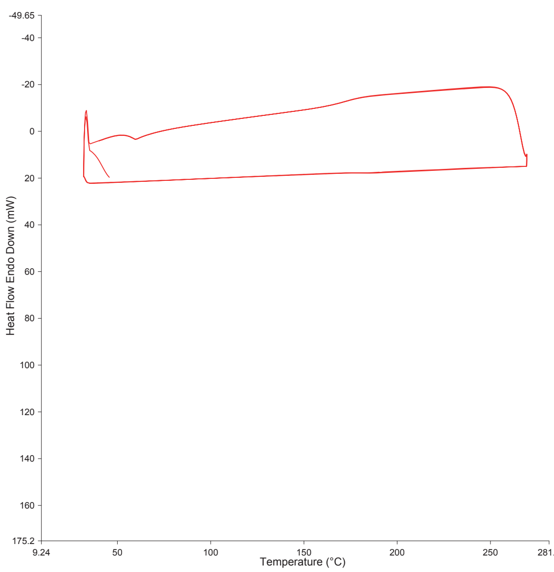


Figure 14: Thermal Analysis of ULTEM9085

ULTEM9085 thermal analysis is shown in Figure 14. From Figure 14, we can see there are no peaks appearing during the first or the second cycle and the uniform shape of the curves at the Figure 14 indicates that the ULTEM9085 is an amorphous polymer.

The thermal analysis for PA2200 is shown in Figure 15, showing two sharp peaks. The first peak was exothermic and appeared around 150 °C and the second one is endothermic around 180 °C, which is the melting point (*T*m) of PA2200. These sharp peaks appear clearly during the first and second cycle, which shows crystalline behavior of the PA2200.

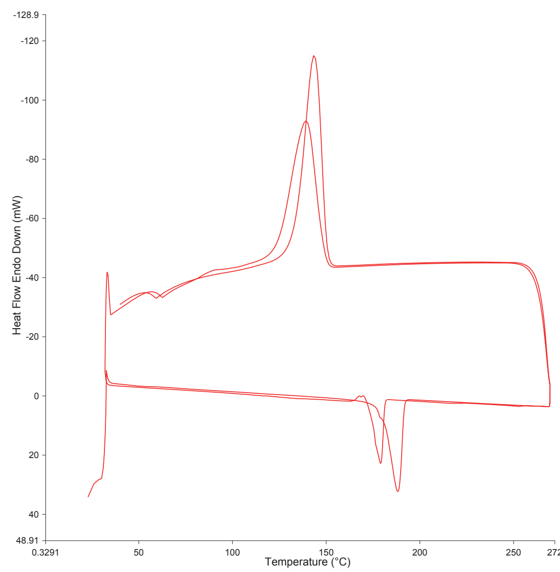


Figure 15: Thermal Analysis of PA2200

These results indicate that ABS and ULTEM can show better leveling, and hence smoother surfaces if an annealing step is included in the printing process. Annealing can be of some value for PLA, but probably is of little value for PA2200.

4. Summary and Conclusion

Five polymers, ABS, PLA, PA2200, ULTEM9085, and Digital ABS™ were printed and tested for selected properties in tensile strength tests, compressive tests and bending tests. The thermoplastic materials ABS, PLA and ULTEM 9085 were printed at 100 % of infill using FDM technology. The thermoplastic polymer PA2200 was printed using SLS technology at 100 % of infill. Digital ABS™ was printed using PolyJet™ technology. Five replicates from each material were printed and tested for each property. The average tensile strength and Young's moduli of the 3D printed samples and flexural strength properties were slightly lower than the values of the MSDS that were obtained from the manufacturer. The curves show near linear trends, showing that the rupture occurs without any dramatic change in elongation, which is typical for brittle structures.

Also, the values of the compressive modulus and compressive strength of the tested samples are lower than the original values obtained from the MSDS. This was most likely due to the heating and extrusion of the 3D printed tested samples, since they were extruded for a second time. For PA2200, which was printed using SLS, the tensile strength and Young modulus were indistinguishable from the values that obtained from the manufacturer (MSDS). Compression tests show that PLA and

Digital ABS™ are anisotropic polymers because they have different properties in different printing directions. ABS, ULTEM9085, and PA2200 have the same shape in both printing directions, but different slopes.

The highest values for both Young's modulus and tensile strength has PLA, while ULTEM9085 has the lowest Young's modulus value and ABS has the lowest tensile strength value. Further, PLA has the highest compressive modulus in the X direction and the second highest compressive strength in the Z direction. Digital ABS™ has the highest compressive strength in the Z direction and the second highest compressive modulus in X direction; PA2200 has the lowest compressive modulus in the X direction and ABS has the lowest compressive modulus value in the Z direction. Finally, PLA has the highest flexural modulus value, ULTEM9085 has the second highest value and PA2200 the third highest.

Bending tests show that all the curves of the polymers appear clearly convex except for digital ABS™ that appears concave. The values of the flexural modulus after testing with the MTS machine are less than the values of the flexural moduli obtained from the MSDS, and the values of the flexural strength after testing with the MTS machine are also less than the ones obtained from the MSDS.

The PA2200 has the highest breaking energy per unit mass for both tensile test and energy absorbed per unit mass per unit strain, 121 kJ/kg and 3 951 kJ/kg, respectively. It also has the highest values for compressive breaking energy and compressive energy absorbed per unit mass per unit strain in both printing directions X and Z. The compressive breaking energy per unit mass is 121 kJ/kg in X and 128 kJ/kg in Z direction. The compressive energies absorbed per unit mass per unit strain are 2 733 kJ/kg in X and 2 474 kJ/kg in Z direction. In addition, PA2200 has the highest flexural breaking energy and flexural energy absorbed per unit mass per unit strain, 69.8 kJ/kg and 3 465 kJ/kg, respectively.

For ABS cubes, after testing with the MTS machine, two different strain regions were obtained for all the cubes; low strain region and high strain region. The results of the high strain region of ABS cubes approximately match the results of the samples that have dimensions according to the standard ASTM D695, while the results of low strain region never match.

The thermal analyses of these polymers indicate that ABS and ULTEM9085 are amorphous, while PLA is partially crystalline and PA2200 is completely crystalline. These indicate that the ABS and ULTEM9085 can show better leveling, and hence smoother surfaces if an annealing step is included in the printing process. Annealing can be of some value for PLA, but probably is of little value for PA2200.

Regarding the results of mechanical properties, strength and modulus of the polymers of 3D printed trabecular structures are higher than the ones of the real trabecular bones. In contrast, the 3D printed compact bones show lower mechanical properties (both strength and modulus) than the real compact bones structure. We believe we can strengthen the structure and geometry to match these requirements in future work.

After reaching the best mechanical properties of the 3D printed biopolymers in a specific design that replaces the missing bony part, animal trials need to be conducted to investigate the influence of the implants on the tissue healing process. The technology of 3D printing is expanding continuously. Processing costs, including material costs, energy costs and production speed are being wisely estimated together with that involved in more conventional manufacturing processes.

References

Ahn, S.-H., Montero, M., Odell, D., Roundy, S. and Wright, P.K., 2002. Anisotropic material properties of fused deposition modeling ABS. *Rapid Prototyping Journal,* 8(4), pp. 248–257.

ASTM International, 2015a. *ASTM D695-15 Standard Test Method for Compressive Properties of Rigid Plastics.* Westconchocken, PA: ASTM International.

ASTM International, 2015b. *ASTM D790-15e2 Standard Test Method for Flexural Properties of Unreinforced and Reinforced Plastics and Electrical Insulating Materials.* Westconchocken, PA: ASTM International.

Beer, F.P., Johnston, E.R., DeWolf, J.T. and Mazurek, D.F., 2012. *Mechanics of Materials.* New York: McGraw Hill Companies.

Boyd, S.P. and Vanderberghe, L., 2004. *Convex Optimization.* New York: Cambridge University Press.

Ehrenberg, R., 2013a. Health & Illness: Skull patched with plastic. *Science News,* 183(8), p. 12.

Ehrenberg, R., 2013b. Plastic implant replaces three-quarters of man's skull. *Science News*, 11 March 2013.

EOS, 2015. *Material data sheet: PA 2200.* [pdf] EOS GmbH – Electro Optical System. Available at: <https://www.shapeways.com/rrstatic/material_docs/mds-strongflex.pdf> [Accessed September 2015].

Fischer, F., 2011. *Thermoplastics: The Best Choice for 3D Printing.* Eden Prairie, MN: Stratasys Inc.

Hutmacher, D.W., 2000. Scaffolds in tissue engineering bone and cartilage. *Biomaterials,* 21(24), pp. 2529–2543.

Ikonomov, P. and Yahamed, A., 2014. Testing of plastic materials for 3D printing of bone structure. *International Journal of Advanced Manufacturing Systems, 15*(1), pp. 23–29.

Jia, N. and Kagan, V.A., 2001. Mechanical performance of polyamides with influence of moisture and temperature – accurate evaluation and better understanding. In: J. Moalli, ed. 2001. *Plastic Failure Analysis and Prevention.* Norwich, NY: William Andrew Inc. pp. 95–104.

Lasprilla, A.J., Martinez, G.A., Lunelli, B.H., Jardini, A.L. and Filho, R.M., 2012. Poly-lactic acid synthesis for application in biomedical devices – a review. *Biotechnology Advances,* 30(1), pp. 321–328.

Leukers, B., Gülkan, H., Irsen, S.H., Milz, S., Tille, C., Schieker, M. and Seitz, H., 2005. Hydroxyapatite scaffolds for bone tissue engineering made by 3D printing. *Journal of Materials Science: Materials in Medicine,* 16(12), pp. 1121–1124.

MakeItFrom, 2015. *Polylactic Acid (PLA, Polylactide).* [online] Available at: <http://www.makeitfrom.com/material-properties/Polylactic-Acid-PLA-Polylactide> [Accessed September 2015].

Materialise, 2016a. *Fused Deposition Modeling.* [online] Available at: <http://manufacturing.materialise.com/fdm> [Accessed 16 June 2016].

Materialise, 2016b. *Laser Sintering.* [online] Available at: <http://manufacturing.materialise.com/laser-sintering-0> [Accessed 16 June 2016].

Materialise, 2016c. *Stereolithography.* [online] Available at: <http://manufacturing.materialise.com/stereolithography> [Accessed 16 June 2016].

MTS, 2015. *MTS Bionix® Tabletop Test Systems.* [pdf] Eden Prairie, MN: MTS Systems Corporation. Available at: <http://www.mts.com/ucm/groups/public/documents/library/dev_003992.pdf> [Accessed 1 October 2015].

Palermo, E., ed., 2013. What is Selective Laser Sintering? *Live Science.* [online] Available at: <http://www.livescience.com/38862-selective-laser-sintering.html> [Accessed 13 August 2013].

Pekarovicova, A., Chovancova-Lovell, V. and Fleming, P.D., 2006. Novel phase change inks for printing three-dimensional structures. *Journal of Imaging Science and Technology,* 50(6), pp.550–555.

Razak, S.I.A., Sharif, N.F.A. and Rahman, W.A.W.A., 2012. Biodegradable polymers and their bone applications: a review. *International Journal of Basic & Applied Sciences IJBAS IJENS,* 12(1), pp. 31–49.

Stoia, D.I., Vigaru, C. and Rusu, L., 2015. Laser sinterization aspects of PA2200 biocompatible powder – spinal cage application. *Key Engineering Materials*, 638, pp. 352–356.

Stratasys, 2016a. *PolyJet Technology.* [online] Available at: <http://www.stratasys.com/3d-printers/technologies/polyjet-technology> [Accessed February 2016].

Stratasys, 2016b. *ULTEM 9085 Resin.* [online] Available at: <http://www.stratasys.com/materials/fdm/~/media/83DA2BBEE7DE4A669CFEF6B1FCA118AA.ashx> [Accessed 16 June 2016].

Stratasys, 2016c. *Polyjet Materials Data Sheet.* [online] Available at: <http://usglobalimages.stratasys.com/Main/Files/Material_Spec_Sheets/MSS_PJ_PJMaterialsDataSheet.pdf?v=635785205440671440> [Accessed 16 June 2016].

Tao, C.T. and Young, T.H., 2006. Polyetherimide membrane formation by the cononsolvent system and its biocompatibility of MG63 cell line. *Journal of Membrane Science,* 269(1-2), pp. 66–74.

Test Standard Labs, 2016. *ABS Material Data Sheet.* [pdf] Dade City, FL: Test Standard Labs LLC. Available at: <http://teststandard.com/data_sheets/ABS_Data_sheet.pdf> [Accessed 16 June 2016].

Weisstein, E.W., 2016. Concave Function. *MathWorld – a Wolfram Web Resource.* [online] Available at: <http://mathworld.wolfram.com/ConcaveFunction.html> [Accessed December 2016].

Williams, J.M., Adewunmi, A., Schek, R.M., Flanagan, C.L., Krebsbach, P.H., Feinberg, S.E., Hollister S.J. and Das, S., 2005. Bone tissue engineering using polycaprolactone scaffolds fabricated via selective laser sintering. *Biomaterials,* 23(26), pp. 4817–4827.

Yahamed, A., Ikonomov, P. and Fleming, P.D., 2014. Application of 3D printing for human bone replacement. In: *Proceedings of the 2014 ICAM, International Conference on Advanced and Agile Manufacturing*, Rochester, MI., 28–30 May 2014. Norfolk, VA: International Society of Agile Manufacturing. p. 10.

Appendix A

Figures A1 to A5 show results of tensile strength tests for the materials printed at 100 % infill (ca is abbreviation for calculated).

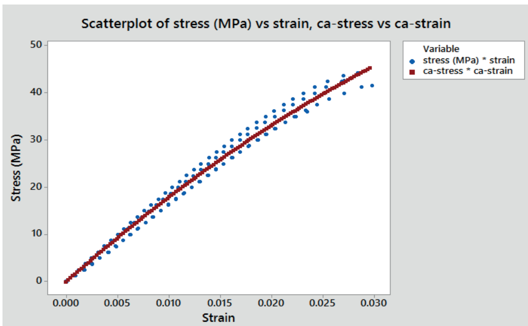


Figure A1: Measured and calculated stress-strain of ABS at 100 % infill

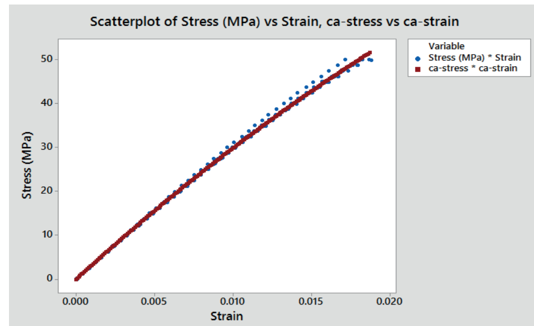


Figure A2: Measured and calculated stress-strain of PLA at 100 % infill

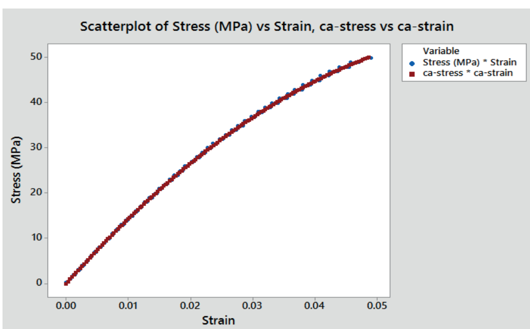


Figure A3: Measured and calculated stress-strain of ULTEM9085 at 100 % infill

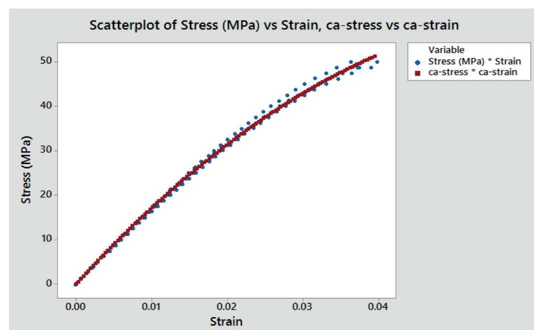


Figure A4: Measured and calculated stress-strain of PA2200 at 100 % infill

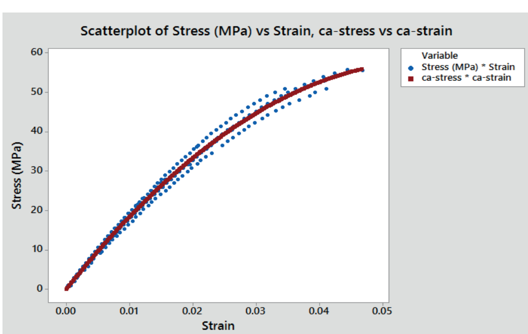


Figure A5: Measured and calculated stress-strain of Digital ABS™ at 100 % infill

Appendix B

Figures B1 to B8 show results of compressive tests in different directions for the materials printed at 100 % infill.

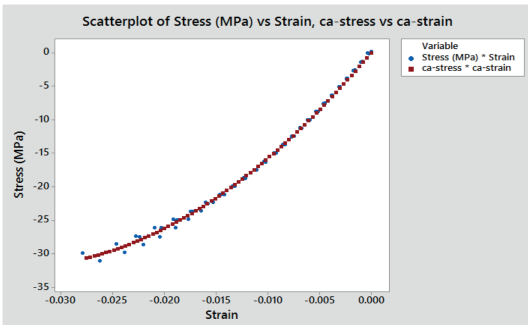


Figure B1: Measured and calculated stress-strain of ABS at 100 % infill in X direction

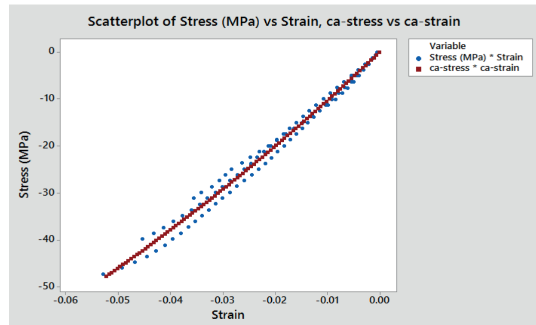


Figure B2: Measured and calculated stress-strain of ABS at 100 % infill in Z direction

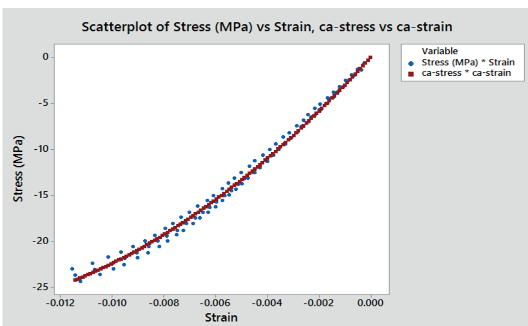


Figure B3: Measured and calculated stress-strain of PLA at 100 % infill in X direction

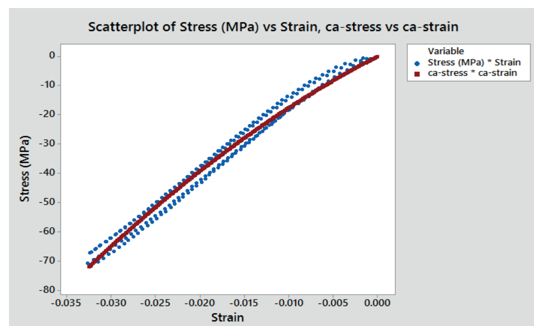


Figure B4: Measured and calculated stress-strain of PLA at 100 % infill in Z direction

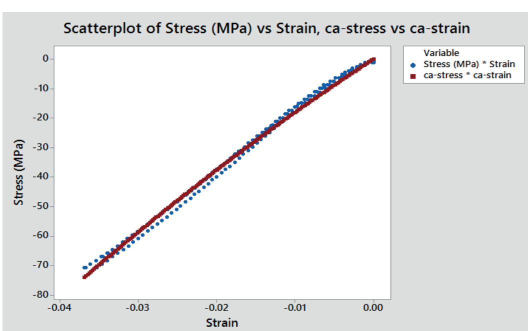


Figure B5: Measured and calculated stress-strain of Digital ABS™ at 100 % infill in X direction

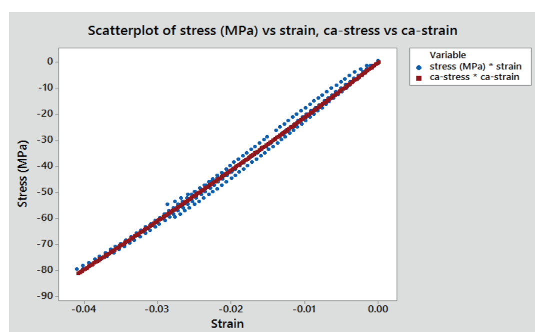


Figure B6: Measured and calculated stress-strain of Digital ABS™ at 100 % infill in Z direction

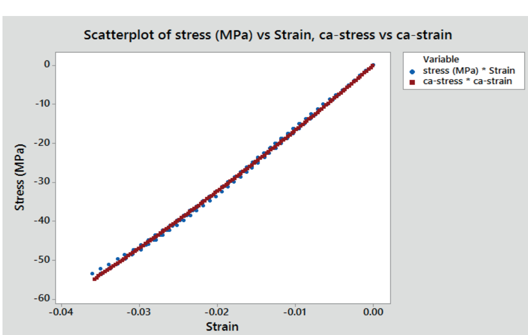


Figure B7: Measured and calculated stress-strain of ULTEM9085 at 100 % infill in X and Z directions

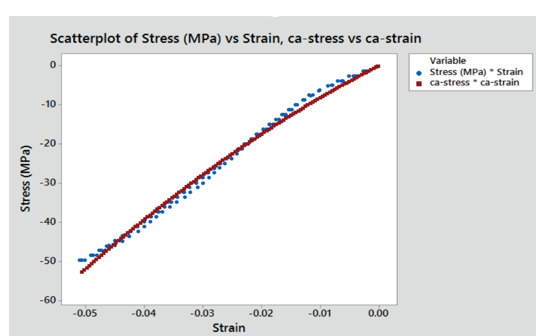


Figure B8: Measured and calculated stress-strain of PA2200 at 100 % infill in X and Z directions

Appendix C

Figures C1 to C5 show results of bending tests for the materials printed at 100 % infill.

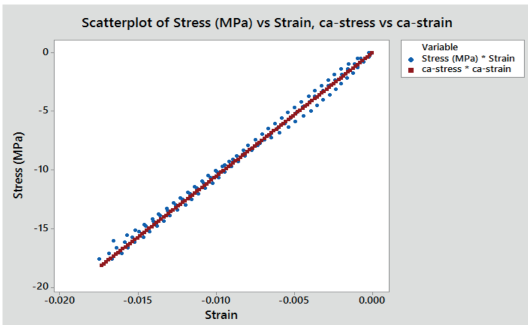


Figure C1: Measured and calculated stress-strain of ABS at 100 % infill

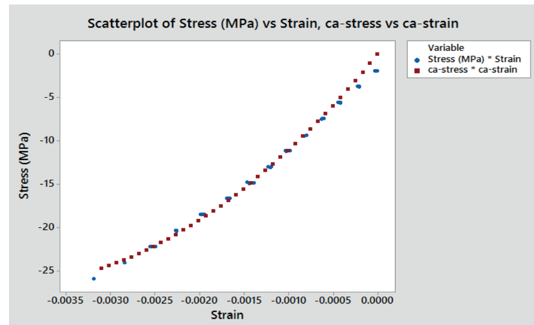


Figure C2: Measured and calculated stress-strain of PLA at 100 % infill

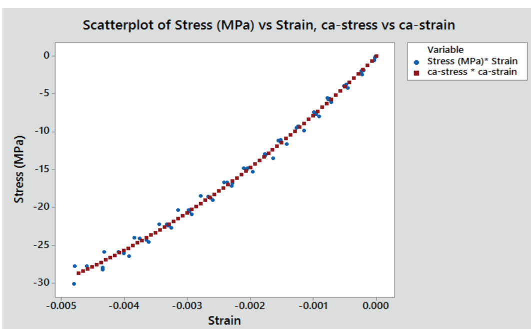


Figure C3: Measured and calculated stress-strain of ULTEM9085 at 100 % infill

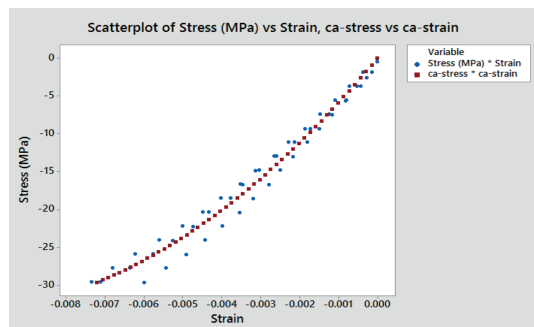


Figure C4: Measured and calculated stress-strain of PA2200 at 100 % infill

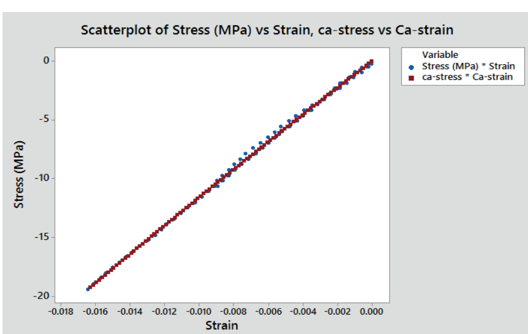


Figure C5: Measured and calculated stress-strain of Digital ABS™ at 100 % infill

Appendix D

Figures D1 to D6 show results of compressive tests for ABS cubes printed at 100 % infill at two different speeds 0.2 mm/s and 0.05 mm/s.

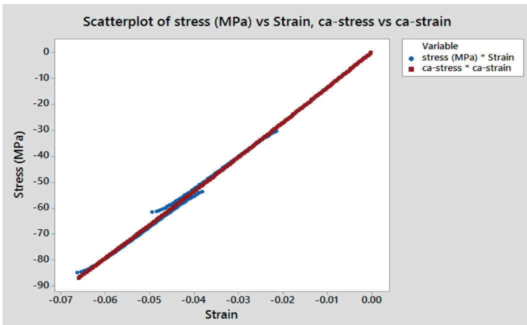


Figure D1: Measured and calculated stress-strain of ABS cube at 100 % infill for high strain in X direction at speed of 0.2 mm/s

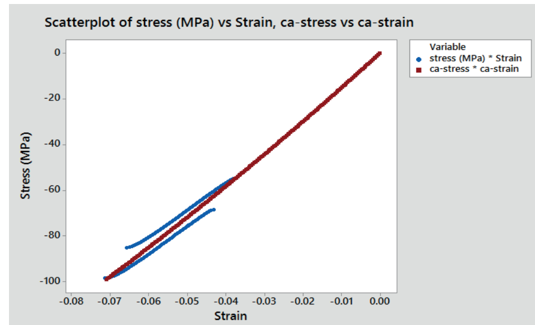


Figure D2: Measured and calculated stress-strain of ABS cube at 100 % infill for high strain in Y direction at speed of 0.2 mm/s

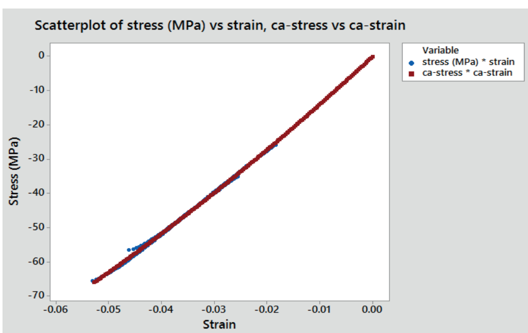


Figure D3: Measured and calculated stress-strain of ABS cube at 100 % infill for high strain in Z direction at speed of 0.2 mm/s

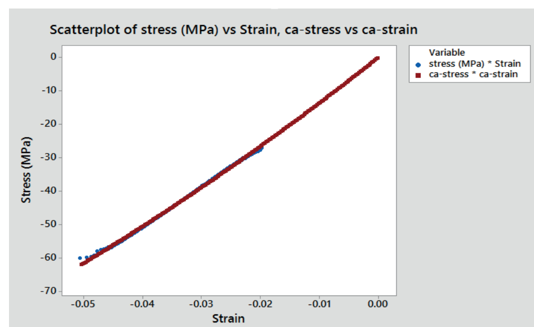


Figure D4: Measured and calculated stress-strain of ABS cube at 100 % infill for high strain in X direction at speed of 0.05 mm/s

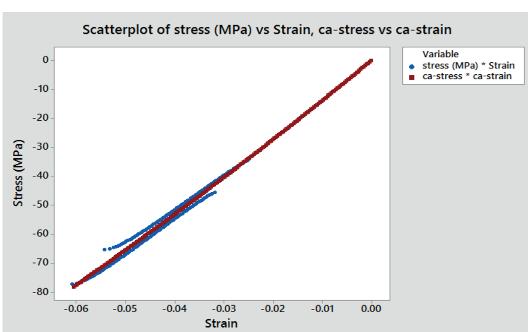


Figure D5: Measured and calculated stress-strain of ABS cube at 100 % infill for high strain in Y direction at speed of 0.05 mm/s

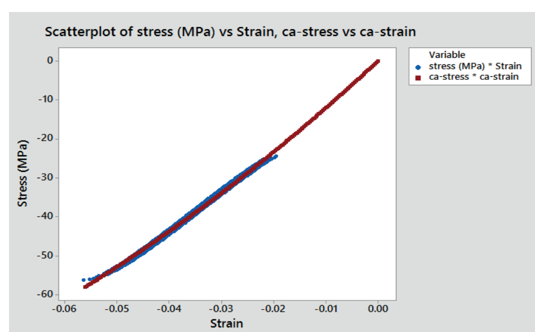


Figure D6: Measured and calculated stress-strain of ABS cube at 100 % infill for high strain in Z direction at speed of 0.05 mm/s

JPMTR 089 | 1614
DOI 10.14622/JPMTR-1614
UDC 620-024-035.56

Research paper
Received: 2016-11-08
Accepted: 2016-12-27

Designed structures for bone replacement

Azem Yahamed[1], Pavel Ikonomov[2], Paul D. Fleming[1], Alexandra Pekarovicova[1] and Peter Gustafson[3]

[1] Department of Chemical and Paper Engineering, Western Michigan University, Kalamazoo, MI 49008

[2] Department of Engineering Design Manufacturing, and Management Systems, Western Michigan University, Kalamazoo, MI 49008

[3] Department of Mechanical Engineering, Western Michigan University, Kalamazoo, MI 49008

E-mails: azemkhalifa.yahamed@wmich.edu
pavel.ikonomov@wmich.edu
dan.fleming@wmich.edu
a.pekarovicova@wmich.edu
peter.gustafson@wmich.edu

Abstract

Bone replacements are needed to help repair or replace damaged and diseased tissues ranging from trauma, degenerative disease, cancer and plastic surgery requirements. To create artificial bone implants from plastics, the structure and mechanical properties must be tested to closely match or be able to sustain greater forces than the original. It is essential to use proper bone replacement material that provides biocompatibility with sufficient stiffness and strength. The materials can be biocompatible polymers, such as polylactic acid (PLA), polyvinyl alcohol (PVA), polycaprolactone (PCL) and polyether-ether ketone (PEEK). Also, it is important to create internal structures that can accurately mimic the real human bone structure with a solid outer shell that represents the compact bone and porous internal volume that represents the trabecular (spongy) bone. Designing of the proper trabecular bone is one of the most critical steps, because its structure helps support the entire bone, while at the same time reduces the weight. Due to the low resolution of DICOM images, the trabecular bone structures cannot be obtained directly from CT and MRI scans. Therefore, we used CAD software – SolidWorks to design special 3D structures (hexagonal, triangular, and square). The reason for using these structures is that they are widely used in industry and aerospace applications, because they provide high strength, while keeping the weight low. The geometry of the void structure reduces the amount of material, reducing the overall weight and cost by reducing the structural density. We designed and produced 3D printed samples to test the structure properties with different geometric shapes. Structure property tests, such as tensile strength test, compressive strength test, and bending test were investigated. We found that the mechanical properties of the designed plastic structures either exceed or fall within the range of the mechanical properties of the human trabecular bones.

Keywords: mechanical property, 3D printing, biomaterial, bone structure

1. Introduction

Designed void structures, with their unique design properties providing mechanical strength and light weight, have attracted massive attention lately for both fundamental research and practical applications and progressively have become a hot research area (Heng et al., 2013). These structures have great properties, such as high mechanical strength, excellent structural stability, large space area, and low density. For example, the honeybee comb is one of the natural cellular structures that has been investigated by several groups of researchers: physicists, mathematicians, and biologists. The microstructure of the walls and the macroscopic properties of honeybee combs have been researched in depth. The natural honeybee comb has been a typical example of interest for engineered cellular structures (Heng et al., 2013).

1.1 Three-dimensional printing

Three-dimensional printing technology is able to create 3D items by using many different materials. The technology is also called rapid prototyping, because it is a programmed process where 3D items are rapidly made (Tyagi, 2011). Building 3D models using 3D printing technology saves time and cost because designing, manufacturing, and assembling of separate parts of a product are not required. The technology of 3D printing can make models of objects either designed with Computer Aided Design (CAD) programs or scanned with 3D scanners. The technology has been widely used in many applications such as industrial design, engineering, architecture, aerospace, dental and medical applications (Tyagi, 2011).

One of the uses of 3D printing in the medical field is to substitute for damaged bones. For example, the 3D printing technology has been already applied to replace the bone structure of the injured or missing parts of people's skulls damaged by diseases or trauma (Ehrenberg, 2013). There are many cases when the bone structure is extensively damaged and cannot be recovered with regular methods, such as casts. Currently, damaged bones are repaired with metal parts, but many cases show that the bone cannot be properly replaced or repaired. However, there have been several successful attempts of using 3D printing to create and replace human bone structures even for most complex shapes, such as jaws (Bahat and Fontanessi, 2001). Many different biocompatible and biodegradable materials have been studied and tested for 3D printed bone structure. There are different 3D printing methods that can be applied for bone tissue-engineering: Fused Deposition Modeling (FDM) (Ahn et al., 2002), Selective Laser Sintering (SLS) (Materialise, 2016), and stereolithography (Yahamed et al., 2016).

1.2 Thermoplastics

Thermoplastics have been used successfully as replacements for certain metals for many years in manufacturing, and recently they have been used widely in medical applications. Polymer 3D printing plays a significant role in applying these materials, providing high performance, cost efficiency and enhanced resistance to environmental conditions (Jia and Kagan, 2001).

1.3 Biomaterials

The study of biomaterials for bone replacement has progressed significantly over many years (Stevanovic et al., 2013). There are many examples of applications of 3D printing in creating implantable organs that are designed for specific patients to enhance accuracy and efficiency of the manufacturing. Three-dimensional printing uses computer models to build 3D objects by printing layers of materials, including plastics, metals, powders and liquid layer by layer. The process is also used to build items in the medical field that can exactly match the requirements and sizes of specific patients (Yahamed et al., 2015).

1.4 Bioprinting

Three-dimensional printing can improve medical care in some processes, and it will also open new opportunities for bone replacement or cure. For example, this technology has been successfully applied in the field of prosthetics and drug printing (Miller, 2013). Constructive processes are used to produce 3D models, and 3D printing refers to only such technologies that use constructive manufacturing procedures. It is likely that more medical professionals will introduce 3D printing technologies into their practices; 3D printing gives enormous benefits for experts to produce only what they need, which can reduce production time. It allows objects from actual human scans to be modeled and built for further applications in a few hours, even inside medical facilities (Miller, 2013). Several processes can be accomplished only with the use of a 3D printer. Biofabrication is a process that doctors themselves traditionally use to produce organ replacements or order them from specialized companies. However, they can now be more successfully realized by using 3D printing technologies (Yahamed et al., 2015).

2. Methods

2.1 Three-dimensional printing of test samples

Using 3D printing technology, three different 3D printed samples of plastic materials were printed; ULTEM9085, PA2200, and Digital ABS™ were employed. Table 1 shows selected properties of these plastics.

We used SolidWorks software to design the internal engineered structure with different geometric shapes (hexagonal, triangular, and square). The samples were printed using different 3D printing methods (Yahamed et al., 2016). The FDM technique was used to print ULTEM9085 (Stratasys, 2015), with Stratasys machine

Table 1: Selected properties of thermoplastic materials specified by their producers

Material	Tensile strength (MPa)	Young's modulus (MPa)	Melting point (°C)
ULTEM9085	71.6	2200	186
PA2200	48.0	1700	172–180
Digital ABS™	55.0–60.0	2600–3000	47–53*

* Glass transition temperature (*Tg*), since this material cannot be crystallized.

Fortus 400 MC, and SLS was used to print PA2200 with EOSP 396 (EOS, 2015). PolyJet™ technology was used to print Digital ABS™ with a Stratasys Objet 500 Connex3 (Stratasys, 2016). All the samples were printed with designed internal structures with different geometric shapes. Five samples were printed for each category. Although Digital ABS™ is not a biocompatible material, it is used as a reference for comparison with other polymers.From the biocompatible materials, ULTEM9085 is helpful as a tissue engineering scaffold for bone regeneration (Tao and Young, 2006), and PA2200 (polyamide) can be used in several medical applications such as compressed structures for scaffold supporting (Stoia, Vigaru and Rusu, 2015). In this work, we mimic the trabecular (spongy) bone structure with the average pore size of the real one (~400 μm). The designed structures are shown in Figures 1 to 3.

2.2 Testing mechanical properties of 3D printed samples using MTS machine

The tested samples were designed according to the standard with specific dimensions for all mechanical property tests. The following standards were employed: for tensile strength ISO 3167 (International organization for Standardization, 2014), for compression ASTM D695 (ASTM International, 2015a), and for bending ASTM D790 (ASTM International, 2015b). An MTS Bionix Servohydraulic Test Systems Model 370.02 instrument was employed for testing. We tested the 3D printed samples at 0.2 mm/s speed of MTS machine at room temperature. The force capacity of the device is 25 kN and it is used to determine the dynamic properties for a number of biomaterials. The axial alignments of the system are intended to achieve precise tension, compression and bending tests as well as fatigue and fracture studies. Also, they are used to test durability properties of components such as hip, knee and spine implants (Yahamed et al., 2016).

2.3 Calculating void volume and percentage of infill for designed structures

We calculated the void volume and percentage of infill for the designed structures with different geometric shapes. Table 2 shows the void volume fraction, fill fraction and percentage of infill for the geometric shapes. We wanted to investigate the influence of the geometry shape on the percentage of infill and the impact of the percentage of infill on the strength. From Table 2, we observe that the hexagonal structure has the highest percentage of infill (92.6 %), followed by the triangular structure (83.6 %), and the lowest infill has the square structure (82.9 %).

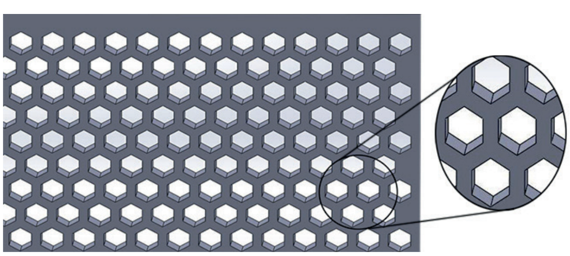


Figure 1: Hexagonal structure

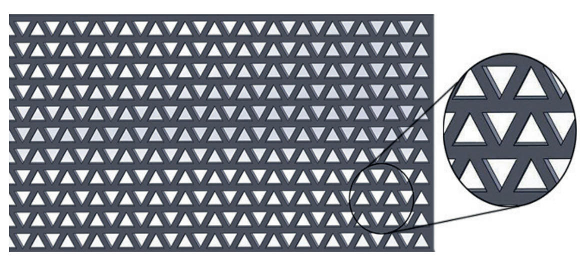


Figure 2: Triangular structure

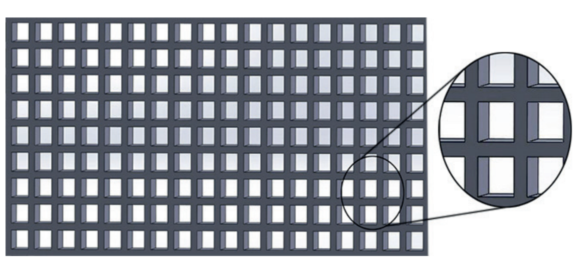


Figure 3: Square structure

Table 2: Void volume fraction, fill fraction and percentage of infill for designed structures

Geometric structure	Void volume fraction	Fill fraction	Infill (%)
Square	0.172	0.829	82.9
Triangular	0.164	0.836	83.6
Hexagonal	0.074	0.926	92.6

3. Results and discussion

3.1 Tensile strength tests

Table 3 shows the results of the average tensile strength and Young's modulus for ULTEM9085, PA2200, and Digital ABS™ geometric structures after testing with the MTS machine, compared to values of corresponding solid samples. In all cases, the structures (see Figures 1 to 3) are perpendicular to the tension direction and parallel to the Z direction.

The ULTEM9085 polymer printed with three different geometries, hexagonal, triangular and square, gave the same values for the tensile strength, but different Young's modulus values (Table 3). The triangular structure has the highest Young's modulus, followed by square structure, and the lowest Young's modulus was found in ULTEM9085 hexagonal structure.

The hexagonal structure of PA2200 has the highest tensile strength average and Young's modulus (Table 3), followed by PA2200 square structure and triangular structure. For Digital ABS™, the square structure has the highest average value for both tensile strength and Young's modulus, followed by hexagonal structure and triangular structure. Generally, the values are in the same range for all the structures. However, if we look at hexagonal structure, the PA2200 resulted in highest tensile strength (43 MPa) along with highest Young's modulus (1 508 MPa). Similarly, ULTEM9085 resulted in the strongest triangular structure, with Young's modulus of 1 480 MPa and tensile strength of 32 MPa. Triangular structure of ULTEM9085 had slightly higher Young's modulus (1 480 MPa) than that of PA2200 (1 456 MPa). The strongest square structure with the highest tensile strength of 43 MPa and Young's modulus of 1 487 MPa.

Figure 4 shows Young's modulus vs. tensile strength for designed structures. Tensile strength is the capacity of the material or structure to withstand loads tending to elongate. Tested 3D printed polymer structures show particular trend in values. There is significant relation between Young's modulus and tensile strength and the correlation is close to linear.

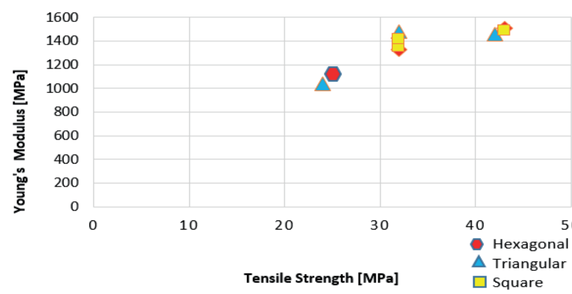


Figure 4: Young's modulus vs. tensile strength for tested materials and structures

Figure 5 shows the stress-strain curves calculated from the least squares fit to the tensile data for ULTEM9085 hexagonal, triangular, and square structures at the MTS machine speed of 0.2 mm/s and room temperature.

Similarly, the stress-strain curves calculated from the least squares fit to the tensile data for PA2200 and Digital ABS™ structures were obtained, as given in Figures 6 and 7, respectively. The curves exhibit near linear trend, showing that the rupture occurs without

Table 3: The values and standard deviations of tensile strength and Young's modulus for different geometric structures; standard deviation of Young's modulus was calculated from the standard error of the coefficient of the linear term in a quadratic fit to the tensile data

Geometric structure	Tensile strength (MPa)	SD (MPa)	Young's modulus (MPa)	SD (MPa)
ULTEM9085 solid	49.7	0.6	1 540	3
ULTEM9085 hexagonal	32.0	3.0	1 327	10
ULTEM9085 triangular	32.0	2.0	1 480	11
ULTEM9085 square	32.0	1.0	1 347	3
PA2200 solid	49.7	0.7	1 699	12
PA2200 hexagonal	43.0	3.0	1 508	17
PA2200 triangular	42.0	3.0	1 456	15
PA2200 square	43.0	2.0	1 487	4
Digital ABS™ solid	55.0	3.0	2 013	12
Digital ABS™ hexagonal	24.7	0.6	1 124	3
Digital ABS™ triangular	23.8	0.5	1 036	3
Digital ABS™ square	32.0	3.0	1 414	15

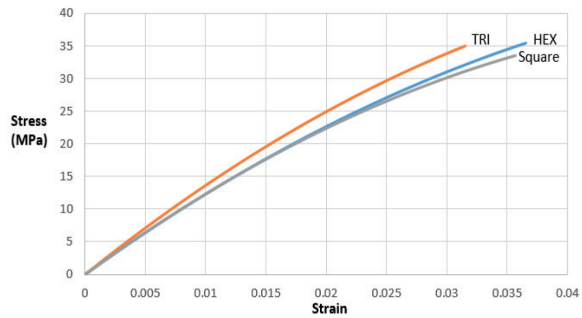


Figure 5: ULTEM9085 structures stress-strain calculated from tensile data

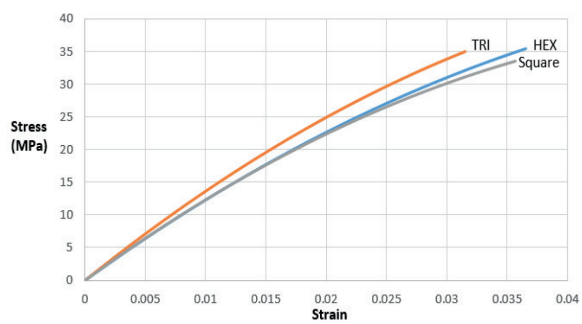


Figure 6: PA2200 structures stress-strain calculated from tensile data

any dramatic change in elongation, which is typical for brittle structures (Beer et al., 2012).

Figure 6 shows the stress-strain curves for PA2200 structures. The shape of the stress strain curves pinpoints brittle structures, which do not exhibit any dramatic change in elongation prior to rupture. Figure 7 shows the stress-strain curves for Digital ABS™

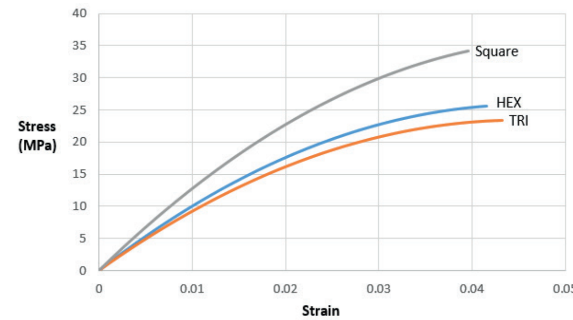


Figure 7: Digital ABS™ structures stress-strain calculated from tensile data

geometric structures, which show a stress-strain trend of brittle structures. The brittle material ruptures without any obvious prior change in the rate of elongation.

Table 4 shows the tensile breaking energy and energy per unit strain per unit mass for different geometric structures of the materials, along with values of corresponding solid samples. From Table 4, PA2200 square has the highest value for both tensile energy per unit strain per unit mass, and breaking energy per unit mass. After that PA2200 triangular is the second. Then PA2200 hexagonal is the third. The PA2200 breaking energy values for both triangular and square are almost indistinguishable from the 100 % infill case for this polymer. This is an indication that these two structures can absorb about the same tensile energy per unit mass as the corresponding solid structure without failing. This could have a profound effect in using this polymer for replacements of original components in many applications. Digital ABS™ hexagonal has the lowest values for both tensile energy per unit strain per unit mass and breaking energy per unit mass.

Table 4: The values and standard deviations of tensile breaking energy and energy per unit mass per unit strain for designed structures

Geometric structure	Breaking energy per unit mass (kJ/kg)	SD (kJ/kg)	Energy per unit mass absorbed per unit strain (kJ/kg)	SD (kJ/kg)
ULTEM9085 solid	37.3	0.4	1 149	2
ULTEM9085 hexagonal	25.8	2.4	1 070	8
ULTEM9085 triangular	28.6	1.8	1 321	10
ULTEM9085 square	28.8	0.9	1 203	3
PA2200 solid	121.0	2.0	3 951	28
PA2200 hexagonal	108.0	8.0	3 789	43
PA2200 triangular	117.0	8.0	4 044	42
PA2200 square	119.0	5.0	4 130	11
Digital ABS™ solid	47.0	3.0	1 706	10
Digital ABS™ hexagonal	23.0	1.0	1 028	3
Digital ABS™ triangular	24.0	1.0	1 050	3
Digital ABS™ square	33.0	3.0	1 446	13

3.2 Compressive strength

Compressive strength tests provide information about the compressive properties of geometric structures. The compressive test properties explain the performance of the material with its internal engineered structure when it is compressed under a load that is relatively low and uniform. Compressive strength of trabecular bones is in the range of 5 MPa to 10 MPa (Razak, Sharif and Rahman, 2012).

The specimen dimensions were printed as blocks according to ASTM D695 standard. Table 5 shows the results of the compressive strength and compressive modulus for selected materials from material safety data sheets (MSDS).

Table 5: Compressive strength and compressive modulus for selected materials from MSDS

Material	Compressive strength (MPa)	Compressive modulus (MPa)
ULTEM9085	104	1 930
PA2200	58	1 500
Digital ABS™	70	2 200

Table 6 shows the average compressive strength and compressive modulus for ULTEM9085, PA2200, and Digital ABS™ structures and corresponding solid samples after testing with the MTS machine.

Table 6 shows that all the materials have compressive strength sufficient for replacement of trabecular bones. The compressive modulus is the highest for Digital ABS™ hexagonal structure, followed by ULTEM 9085 triangular and square structures. On the other hand, compressive strength values were indistinguishable among PA2200 structures and ULTEM9085 square and triangular structures. The least compressive strength was found for Digital ABS™ hexagonal structures, which had the highest compressive modulus.

For brittle materials, the eventual strength in compression is much higher than the eventual strength in tension. This refers to the existence of microscopic cracks or cavities, which tend to deteriorate the material in tension, while not significantly affecting its resistance to compressive failure (Beer et al., 2012).

Figure 8 shows compressive strength vs. compressive modulus for the designed structures. Compressive strength is the capacity of the material or structure to resist loads tending to decrease in size differently than when under tensile strength, which resists loads tending to elongate. Roughly, Figure 8 shows a random relation between compressive strength and compressive modulus of chosen polymer 3D structures, as confirmed by statistical analysis.

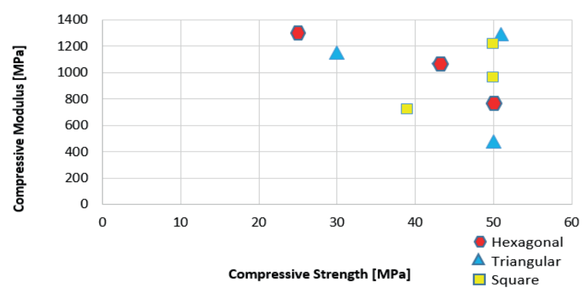


Figure 8: Compressive modulus vs. compressive strength for tested materials and structures

Table 6: The values and standard deviations of compressive strength and compressive modulus for various geometries; standard deviation of compressive modulus was calculated from the standard error of the coefficient

Geometric structure	Compressive strength (MPa)	SD (MPa)	Compressive modulus (MPa)	SD (MPa)
ULTEM9085 solid	69.98	0.05	1 870	13
ULTEM9085 hexagonal	42.98	0.02	1 068	13
ULTEM9085 triangular	50.98	0.02	1 293	16
ULTEM9085 square	49.99	0.02	1 216	4
PA2200 solid	54.93	0.15	1 175	23
PA2200 hexagonal	49.99	0.01	763	10
PA2200 triangular	49.70	0.60	476	4
PA2200 square	49.70	0.70	962	13
Digital ABS™ solid	75.00	5.00	2 157	20
Digital ABS™ hexagonal	25.00	3.00	1 298	10
Digital ABS™ triangular	29.99	0.01	1 153	11
Digital ABS™ square	39.00	1.00	716	7

Compressive modulus values of human trabecular bone range from 1 MPa to 5 000 MPa, with strength values ranging from 0.10 MPa to 27.3 MPa (Williams et al., 2005). The plastics structures show compressive modulus values ranging from 476 MPa to 1 298 MPa. The strength values of the plastic structures range from 25 MPa to 60 MPa. The compressive moduli values fall within the range of human trabecular bone, while the compressive strength values exceed the range of human trabecular bone. Figure 9 shows the stress-strain curves calculated from least squares fit to compression data for ULTEM9085 geometric structures.

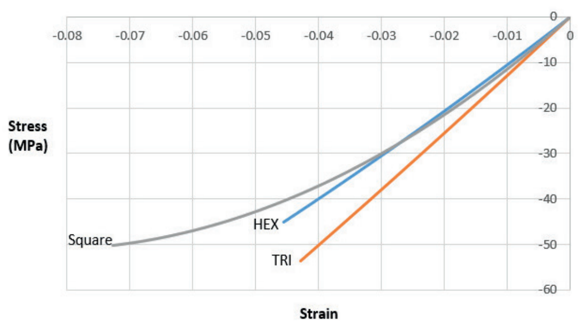


Figure 9: ULTEM9085 structures stress-strain calculated from fit to compression data

Figure 10 shows the stress-strain curves of PA2200 geometric structures under the compression test. The hexagonal and square PA2200 structures appear to have convex trend while triangular PA2200 structure shows concave trend.

Figure 11 shows the stress-strain curve calculated from least squares fit to compression data for Digital ABS™ geometric structures.

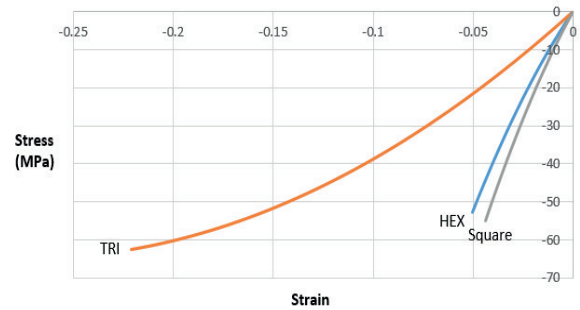


Figure 10: PA2200 structures stress-strain calculated from fit to compression data

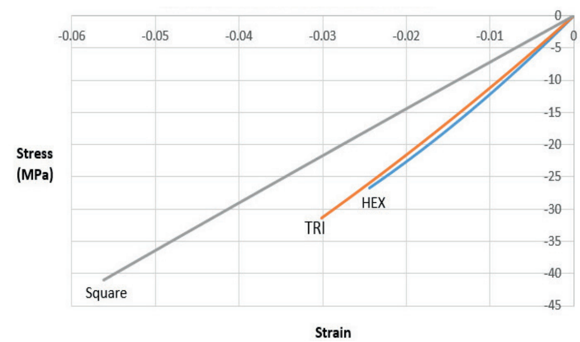


Figure 11: Digital ABS™ structures stress-strain calculated from fit to compression data

Table 7 shows the breaking energy per unit mass and energy per unit mass per unit strain for the different geometric structures of the materials, compared to values of corresponding solid samples. From Table 7, PA2200 square has the highest compressive energy per unit strain value per unit mass. Then, PA2200 hexagonal is the second and PA2200 triangular is the third,

Table 7: The values and standard deviations of compressive breaking energy and energy per unit mass per unit strain for designed structures

Geometric structure	Breaking energy per unit mass (kJ/kg)	SD (kJ/kg)	Energy per unit mass per unit strain (kJ/kg)	SD (kJ/kg)
ULTEM9085 solid	52	0.04	1 396	10
ULTEM9085 hexagonal	35	0.02	861	10
ULTEM9085 triangular	46	0.02	1 155	14
ULTEM9085 square	45	0.02	1 096	3
PA2200 solid	121	34.00	2 733	53
PA2200 hexagonal	126	0.02	1 917	25
PA2200 triangular	139	2.00	1 322	11
PA2200 square	140	2.00	2 702	36
Digital ABS™ solid	64	4.00	1 828	16
Digital ABS™ hexagonal	23	3.00	1 188	9
Digital ABS™ triangular	30	0.01	1 168	11
Digital ABS™ square	40	1.00	732	7

while Digital ABS™ square has the lowest compressive energy per unit strain per unit mass. Further, PA2200 square has the highest compressive breaking energy per unit mass, with Digital ABS™ hexagonal having the lowest. All of the various void structures for PA2200 seem to be able to absorb more compressive energy per unit mass than the corresponding solid structure.

3.3 Bending strength

Bending strength tests measure the force required to bend a beam under three-point loading conditions. The goal of this test is to select materials for parts that should support loads without flexing. A homogeneous, isotropic material would have identical tensile and bending strengths. More flexible polymers have lower bending strength values than stiffer ones (MatWeb, 2016). However, printed 3D polymer structures are not expected to be isotropic; the polymer chains may be oriented in the print direction, which ultimately gives non-isotropic character to the structure.

On the macroscopic level, non-isotropic character is created by selection of the particular structure. The flexural modulus indicates the stiffness of material depending on its internal structure when bent. Flexural or bending modulus would ideally have the same value as compressive or tensile modulus, but it often differs, especially for polymers. The load is applied to the center generating three-point bending at a certain rate. The test parameters are the support span, loading rate, and the determined deflection. They all are based on the specimen thickness and are defined by ASTM D790 standard. Table 8 shows the flexural strength and flexural modulus of the selected materials from their MSDS.

Table 8: Flexural strength and flexural modulus for selected materials from MSDS

Material	Flexural strength (MPa)	Flexural modulus (MPa)
ULTEM9085	115	2500
PA2200	58	1500
Digital ABS™	66–75	1700–2200

Table 9 shows the average flexural strength and flexural modulus for ULTEM9085, PA2200, and Digital ABSTM structures after testing with the MTS machine, as well as values of corresponding solid samples.

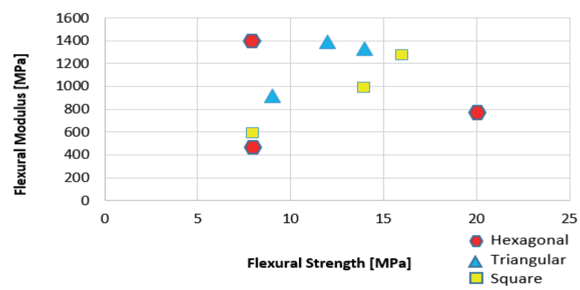


Figure 12: Flexural modulus vs. flexural strength for tested materials and structures

Figure 12 shows the relationship between flexural strength and flexural modulus of 3D printed polymer structures, showing no particular trend in values. The behavior between flexural strength and flexural modulus follows a random relation. There is no significant relation between flexural strength and flexural modulus, as confirmed by statistical analysis. Hexagonal Digital ABS™ and square Digital ABS™ structure with 8 MPa

Table 9: The values and standard deviations of flexural strength and flexural modulus for structures; standard deviation of flexural modulus was calculated from the standard error of the coefficient of the linear term in a quadratic fit to the bending data

Geometric structure	Flexural strength (MPa)	SD (MPa)	Flexural modulus (MPa)	SD (MPa)
ULTEM9085 solid	30.00	1.00	2049	20
ULTEM9085 hexagonal	19.89	0.22	767	3
ULTEM9085 triangular	12.00	2.00	1390	5
ULTEM9085 square	13.99	0.01	983	4
PA2200 solid	29.93	0.14	1490	30
PA2200 hexagonal	7.99	0.01	1400	15
PA2200 triangular	13.64	0.73	1331	13
PA2200 square	15.96	0.08	1270	12
Digital ABS™ solid	20.00	5.00	1120	8
Digital ABS™ hexagonal	7.87	0.26	465	8
Digital ABS™ triangular	8.89	0.21	915	10
Digital ABS™ square	8.84	0.32	590	10

bending strength have a much lower flexural modulus (465 MPa and 590 MPa) than PA2200 hexagonal structure with the same bending strength, but much higher flexural modulus of 1 400 MPa. Overall, all PA2200 structures had flexural modulus over 1 000 MPa.

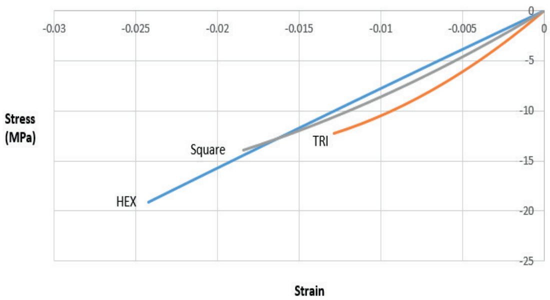


Figure 13: ULTEM9085 structures stress-strain calculated from fit to bending data

Figure 13 shows the stress-strain curve calculated fit to bending data for ULTEM9085 geometric structures at an MTS machine speed of 0.2 mm/s at room temperature. The hexagonal structure appears convex for ULTEM9085, while triangular and square structures appear concave. Figure 14 shows the stress-strain curve calculated least squares fit to bending data for PA2200 geometric structures. All the structures appear to have a concave trend. Figure 15 shows the stress-strain curve calculated from least squares fit to bending data for Digital ABS™ structures, with concave character as well.

Table 10 shows the flexural breaking energy per unit mass and energy per unit mass per unit strain for different geometric structures of the materials, along with values of corresponding solid samples. From Table 10, PA2200 triangular has the highest flexural energy per unit strain value per unit mass, after that PA2200

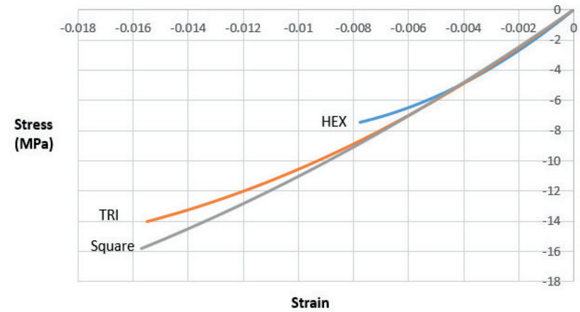


Figure 14: PA2200 structures stress-strain calculated from fit to bending data

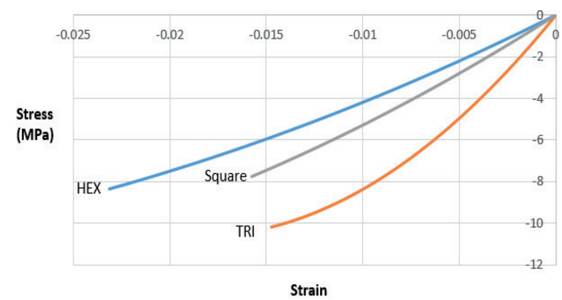


Figure 15: Digital ABS™ structures stress-strain calculated from fit to bending data

square has the second highest and PA2200 hexagonal the third. Digital ABS hexagonal has the lowest values for both flexural energy per unit strain per unit mass and flexural breaking energy per unit mass. The flexural strength per unit mass for the PA2200 square is not quite as much as the corresponding solid structure, but it is stiffer on a mass basis than the solid structure. This indicates that as long as the structure doesn't fail, it will bend less under moderate forces than the corresponding solid structure having the same mass.

Table 10: The values and standard deviations of flexural breaking energy and energy per unit mass per unit strain for designed structures

Geometric structure	Breaking energy per unit mass (kJ/kg)	SD (kJ/kg)	Energy per unit mass per unit strain (kJ/kg)	SD (kJ/kg)
ULTEM9085 solid	22.4	0.70	1 529	15
ULTEM9085 hexagonal	16.0	0.18	619	2
ULTEM9085 triangular	10.7	1.80	1 241	4
ULTEM9085 square	12.6	0.10	886	3
PA2200 solid	69.8	0.30	3 465	70
PA2200 hexagonal	20.0	0.03	3 517	37
PA2200 triangular	39.0	2.00	3 697	36
PA2200 square	44.8	0.22	3 576	33
Digital ABS™ solid	17.0	4.00	949	7
Digital ABS™ hexagonal	7.3	0.24	425	7
Digital ABS™ triangular	9.1	0.21	927	10
Digital ABS™ square	8.2	0.32	603	10

4. Conclusion

From the tensile results, the highest Young's modulus for ULTEM9085 was obtained with the triangular structure and the lowest value was obtained with the hexagonal structure. The tensile strength test values are the same for all three structures of ULTEM9085, but lower than the solid value. For PA2200, hexagonal structure has the highest value of Young's modulus, while the triangular structure has the lowest, although they are not that much different from one another. For Digital ABS™, the square structure has the highest values for both Young's modulus and tensile strength, while the triangular structure has the lowest values for both. The relationship between tensile strength and Young's modulus is well correlated.

For the compressive test, the highest values are obtained with the triangular structure and the lowest ones are obtained with the hexagonal structure for ULTEM9085. For PA2200, the square structure has the highest compressive modulus and the triangular has the lowest compressive modulus, but the tensile strengths are the same for all three structures. For Digital ABS™ the hexagonal structure has the highest compressive modulus value but the lowest compressive strength. The square structure has the lowest compressive modulus but the highest compressive strength. This indicates that the compressive modulus is acting contrary with compressive strength for this polymer. The eventual strength in compression is higher than the eventual strength in tension for brittle materials. This is because the existence of microscopic cracks or cavities, which tend to deteriorate the material in tension, while not significantly affecting its resistance to compressive failure. However, the microcracked compressed sample will likely not return to its original shape, which would compromise its behavior to additional stresses.

For the bending test, the ULTEM9085 triangular structure has the highest value of flexural modulus, but the lowest bending strength value, whereas ULTEM9085 hexagonal structure has the lowest value of flexural modulus, but has the highest bending strength. The hexagonal structure of PA2200 showed the highest flexural modulus value, but the lowest bending strength. The square structure showed the lowest flexural modulus value, but the highest bending strength. Digital ABS™ triangular structure has the highest flexural modulus value and the highest bending strength. The hexagonal structure for Digital ABS™ has the lowest flexural modulus. The highest bending strength was obtained with the triangular structure, while the hexagonal and square structures have the same bending strength values. The behavior between flexural strength and flexural modulus follow random relation, with no significant correlation between flexural strength and flexural modulus.

The square structure of PA2200 has the highest values for both tensile energy per unit strain per unit mass and tensile breaking energy per unit mass. After that PA2200 triangular is the second and PA2200 hexagonal is the third. The PA2200 tensile breaking energy values for both triangular and square are virtually indistinguishable from the 100 % infill case for this polymer. This is an indication that these two structures can absorb about the same tensile energy per unit mass as the corresponding solid structure without failing. Digital ABS™ hexagonal has the lowest values for both tensile energy per unit strain and tensile breaking energy per unit mass.

Further, PA2200 square also has the highest compressive energy per unit strain value per unit mass. Then, PA2200 hexagonal is the second and PA2200 triangular is the third, while Digital ABS™ square has the lowest compressive energy per unit strain per unit mass. Moreover, PA2200 square has the highest compressive breaking energy per unit mass and Digital ABS™ hexagonal has the lowest compressive strength value per unit mass. All of void structures for PA2200 seem to be able to absorb more compressive energy per unit mass than the corresponding solid structure.

Finally, PA2200 triangular has the highest flexural breaking energy value per unit mass. After that PA2200 square has the second highest flexural breaking energy value per unit mass and PA2200 hexagonal has the third. Digital ABS™ hexagonal has the lowest values for both flexural breaking energy per unit mass and flexural energy absorbed per unit strain per unit mass. The flexural strength per unit mass for the PA2200 square is not quite as much as the corresponding solid structure, but it is stiffer on a mass basis than the solid structure. This indicates that as long as the structure doesn't fail, it will bend less under moderate forces than the corresponding solid structure having the same mass.

From the results, it is hard to identify which structure is the strongest and has the best mechanical properties. This is because the 3D printed samples of the structures were printed using different 3D printing methods of the printed materials. The results of the thermoplastic designed structures either exceed or fall within the range of the mechanical properties of the human trabecular bone. However, the PA2200 shows the most promise for all of the void structures. It would be even more interesting if the behavior reported here could be replicated using other printing methods such as FDM or inkjet.

References

Ahn, S.-H., Montero, M., Odell, D., Roundy, S. and Wright, P.K., 2002. Anisotropic material properties of fused deposition modeling ABS. *Rapid Prototyping Journal,* 8(4), pp. 248–257.

ASTM International, 2015a. *ASTM D695-15 Standard Test Method for Compressive Properties of Rigid Plastics*. Westconchocken, PA: ASTM International.

ASTM International, 2015b. *ASTM D790-15e2 Standard Test Method for Flexural Properties of Unreinforced and Reinforced Plastics and Electrical Insulating Materials*. Westconchocken, PA: ASTM International.

Bahat, O. and Fontanessi, R.V., 2001. Implant placement in three-dimensional grafts in the anterior jaw. *International Journal of Periodontics & Restorative Dentistry,* 21(4), pp. 357–365.

Beer, F.P., Johnston, E.R., DeWolf, J.T. and Mazurek, D.F., 2012. *Mechanics of Materials*. New York: McGraw Hill Companies.

Ehrenberg, R., 2013. Health & Illness: Skull patched with plastic. *Science News,* 183(8), p. 12.

EOS, 2015. *Material data sheet: PA 2200*. [pdf] EOS GmbH – Electro Optical System. Available at: <https://www.shapeways.com/rrstatic/material_docs/mds-strongflex.pdf> [Accessed September 2015].

Heng, L., Wang, B., Li, M., Zhang, Y. and Jiang, L., 2013. Advances in fabrication materials of honeycomb structure films by the breath-figure method. *Materials*, 6(2), pp. 460–482.

International Organization for Standardization, 2014. *ISO 3167:2014 – Plastics – Multipurpose test specimens*. Geneva: ISO.

Jia, N. and Kagan, V.A., 2001. Mechanical performance of polyamides with influence of moisture and temperature – accurate evaluation and better understanding. In: J. Moalli, ed. 2001. *Plastic Failure Analysis and Prevention*. Norwich, NY: William Andrew Inc. pp. 95–104.

MatWeb, 2016. *Flexural Strength Testing of Plastics*. [online] Available at: <http://www.matweb.com/reference/flexuralstrength.aspx> [Accessed November 2016].

Materialise, 2016. *Stereolithography*. [online] Available at: <http://manufacturing.materialise.com/stereolithography> [Accessed 15 January 2016].

Miller, M.B., 2013. *Applications of 3D Printing in the Medical Field*. [e-book] Smashwords Inc. Available through: Smashwords Inc. website: <https://www.smashwords.com/books/view/327956> [Accessed 1 Febraury 2016].

Razak, S.I.A., Sharif, N.F.A. and Rahman, W.A.W.A., 2012. Biodegradable polymers and their bone applications: a review. *International Journal of Basic & Applied Sciences IJBAS IJENS,* 12(1), pp. 31–49.

Stevanovic, S., Chavanne, P., Braissant, O., Pieles, U., Gruner, P. and Schumacher, R., 2013. Improvement of mechanical properties of 3D printed hydroxyapatite scaffolds by polymeric infiltration. *Bioceramics Development and Applications*, S1:012.

Stoia, D.I., Vigaru, C. and Rusu, L., 2015. Laser sinterization aspects of PA2200 biocompatible powder – spinal cage application. *Key Engineering Materials*, 638, pp. 352–356.

Stratasys, 2015. *ULTEM 9085 Resin*. [online] Available at: <http://www.stratasys.com/materials/fdm/~/media/83DA2BBEE7DE4A669CFEF6B1FCA118AA.ashx> [Accessed September 2015].

Stratasys, 2016. *PolyJet Technology*. [online] Available at: <http://www.stratasys.com/3d-printers/technologies/polyjet-technology> [Accessed February 2016].

Tao, C.T. and Young, T.H., 2006. Polyetherimide membrane formation by the cononsolvent system and its biocompatibility of MG63 cell line. *Journal of Membrane Science,* 269(1–2), pp. 66–74.

Tyagi, G., 2011. *Introduction to 3D Printing*. [pdf] Lucknow, Uttar Pradesh, India: National Informatics Centre. Available at: <nicsu.up.nic.in/knowdesk/3D-Printing-Technology.pdf> [Accessed 12 January 2015].

Williams, J.M., Adewunmi, A., Schek, R.M., Flanagan, C.L., Krebsbach, P.H., Feinberg, S.E., Hollister S.J. and Das, S., 2005. Bone tissue engineering using polycaprolactone scaffolds fabricated via selective laser sintering. *Biomaterials,* 23(26), pp. 4817–4827.

Yahamed, A., Ikonomov, P., Fleming P.D., Pekarovicova A. and Gustafson, P., 2016. 3D printing of model polymeric resins for mediacal applications. In: P. Gane, ed. *Advances in Printing and Media Technology: Proceedings of the 43rd International Research Conference of iarigai*. Toronto, Canada, August 2016. Darmstadt: International Association of Research Organizations for the Information, Media and Graphic Arts Industries. pp. 137–142.

Yahamed, A., Joyce, M., Fleming, P.D. and Pekarovicova, A., 2015. Biopolymers for 3D printed bone structure. In: *31st International Conference on Digital Printing: Digital Fabrication and Digital Printing*. Portland, 27 September to 1 October 2015. Springfield: Society for Imaging Science and Technology. pp. 406–410.

Appendix A

Figures A1 to A9 show the results of tensile strength tests for designed structures (ca is abbreviation for calculated).

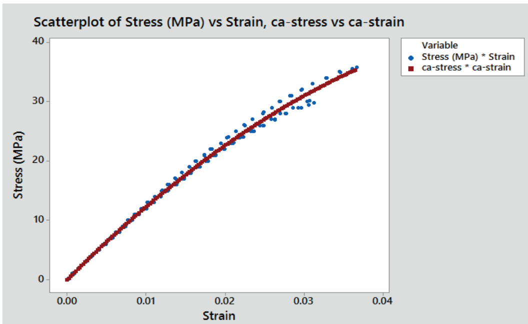


Figure A1: Measured stress-strain and calculated stress-strain of ULTEM9085 hexagonal structure

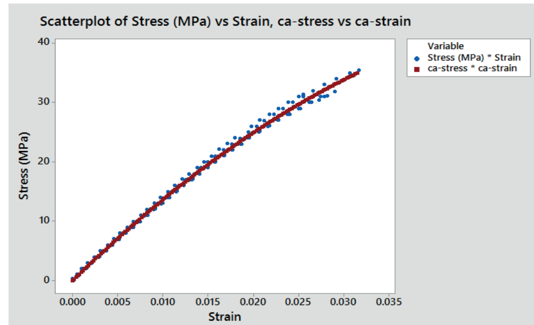


Figure A2: Measured stress-strain and calculated stress-strain of ULTEM9085 triangular structure

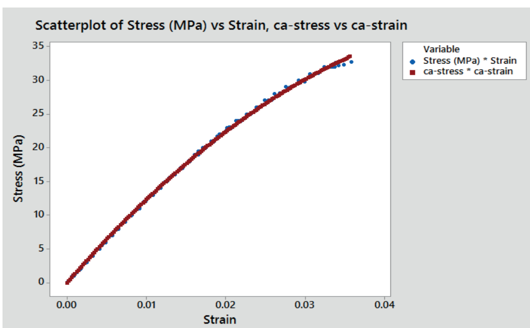


Figure A3: Measured stress-strain and calculated stress-strain of ULTEM9085 square structure

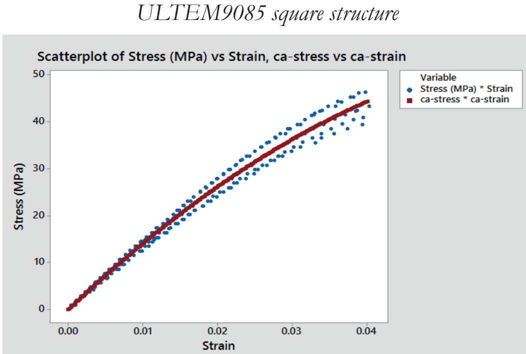


Figure A4: Measured stress-strain and calculated stress-strain of PA2200 hexagonal structure

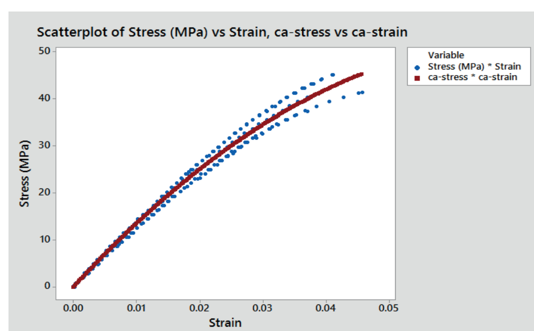


Figure A5: Measured stress-strain and calculated stress-strain of PA2200 triangular structure

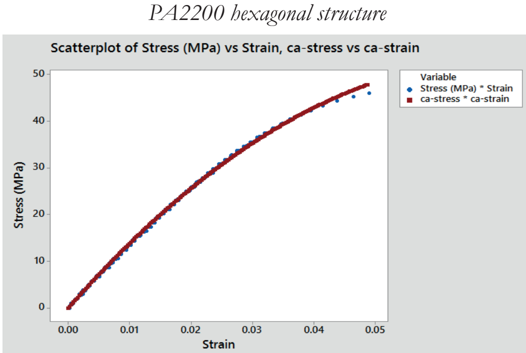


Figure A6: Measured stress-strain and calculated stress-strain of PA2200 square structure

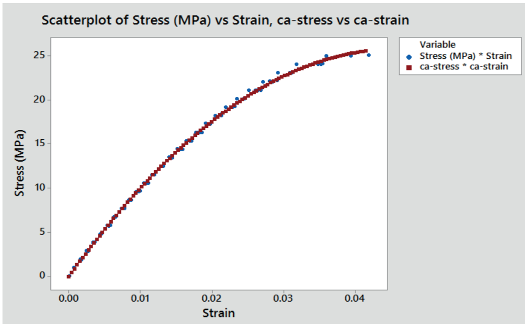
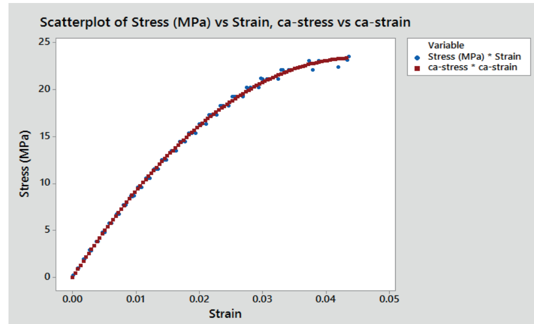


Figure A7: Measured stress-strain and calculated stress-strain of Digital ABS™ hexagonal structure



FigureA8: Measured stress-strain and calculated stress-strain of Digital ABS™ triangular structure

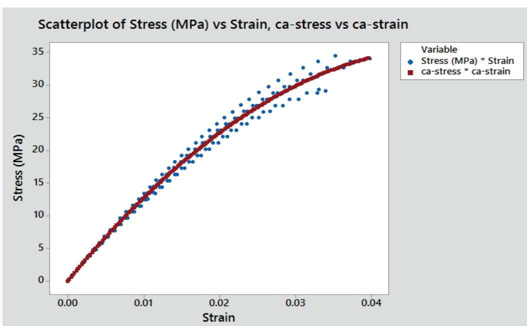


Figure A9: Measured stress-strain and calculated stress-strain of Digital ABS™ square structure

Appendix B

Figures B1 to B9 show results of the compressive strength tests for designed structures.

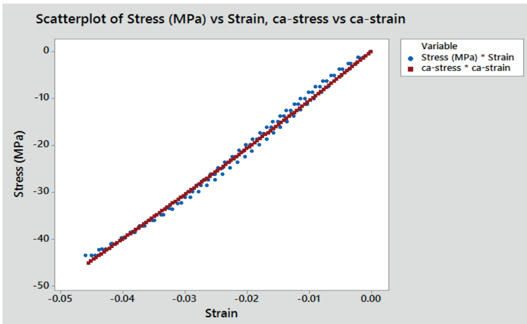


Figure B1: Measured stress-strain and calculated stress-strain of ULTEM9085 hexagonal structure

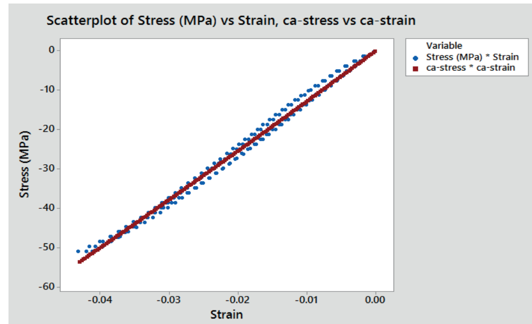


Figure B2: Measured stress-strain and calculated stress-strain of ULTEM9085 triangular structure

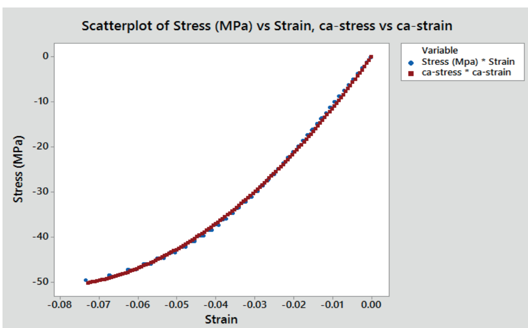


Figure B3: Measured stress-strain and calculated stress-strain of ULTEM9085 square structure

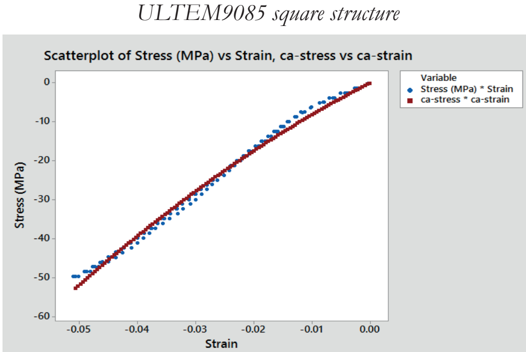


Figure B4: Measured stress-strain and calculated stress-strain of PA2200 hexagonal structure

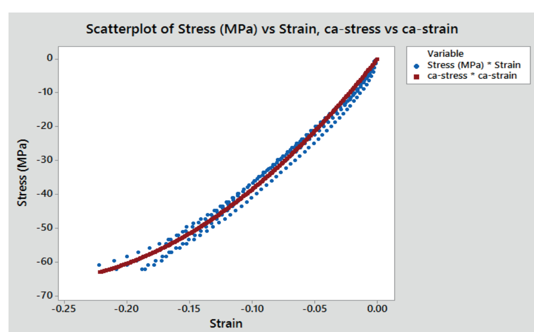


Figure B5: Measured stress-strain and calculated stress-strain of PA2200 triangular structure

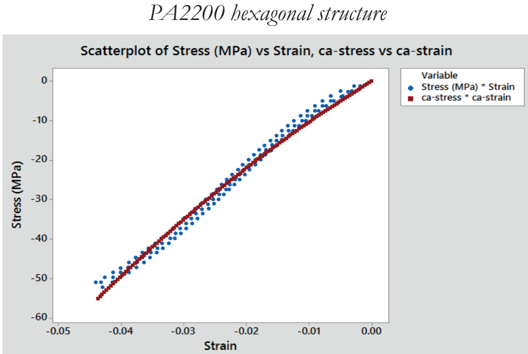


Figure B6: Measured stress-strain and calculated stress-strain of PA2200 square structure

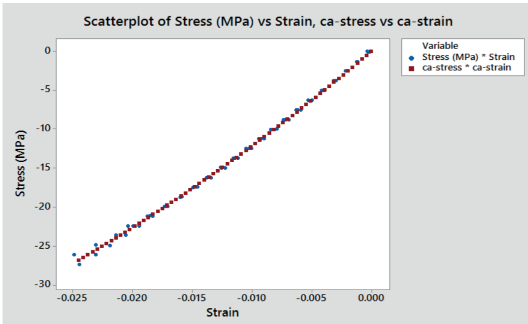


Figure B7: Measured stress-strain and calculated stress-strain of Digital ABS™ hexagonal structure

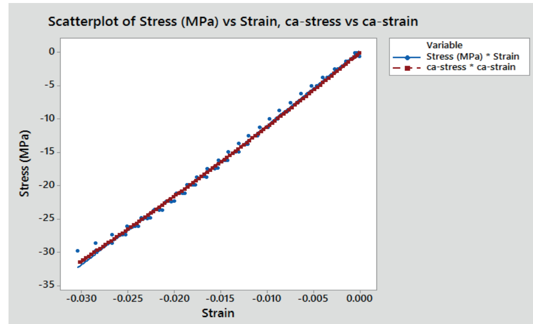


Figure B8: Measured stress-strain and calculated stress-strain of Digital ABS™ triangular structure

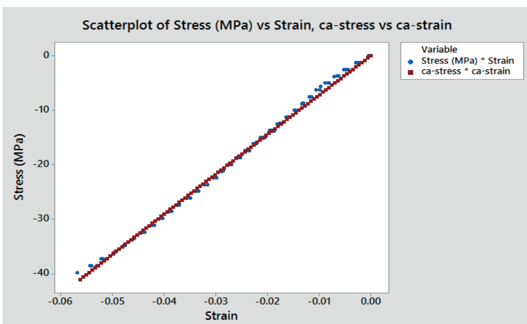


Figure B9: Measured stress-strain and calculated stress-strain of Digital ABS™ square structure

Appendix C

Figures C1 to C9 show results of the bending strength tests for designed structures.

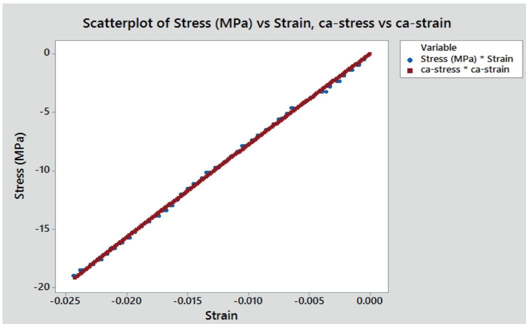


Figure C1: Measured stress-strain and calculated stress-strain of ULTEM9085 hexagonal structure

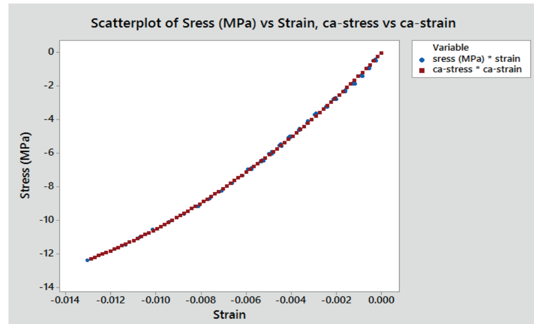


Figure C2: Measured stress-strain and calculated stress-strain of ULTEM9085 triangular structure

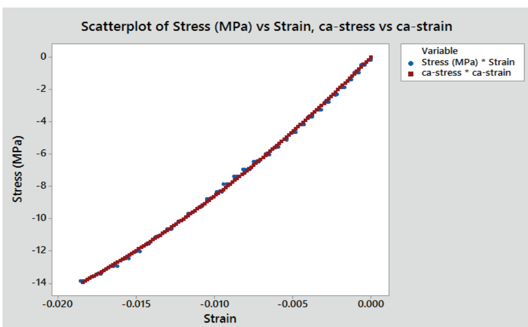


Figure C3: Measured stress-strain and calculated stress-strain of ULTEM9085 square structure

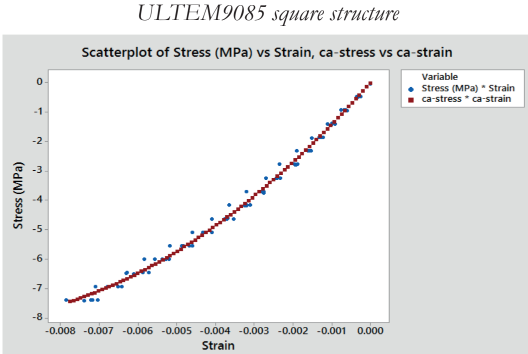


Figure C4: Measured stress-strain and calculated stress-strain of PA2200 hexagonal structure

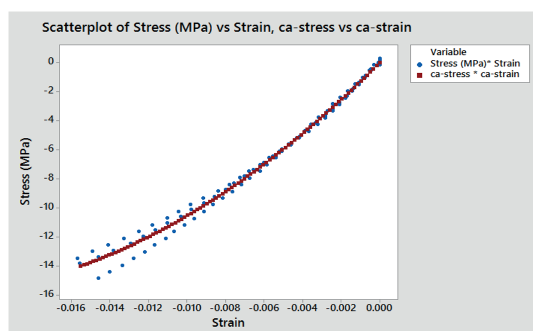


Figure C5: Measured stress-strain and calculated stress-strain of PA2200 triangular structure

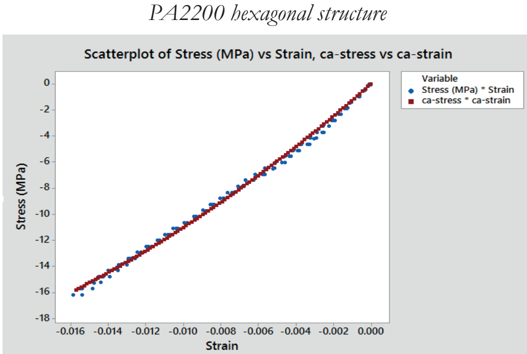


Figure C6: Measured stress-strain and calculated stress-strain of PA2200 square structure

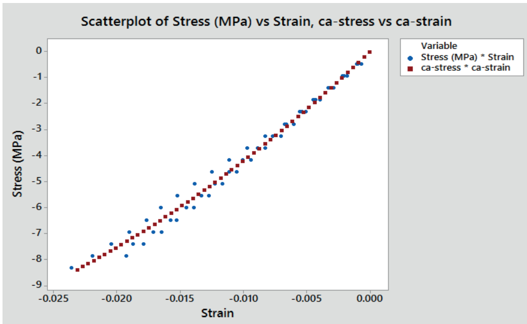


Figure C7: Measured stress-strain and calculated stress-strain of Digital ABS™ hexagonal structure

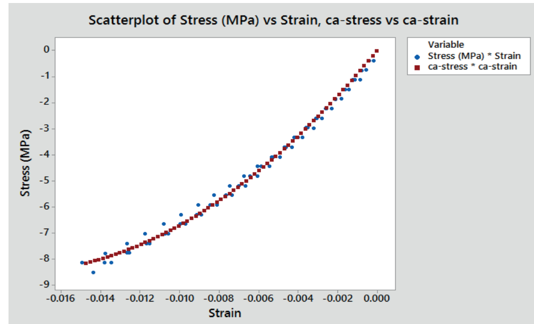


Figure C8: Measured stress-strain and calculated stress-strain of Digital ABS™ triangular structure

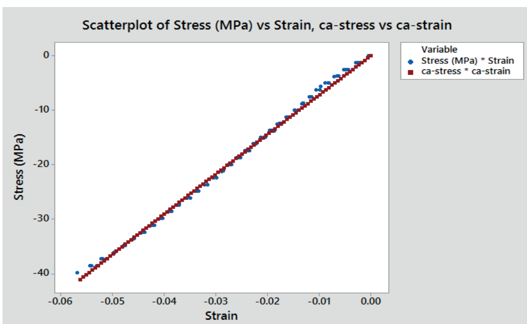


Figure C9: Measured stress-strain and calculated stress-strain of Digital ABS™ square structure

JPMTR 090 | 1613
DOI 10.14622/JPMTR-1613
UDC 659.1:070-055.1/3

Case study
Received: 2016-10-07
Accepted: 2016-12-27

Gender stereotype and advertisement language on newspaper and magazine media platform in Nigeria

Ojinga Gideon Omiunu

Unicorn Academics and Organisation Developmental Research Centre, Ibadan, Nigeria,
P.O. Box 20671, UI Post office, Ibadan, Oyo State, Nigeria

E-mails: omiunuojingag@gmail.com
ohiojingao@yahoo.com

Abstract

This study seeks to investigate gender stereotype and the language of advertising used in media platform in Nigeria. A convenient sampling was deployed to select three indigenous newspapers and two magazines in Nigeria. The three newspapers used for this study are the Tribune, Guardian and the Nation; and the two magazines used are Ovation and City people. The findings of the study revealed that gender bias occurs in media advertisement in Nigeria and it is more pronounced in newspaper than in the magazines. Body images of females in advertisement were more exposed that those of male and the most revealed female body parts were the arms, thigh and chest, among others, while for the males only their arms and legs were revealed. The majority of advertisement done in newspaper and magazines are gender specific, that is, they addressed particular and specific gender type thus neglecting the other gender type. The study recommends that the female gender should not be portrayed in the society as mere sex objects. Also, advertising agencies should endeavor to make advertisements to be gender neutral; however, it is also important to put into cognizance the particular gender for which the advertisement is produced.

Keywords: advertising model, gender differences, human body, image, media market

1. Background to the study

Advertising which is the promotion of commercial goods through the media has been an important phenomenon among producers and marketers and is increasingly influencing daily lives of individuals and activities of organizations. It is a double stand with two major functions: one is to persuade potential customers, and the other is to provide information to the potential customers (Yang, 2010). To achieve this, the mass media such as newspapers, magazines, radio and television are tools used by producers and marketers to convey these information and awareness of products and services to potential customers. This is done because potential customers are individuals from different backgrounds and with different views and perspectives of life, thus advertising agencies need to put and pull along resources to win them. This implies that advertising has to cater for different kinds of customers if such business would achieve higher competitive edge over its competitors.

In addition, the type of language used for communicating such information about products and services to potential customers is also of paramount interest to advertising agencies. To this end, how to make advertising more effective has attracted many attention in the field of marketing and communication and other relevant fields of interest. For example, Mladenović, Vujović and Cigrovski (2010) affirmed that, almost every advertising agency employs both psychologists and sociologists who try to construct images and messages which the readers are more likely to accept. Images and messages that are in compliance with the views and values which the audiences (which in this study are known as potential customers) of a particular publication already have, are most likely to appeal to them. Thus, the need for readers to be constantly and continuously being surveyed (Vestergaard and Schrøder, 1985, p. 73). Therefore, the portrayal of men and women in adverts in magazines and other media need to correspond to the socially accepted images and values of their readers. Furthermore, van Herpen et al. (2000) stated that some potential customers prefer clear and credible advertisements, which are also easy to understand, howbeit, others prefer images. Advertisers are changing advertising strategies to make advertising more attractive and influential. This makes advertisers including marketers and producers to selectively identify (which could include different genders) and use different languages that would meet the expectation of their potential customers. To this end, many advertisers use different means (which could include different genders) and languages to attract the majority to their products and services.

Language is known to be the medium of communication among individuals living in a community. Valiulis, O'Driscoll and Redmond (2007) state that meaning conveyed through language is critical to developing an understanding of how language can be used to reinforce gender stereotypes. The language of advertising has been connected with gender issues in every society. In particular, language and gender are significant issues that remain widely controversial in the domain of advertising. In addition, the development of advertising can be divided into four stages: the product information stage, the product image stage, the personalization stage and the lifestyle stage (Cheng and Schweitzer, 1996). This is the major reason why Yang (2010) states that information conveyed in advertisements to potential customers is turning from impersonal to personal. This is because potential customers/ readers of these media tend to personalize such messages and information which they could use and the advertisers makes the information or messages easy to be personalized by them.

Furthermore, many media often divide the public into various demographic characteristics such as gender, age, educational qualification or occupational types, among others. For example, Yang (2010, p. 9) has stated that many media divide the public into female and male audience. Others focus their advertising on specific age group such as teenage boys and teenage girls. In addition, content and language of such advertisers and advert are often gender stereotypic (Willemsen, 1998). Also, some famous magazines and other media provide leading fashion for women all around the world and some have excluded female readers and only focused on supposed male interests, thus, making advertising a gender sensitive activity. Also, Smith (1985), Tannen (1991) and Coates (1993) state that women and men differ in the use of language. The problem is whether this gives a reason for advertisers to use different languages in advertising for female and male separately because this may consequently influence people's usage of language and the use of gender related images and pictures in advertising.

In addition, advertisers and marketers use women to sell everything ranging from household items, cigarettes, alcohol, furniture, etc., giving the impression that women need everything to make them complete or satisfied. For example, Ferguson, Kreshel and Tinkham (1990) affirm that women are portrayed as subordinate to men or merely as a decorative items when used in advertisement and Iijima Hall and Crum (1994) state that women are used as images of sex objects and decoration. Furthermore, when women appear in these adverts, their bodily exposure are greater: women are portrayed in these commercials through shots of the chest, leg, buttock and crotch and they appear in either leisure wear or swim wear, whereas the men were always dressed in work clothes (Iijima Hall and Crum, 1994). This could lead to problems in to the society as such adverts are contrary to the culture of most societies. As a product of human culture, adverts can reveal many cultural factors. Furthermore, women tend to be portrayed either in a degrading or demeaning fashion or in sex-role stereotypic behaviors (Yang, 2010). Also, Frith, Cheng and Shaw (2004), Matud, Rodríguez and Espinosa (2011) and Arima (2003) revealed that gender difference in advertising is a general phenomenon across the world. In Nigeria, such studies are limited. To this end, this study seeks to investigate gender sterotype and the language of advertising used in media platform in Nigeria. Also, the following research questions would drive this study.

1. Are advertising in Nigeria media gender biased?
2. What kind of product and service advert do males and females feature the most in Nigeria media?
3. How are males and females portrayed in these adverts?
4. Is there difference in the language employed in the selected adverts with respect to the different gender used?

1.1 Previous studies

Language is a means of communication used in a given society (Golzadeh et al., 2012) and without language, people living in a society may not be able to communicate (Udebunu, 2011). Also, we can use signs and symbols in language – whether they are sounds, written words, electronically produced images, musical notes, even objects – to stand for or to represent to other people our concepts, ideas and feelings. Thus, representation through language is therefore central to the processes by which meaning is produced (Devlin, 2006).

Furthermore, gender studies arise with the reaction against the main stream in which males were the center of society (Coates, 1993). However, women now gain the right to perform the activities of men in our societies (Yang, 2010). Since then, there have been changes not only in workplace and at home but also in the attitudes of people on the issue of gender roles especially with regards to their community or society. Although, study such as Cameron (1992) has proven that women were inferior to men. Feminists study have been mostly interested in gender differences, and they believe that through linguistic behavior, the nature and status of women can be revealed (Cameron, 1992). The issue of gender with regards to language used had earlier been visited and worked upon. For example, Lakoff's (1975) study on Language and woman's place revealed that differences exist in the way women and men use language. Women are taught to behave properly and to talk like ladies. There is the language of women which men are reluctant to use. Yang (2010) argued that Lakoff's result about language and gender in some cases was found incorrect; however, her work gave necessary shape to later research. Due to women's insecure social position, they are more sensitive to linguistic norms than men (Yang, 2010). Coates (1993) believed that women and men have different standard on communication competence. Although, there are many approaches with regards to the relationship between gender and language use, some scholars focus on gender differences in conversational practice. (Graddol and Swann, 1989; Tannen, 1991; Yang, 2010). According to Eckert and McConnell-Ginet (2003) who studied the language of Yanyuwa within aboriginal Australia, they found out that there are distinctive dialects for females and males even within a particular culture. The relationship between advertising and gender has attracted a lot of attention because advertising has become a part of our everyday life (Yang, 2010) and according to Golzadeh et al. (2012), gender is one of the main and probably the most important discussion in advertising.

Furthermore, Yang (2010) affirmed with examples that it is not unusual to observe a beautiful and attractive woman appearing in an advert for male customers or a seemingly perfect woman in an advert for a female product. In addition, studies on gender and advertising are divided into two directions – mold and mirror (Yang, 2010): either gender differences in reality lead to those portrayed in advertising, or adverts in a way shaping people's minds about gender. The media is part of our gender-role socialization; research on television commercials have indicated that both men and women are portrayed in a sex-stereotyped way (Burn, 1996, p. 14). In another research conducted by Williams and Best (1990) in 25 countries, participants were asked to associate 300 adjectives with either males or females. The result of the study revealed that men are widely considered to be active, determined, ambitious, courageous, dominant, independent, strong, unemotional, and rational, while women are seen as affectionate, attractive, dependent, fearful, sentimental, sexy, sensitive, and emotional.

The media such as magazines and newspapers, among others, often divide the public into female readership and male readership. Also, some media deem it fit to divide their readers according to their age group as some specializes on providing goods and services for teenage boys and teenage girls separately, and such content and language from such media are often gender stereotypic (Willemsen, 1998). This was why Golzadeh et al. (2012) stated that gender is one of the main criteria to dividing any market, therefore, there is a need to arrange combined marketing elements, such as advertising, regarding the existing differences between men and women for each part of the market. The study of Asemah, Edegoh and Ojih (2013) clearly affirmed that women are traditionally portrayed in advertising in stereotypical roles or in ways that do not necessarily match reality which often form negative representations of women in advertising and affect young women. Women, traditionally have been over-represented in the homes and under-represented outdoors and in business settings and there is evidence that advertising presents a traditionally stereotyped portrayal of women and that attitudes have changed dramatically over the past decade (Asemah, Edegoh and Ojih, 2013).

Furthermore, Asemah, Edegoh and Ojih (2013) state that advertisers are culpable for the heightened body dissatisfaction amongst women, because they constantly use sexy unrealistic images of ultra thin models, the depiction of women as sex objects and the frequent use of sex, to sell products. Since the late 1960s, there have been concerns regarding the portrayal of women in the media. Bardwick and Schumann (1967) analysed the portrayal of women in commercials and concluded that to an amazing extent, women are portrayed as sex objects. Visual adverts are bombarded with images and slogans portraying women in an unrealistic manner. Also, Whipple and Courtney's (1985) study found out that advertising presents a traditionally stereotyped portrayal of women. Although advertisers aim to reach all segments of the consuming public, their portrayal of society is not necessarily an accurate reflection of how society is composed; most of such adverts are skewed. In most adverts, women are generally portrayed as subordinate to men or merely as a decorative item (Asemah, Edegoh and Ojih, 2013).

Furthermore, Mladenović, Vujović and Cigrovski (2010) in their study divided the language of advertising into: figuratives, repetition, personification, alliteration, rhetorical questions, imperative, lexis, and other stylistic devices. Among them, only the use of lexis and imperatives is used differently among media. This implied that there could be some level of similarities and differences in the use of advertising language during adverts. In addition, advertising language incorporates gender in a gender-neutral, gender-specific, or gender-biased manner (Artz, Munger and Purdy, 1999). Every utterance or piece of text can be categorized this way. Gender-neutral language either has no reference to gender (e.g., 'someone') or it simultaneously refers to both genders (e.g., 'women and men', 'his or her', or 'she/he'). Gender-specific language refers to either male or female in a non-biased way. For example a male spokesperson could be referred to as 'he'. Gender-bias can take a variety of forms in language and may include language that excludes one gender (e.g., 'the average man' when used to refer to 'people'), convey unsupported or biased connotations (e.g., 'doctors spend little time with their wives' rather than spouses), or imply or contain irrelevant evaluation of gender (e.g., 'the little woman').

Of importance to this study is gender images used in advertisements. Studies conducted by Harrison, Juric and Cornwell (2001), Kuntjara (2001) and Lim and Ting (2011) have affirmed that images in adverts have the power to shape the perception of a society as far as the way they look at the world. Women in particular, are often portrayed as sexual objects in advertising through their images (Berger, 1999; Ford, LaTour and Lundstrom, 1991; Stankiewicz and Rosselli, 2008). Relationally, the conventional beauty is typically women's main attribute of attraction (Ingham, 1995; Johnston and Taylor, 2008; Ong and Seah, 2001). However, the images of women portrayed in most adverts are frequently observed as a creation of artificiality that establishes an impossible standard of physical perfection for women (Kuntjara, 2001; Workman and Johnson, 1991). Bardwick and Schumann (1967) analysed male and female role portrayals in television commercials and concluded that women are portrayed primarily as homebound or as housewives. Putting into consideration the African culture, what are the various languages of advertising used and how are gender (male and female) images displayed on Media Platform in Nigeria? These are major gaps this present study seeks to fill.

2. Theoretical underpinning

The theories deployed in this study are the feminist and constructivist theory and the queer theory of Khan and Ali (2012). The social construction of gender asserted that in a society, gender is thought to be bred into our genes. It is hard to believe that it is created out of human interactions, social life and is a structure of that society. In a society, every gender has its significance. For example, Butler (1990) has also shown that the exploitation of women and social domination of men has social functions and a social history, it is not the result of sex, philosophy, structure or hormones. It is created by identifiable social processes. Thus, Butler called this phenomenon gender trouble. In addition, Butler (1990, p. 278) said that '*Gender reality is performative which means, quite simply, that it is real only to the extent that it is performed.*'

Eckert and McConnell-Ginet (1995) have stated in Constructing meaning and constructing selves, that people use language as a basic tool to construct themselves and others as "kinds" of people so that characteristics, attributes, duties and participation in social practice such as advertising can be regularized. Constructivist paradigm believes that these categories and characterizations are social and human productions and creations: the images attached with them are not ready-made and pre-formed; rather they are constructed, created, maintained and transmitted by social procedures such as in the advertising.

These frameworks will be used to examine advertising for evidence of gender stereotyping. They offer the possibility of identifying overt evidence of stereotyping and more subtle stereotypical portrayals and of illuminating the processes by which gendered messages might be communicated in the marketing of products and services in advertisement. Thus, the resultant framework used to this end was the Analysis of gender equality issues in the marketing and design of goods by Valiulis, O'Driscoll and Redmond (2007). The framework is presented in Figure 1.

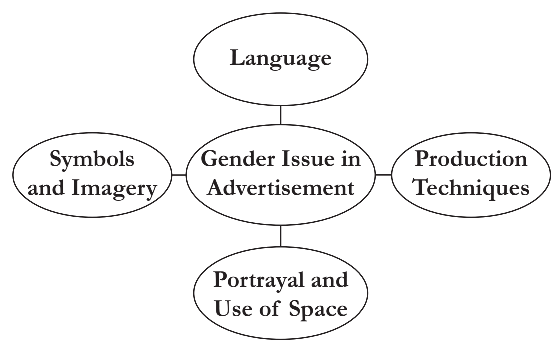


Figure 1: Gender equality framework for marketing and design of goods, adopted from Valiulis, O'Driscoll and Redmond (2007)

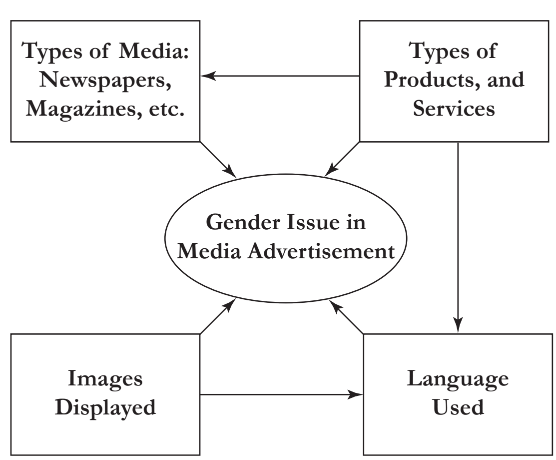


Figure 2: Gender issues – media advertisement model

According to Valiulis, O'Driscoll and Redmond (2007), the examination of gender equality issues in the marketing and advertising of products and services needs to encompass a series of related dimensions if it is to assess adequately the extent to which gender stereotyping is present in these strategies. Thus, the resultant model derived for this present study is presented in Figure 2.

From the Figure 2, it could be observed that language used, types of products and services, types of media and images displayed could individually play major roles respectively on gender issues in advertisements. In addition, types of products and services could affect the language used; images displayed may also influence language used; while type of media can also influence type of products and services. The main argument of this study is hinged and conceptualized on the fact that there is an appropriate gender role in the advertisement of goods and services; and advertisers should put into cognizance the type of media, products and services, images to display and language to be used to be able to attract their potential customers and increase their competitive advantage – as these factors may put off some potential customers, especially in Nigeria with a culture that does not welcome negative use of sex images and languages that may be offensive and gender biased.

3. Research methods

The study takes a content analysis form, and the population of interest in this study includes adverts placed on the media such as newspapers and magazines in Nigeria. It also includes all products and services. A convenient sampling was deployed to select three indigenous newspapers and two magazines in Nigeria. The three newspapers used for this study are the Tribune, Guardian and the Nation; the two magazines used are Ovation and City people. The newspapers adverts covered the period of one week from Monday August 25th to Sunday August 31st, 2014 and the magazine adverts covered the period of two weeks between Monday August 25th and Sunday September 7th, 2014. This wide gap was chosen for the magazines because issues were produced and published once in a week, while the newspaper is an everyday affair. In addition, 81 adverts were sampled purposively from the three newspapers and two magazines.

Variables of importance in this study are body exposures such as chest, thigh, buttocks, crotch, arms and legs; advert type such as whether the advert is a product which include home items or sanitary wares; or a service base or a corporate one; portrayal in the advert such as whether the advert portrayed the model as sex object or the model is portrayed as a house or homebound, or as a decorative item; gender which captures whether it is male model and how is he been used or a female and how is she been used, among others. Information and data obtained were analysed thematically through a content analysis with respect to the themes in the research questions. This involved the use of careful observation on the selected adverts in the newspapers and magazines used for this study. In addition, the observations obtained were subjected to and analysed qualitatively using frequency and percentage description.

4. Results and findings

The Table 1 summarises the determined distribution of gender used in advertisements in media. The results from Table 1 reveal that gender bias in advertisement occurs in media as over 53 % of the adverts placed on the newspaper and magazines are gender biased. In addition, gender bias in advertisement is more common in the newspaper (58.7 %) than in the magazines (45.7 %). This implies that gender bias in advertisement is more of an issue to recon with in newspaper than in the magazines. The kind of products and services featured with regards to gender difference in Nigeria media is presented in Figure 3.

Table 1: Gender bias in advertisement

	Place				Total	
	Magazine		Newspaper			
Gender bias	**Frequency**	**Share (%)**	**Frequency**	**Share (%)**	**Frequency**	**Share (%)**
Unknown	2	5.7	–	–	2	2.5
No	16	45.7	18	39.1	34	42.0
None	1	0.9	1	2.2	2	2.5
Yes	16	45.7	27	58.7	43	53.1
Total	35	100.0	46	100.0	81	100.0

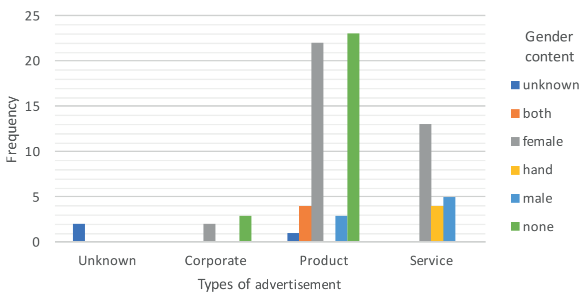


Figure 3: Gender differences in advertisement type

The resulst in Figure 3 reveal that advertisements with female images were more observed in product and service oriented adverts while the males only participate in adverts that are service oriented. This implies that females partake more in both products and services oriented advertisement than the males.

The distribution of gender in advertisement and focus of advert is presented in Table 2. From Table 2, it can be observed that women were used in adverts related to both businesses and homes while males were used in adverts that are only related to businesses. This implies that women are more deployed in businesses and home related adverts than the men.

The categories of body images reveal by gender is presented in Table 3. The results in Table 3 show that body images of females in advertisement were more exposed than those of male. Female body parts revealed the most are their arms, thigh and chest, while for the males only their arms and legs were revealed.

The results in Table 4 document that the females were mostly used as sex object in the advertisement of home

Table 2: Gender in advertisement and focus of advert

Focus	Gender content (frequency and percentage)						Total
	unknown	both	female	hand	male	none	
Unknown	2	–	–	–	–	–	2
	66.7 %	–	–	–	–	–	2.5 %
Business	1	4	26	4	8	25	68
	33.3 %	100.0 %	70.3 %	100.0 %	100. %	100.0 %	84.0 %
Home	–	–	11	–	–	–	11
	–	–	29.7 %	–	–	–	13.6 %
Total	3	4	37	4	8	25	81
	100.0 %	100.0 %	100.0 %	100.0 %	100.0 %	100.0 %	100.0 %

Table 3: Categories of body images reveal with respect to gender

Body images revealed	Image category (frequency and percentage)						Total
	unknown	both	female	hand	male	none	
Unknown	2	–	–	–	–	1	3
	66.7 %	–	–	–	–	4.0 %	3.7 %
Arms	–	–	8	–	–	–	8
	–	–	21.6 %	–	–	–	9.9 %
Arms, chest, leg	–	–	1	–	–	–	1
	–	–	2.7 %	–	–	–	1.2 %
Arms, legs	3	–	2	–	2	–	4
	100.0 %	–	5.4 %	–	25.0 %	–	4.9 %
Arms, thigh, legs	–	–	1	–	–	–	1
	–	–	2.7 %	–	–	–	1.2 %
Buttocks, back	–	–	1	–	–	–	1
	–	–	2.7 %	–	–	–	1.2 %
Chest	–	1	1	–	–	5	7
	–	25.0 %	2.7 %	–	–	20.0 %	8.6 %

Body images revealed	Image category (frequency and percentage)						Total
	unknown	both	female	hand	male	none	
Chest, arms	–	–	4	–	–	–	4
	–	–	10.8 %	–	–	–	4.9 %
Leg	–	–	4	–	1	2	7
	–	–	10.8 %	–	12.5 %	8.0 %	8.6 %
Stomach	–	–	1	–	–	–	1
	–	–	2.7 %	–	–	–	1.2 %
None	1	3	14	4	5	17	44
	33.3 %	75.0 %	37.8 %	100.0 %	62.5 %	68.0 %	54.3 %
Total	3	4	37	4	8	25	81
	100.0 %	100.0 %	100.0 %	100.0 %	100.0 %	100.0 %	100.0 %

Table 4: Gender and how they are portraye

			Image category (frequency and percentage)						Total
			missing values	both	female	hand	male	none	
Corporate	Portrayal	None	–	–	2	–	–	3	5
			–	–	100.0 %	–	–	100.0 %	100.0 %
	Total		–	–	2	–	–	3	5
			–	–	100.0 %	–	–	100.0 %	100.0 %
Product	Portrayal	Unknown	–	–	–	–	–	4	4
			–	–	–	–	–	18.2 %	7.8 %
		Decorative	–	–	–	–	1	–	1
			–	–	–	–	33.3 %	–	2.0 %
		Homebound	–	–	11	–	1	–	12
			–	–	52.4 %	–	33.3 %	–	22.6 %
		Sex object	–	–	2	–	–	1	3
			–	–	9.6 %	–	–	4.5 %	5.9 %
		None	1	4	8	–	1	17	31
			100.0 %	100.0 %	38.1 %	–	33.3 %	77.3 %	60.8 %
	Total		1	4	21	–	3	22	51
			100.0 %	100.0 %	100.0 %	–	100.0 %	100.0 %	100.0 %
Service	Portrayal	Unknown	–	–	1	–	–	–	1
			–	–	7.1 %	–	–	–	4.3 %
		Decorative	–	–	3	–	–	–	3
			–	–	21.4 %	–	–	–	13.0 %
		General	–	–	1	–	–	–	1
			–	–	7.1 %	–	–	–	4.3 %
		Homebound	–	–	5	–	–	–	5
			–	–	35.7 %	–	–	–	21.7 %
		None	–	–	4	4	5	–	13
			–	–	28.6 %	100.0 %	100.0 %	–	56.5 %
	Total		–	–	14	4	5	–	23
			–	–	100.0 %	100.0 %	100.0 %	–	100.0 %

bound products (9.6 %); however, none was used as sex object in the advertisement for the corporate and service. This implies that home bound product advert deploy women as sex object in their advertisements.

The distribution of language used in advertisement is presented in Table 5. Based on the results in Table 5, language employed for advertisement were gender specific in 42 cases, which means that majority of the advertisement language (51,9 %) are gender specific to a particular gender type. Few were gender biased, and few adverts also used language that is gender equal. This implies that majority of the advertisement done in newspaper and magazines is addressing a particular and specific gender type, thus neglecting the other gender type. This could make the other gender frown at such advert because such neglected gender may think that such advert wasn't meant for him or her. This can also reduce the potentials of such advert to attract potential customers which they are meant for.

Table 5: Language employed in the adverts

Language	Frequency	Share (%)
Missing values	26	32.1
Biased	2	2.5
Equality	3	3.7
Neutral	6	7.4
None	2	2.5
Specific	42	51.9
Total	81	100.0

5. Discussions of findings

The findings of this study revealed that gender bias in advertisement occurs in Nigeria media. In addition, gender bias in advertisement is more common in the newspapers than in the magazines. This supports the study of Yang (201, p. 9) that many media divide the public into female and male audience. Also, advertisements with female images were more observed in product and service oriented adverts while the males only participated in adverts that are service oriented. This implies that females partake more in both products and services oriented advertisement than the males. These could be because as stated by Mladenović, Vujović and Cigrovski (2010), almost every advertising agency employs both psychologists and sociologists who try to construct images and messages which the readers are more likely to accept. Results also revealed that women were used in adverts related to both businesses and homes while males were used in adverts that are only related to businesses. This implies that women are more deployed in businesses and home related adverts than the men.

Results from this study have shown that bodies or parts of the bodies of females in advertisement were more exposed than those of male. Female body parts revealed the most are their arms, thigh and chest, while for the males only their arms and legs were revealed. This bolsters the study of Iijima Hall and Crum (1994) that women are used as images of sex objects and decoration and that when women appear in these adverts, their body exposure are greater: women are portrayed in these commercials through shots of the chest, leg, buttock and crotch, whereas the men were always dressed in work clothes. The result of this study supports the findings of Asemah, Edegoh and Ojih (2013) that advertisers are culpable for the heightened body dissatisfaction amongst women, because they constantly use sexy unrealistic images of ultra thin models, the depiction of women as sex objects and the frequent use of sex, to sell products. Furthermore, the study reinforced the works of Berger (1999), Ford, LaTour and Lundstrom (1991), and Stankiewicz and Rosselli (2008) that women in particular, are often portrayed as sexual objects in advertising through their images.

According to findings of this study, the majority of language employed for advertisement are gender specific to a particular gender type. Few were gender biased, and few adverts also used language that respect gender equality. This implies that majority of the advertisement done in newspapers and magazines, being gender specific, addressing a particular and specific gender type thus neglecting the other gender type, with all the possible consequences discussed above.

Bringing into fore play the definition of advertising by Yang (2010) as a double stand with two major functions: to persuade potential customers, and to provide information to the potential customers, it shows that gender specific adverts may fail to perform these two functions. This bolstered the findings of Valiulis, O'Driscoll and Redmond (2007) that meaning produced through language is critical to developing an understanding of how language can be used to reinforce gender stereotypes. This also buttressed the work of Willemsen (1998) that the content and language of most advertisers and advert are often gender stereotypic. This could be because as stated by Smith (1985), Tannen (1991) and Coates (1993), women and men differ in the use of language.

The result of this study also buttressed the findings of Golzadeh et al. (2012) that gender is one of the main criteria to dividing any market, therefore, there is a need to arrange combined marketing elements, such as advertising, regarding the existing differences between men and women for each part of the market. In addition, the findings of this study supports the work of Asemah, Edegoh and Ojih (2013) that although advertisers aimed at reaching all segments of the consuming public, their portrayal is not necessarily an accurate reflection of how society is composed, most of such adverts are skewed to one category of people such as gender, among others which forfeits the purpose of such advertisement.

6. Conclusion and recommendations

In conclusion, it is worth to highlight that:

- Gender bias occurs in media advertisement in Nigeria and it is more pronounced in newspaper than in the magazines.
- Females are more involved in both products and services oriented advertisement than the males.
- Women are used in advertisement related to both businesses and homes and are also used more as sex objects in specific advertisement while the males are mostly used in advertisements that are only related to businesses.
- Body images of females in advertisement were more exposed that those of male and the most revealed female body parts were the arms, thigh and chest, while for the males only their arms and legs were revealed.
- The majority of advertisement done in newspaper and magazines are gender specific, that is, they address particular and specific gender type thus neglecting the other gender type.

The study recommends that:

- Portrayal of a particular gender as sex object in advertisement should be addressed by the stakeholders of advertisement with respect to the culture of the area to which it is meant to cover.
- Advertising agencies should endeavor to make advertisements to be gender neutral; however, it is also important to put into cognizance the particular gender for which products are advertised for.
- In addition, advertising agencies should consider the society so that the exposure of body especially by women is curtail to maintain the society and cultural image and norms especially in the Nigerian culture.
- Furthermore, it is also important for the federal and states government of the nation to put in place policy (ies) to guide the use of media for advertisement in Nigeria.
- Also, it is important that organizations with products and services advertised seek professional advice before deploying and using any advertising agency and any media to advertise their product so that the advertisement can reach a wide range and elastic categories of people both home and abroad so that the intent of advertising such products and/or service would not be abated and relinquished.
- Organizations with products and services advertised and the advertising agencies should be aware and understand their potential customers so as not to put forth advertisement that may scare the potential users from making decision to buy the products or use the services advertised.

References

Arima, A.N., 2003. Gender stereotypes in Japanese television advertisements. *Sex Roles,* 49(1), pp. 81–90.

Artz, N., Munger, J., and Purdy, W., 1999. Gender Issues in Advertising Language. *Women and Language,* 22(2), pp. 20–26.

Asemah, E.S., Edegoh, L.O. and Ojih E.U., 2013. Audience perception of the portrayal of women in television advertising. *AFRREV LALIGENS: An International Journal of Language, Literature and Gender Studies*, 2(1), pp. 21–37.

Bardwick, J. and Schumann, S., 1967. Portrait of American men and women in TV commercials. *Psychology: A Journal of Human Behavior*, 4(4), pp. 18–23.

Berger, A.A., 1999. Sex as symbol in fashion advertising and analyzing signs and sign systems. In: D. George and J. Trimbur, eds. 1999. *Reading culture.* New York: Addison Wesley Longman, Inc. pp. 186–193.

Burn, S.M., 1996. *The Social Psychology of Gender.* New York: McGraw-Hill.

Butler, J., 1990. Performative acts and gender constitution: an essay in phenomenology and feminist theory. In: S. Case, ed. *Performing Feminisms: Feminist Critical Theory and Theatre.* Baltimore: John Hopkins University Press.

Cameron, D., 1992. *Feminism and Linguistic Theory.* New York: Palgrave Publishers.

Cheng, H. and Schweitzer, J.C., 1996. Cultural values reflected in Chinese and US television commercials. *Journal of Advertising Research*, 36(3), pp. 27–44.

Coates, J., 1993. *Women, Men and Language, 2nd edn.* Harlow: Longman.

Devlin, M., 2006. *Inequality and the Stereotyping of Young People.* Dublin: The Equality Authority.

Eckert, P. and McConnell-Ginet, S., 1995. Constructing meaning, constructing selves: snapshots of language, gender and class from Belten High. In: K. Hall and M. Buchholtz, eds. 1995. *Gender Articulated: Arrangements of Language and the Socially Constructed Self.* London and New York: Routledge. pp. 469–507.

Eckert, P. and McConnell-Ginet, S., 2003. *Language and Gender.* Cambridge: Cambridge University Press.

Ferguson, J.H., Kreshel, P.J. and Tinkham, S.F., 1990. In the pages of Ms.: sex role portrayals of women in advertising. *Journal of Advertising*, 19(1), pp. 40–51.

Ford, J.B., LaTour, M.S. and Lundstrom, W.J., 1991. Contemporary women's evaluation of female role portrayals in advertising. *Journal of Consumer Marketing*, 8(1), pp. 15–28.

Frith, K.T., Cheng, H. and Shaw, P., 2004. Race and beauty: a comparison of Asian and Western models in women's magazine advertisements. *Sex Roles,* 50(1-2), pp. 53–61.

Golzadeh, F.A., Golfam, A., Asadi, M. and Hariry, M.B., 2012. The contrastive analysis of gender factor manifestation in the language of advertisement in Iran in 1980's and 2000's. *International Journal of Humanities and Social Science.* 2(2), Special Issue, pp. 151–158.

Graddol, D. and Swann, J., 1989. *Gender Voices.* Oxford: Basil Blackwell.

Harrison, G., Juric, B. and Cornwell, T.B. (2001). The relationship of advertising model attractiveness and body satisfaction to intention to purchase an exercise product. *Asia Pacific Advances in Consumer Research*, 4(1), pp. 217–222.

van Herpen, E., Pieters, R., Fidrmucova, J. and Roosenboom, P., 2000. The information content of magazine advertising in market and transition economies. *Journal of Consumer Policy,* 23(3), pp. 257–283.

Iijima Hall, C.C. and Crum, M.J., 1994. Women and "body-isms" in television beer commercials. *Sex Roles,* 31(5), pp. 329–337.

Ingham, H., 1995. *The Portrayal of Women on Television.* [online] Available at: <http://www.aber.ac.uk/media/Students/pth9601.html/> [Accessed September 2016].

Johnston, J. and Taylor, J., 2008. Feminist consumerism and fat activists: a comparative study of grassroots activism and the Dove Real Beauty campaign. *Journal of Women in Culture and Society*, 33(4), pp. 941–966.

Khan, L.A. and Ali, G., 2012. Language and construction of gender: a feminist critique of sms discourse. *British Journal of Arts and Social Sciences,* 4(2), pp. 342–360.

Kuntjara, E.H., 2001. Beauty and the beast: images of women in advertisements. *Jurusan Desain Komunikasi Visual*, 3(2), pp. 97–106.

Lakoff, R.T., 1975. Language and woman's place. In: M. Bucholtz, ed. 2004. *Language and woman's place: text and commentaries*. New York: Oxford University Press.

Lim, W.M. and Ting, D.H., 2011. The construction of beauty in Malay magazine advertisements. *Contemporary Management Research,* 7(3), pp. 173–196.

Matud, M.P., Rodríguez, C. and Espinosa, I., 2011. Gender in Spanish daily newspapers. *Sex Roles*, 64(39), pp. 253–264.

Mladenović, I., Vujović, M. and Cigrovski, P., 2010. *Gender Issues in the language of advertising in men's and women's magazines: angleščina, raziskovalna naloga*. Maribor: II. gimnazija.

Ong, F.S. and Seah, S., 2001. Women's perceptions toward the portrayals of women in television advertisements. In: *Proceedings of the 7th Asia Pacific Management Conference.* Kuala Lumpur, Malaysia, 2–4 November 2001.

Smith, P.M., 1985. *Language, the Sexes and Society.* Oxford: Basil Blackwell Inc.

Stankiewicz, J.M. and Rosselli, F., 2008. Women as sex objects and victims in print advertisements. *Sex Roles*, 58(7), pp. 579–589.

Tannen, D., 1991. *You Just Don't Understand: Women and Men in Conversation*. London: Virago Press Limited.

Udebunu, C., 2011. Nigeria and the dialectics of multiculturalism. *OGIRISI: a New Journal of African Studies*, (8).

Valiulis, M., O'Driscoll, A. and Redmond, J., 2007. *An Introduction to Gender Equality Issues in the Marketing and Design of Goods for Children*. Dublin: The Equality Authority.

Vestergaard, T., and Schrøder, K., 1985. *The Language of Advertising.* Oxford: Basil Blackwell.

Willemsen, T.M., 1998. Widening the gender gap: teenage magazines for girls and boys. *Sex Roles*, 38(9), pp 851–861.

Williams, J.E. and Best, D.L., 1990. *Measuring Sex Stereotypes: A Multination Study.* Newbury Park, CA: Sage Publications.

Whipple, T.W. and Courtney, A.E., 1985. Female role portrayals in advertising and communication effectiveness: a review. *Journal of Advertising*, 14(3), pp. 4–17.

Workman, J.E. and Johnson, K.K.P., 1991. The role of cosmetics in impression formation. *Clothing and Textiles Research Journal*, 10(1), pp 63–67.

Yang, J., 2010. *Gender Differences in Advertisements – A Study of Adjectives and Nouns in the Language of Advertisements*. [pdf] Kristianstad University. Available at: <http://www.diva-portal.org/smash/get/diva2:397162/FULLTEXT01.pdf> [Accessed September 2016].

JPMTR 091 | 1607
DOI 10.14622/JPMTR-1607
UDC 159.925|81'04:090.1

Research paper
Received: 2016-05-04
Accepted: 2016-12-13

Mental model of a medieval scribe as a basic engine concept for an intelligent, bibliophilic book design system

Bogdan Szczurek[1] *and Tadeusz Szuba*[2]

[1] Ruthenus Publishing House,
Krosno, Poland

E-mails: bogdan.szczurek@ruthenus.pl
szuba@agh.edu.pl

[2] AGH University, Dept. of Applied Computer Science,
Krakow, Poland

Abstract

This paper presents the current state of the research project which aims to build a mental model of an abstract medieval scribe. It will be the basis for the design of a novel intelligent engine for a book design system enabling to easily create books of exceptional artistic and bibliophilic value. A page of a book filled with illustrations, ornaments and text can be considered as an extension of the idea of a Turing Machine infinite tape. From this point of view, a mental model of a scribe can be considered as an extension of Alan Turing's concept of an abstract clerk-mathematician, processing a tape according to this tape's contents and the contents of his brain serving as a control module. Thus, authors want to expand the concept of the Turing Machine to design a model of an abstract medieval scribe and to use it as a basis for a future desktop publishing system. Joint knowledge of the authors on the practice of bibliophilic book edition and on the theory of artificial intelligence and expert systems provides a real chance that this project will be completed and implemented. This paper presents the basic theoretical foundations of the project.

Keywords: Turing Machine, clerk versus scribe, artificial intelligence, editing system, design system

1. Introduction

The daily work of contemporary book graphic designer and illustrator can be considered as a today's extrapolation of a medieval scribe's work whose job was calligraphing and illuminating medieval books in an abbey or monastery. The *horizon of examples* for such a scribe was restricted to perhaps fewer than 100 manuscripts available in his own or affiliated monasteries. Today, graphic designer and an illustrator uses 21st century editing tools and has access to the database of the whole Internet. Here *database of the Internet* is to be understood as a source of inspiration, examples and even ready graphical components. Despite the timelapse of six centuries, the required result is the same: a beautiful bibliophilic book. The today's concept of e-books offers a great chance of demand explosion for books of an exceptional artistic form and bibliophilic character, but which are, at the same time, cheap and available for everybody in contrast to expensive medieval manuscripts. Thus, our intention is to build a theory and later to implement this theory in computer aided manufacturing system which will use artificial intelligence methods and a background Internet search to assist a human-editor or even replace him in creating a book on the artistic level of a medieval scribe as given in Figure 1.

Figure 1: Illuminated bible, 1407, Malmesbury Abbey, Wiltshire, England (Splendor, 2016)

Contemporary design applications like Adobe InDesign, Adobe Illustrator (Adobe, 2016) or QuarkXPress (2016), and widely ubiquitous office-type applications like Microsoft Word (Microsoft, 2016) remain, for the most part, only lifeless tools in the hands of an artisan and amateur alike. Thus, they stay far behind what the today's technology of artificial intelligence and the database of the Internet is providing. Today, editors for web pages place greater emphasis on their appearance and artistic form, but it still cannot be compared to what a medieval scribe was able to do. Thus, new editing tools must be build, but to do this, a proper engine must first be built.

The structure of the paper is as follows: in the first part we will outline the process of bibliophilic book design in relation to contemporary methods and tools. Next, we will present the figure of the medieval scribe. Directly afterwards, we will move on to shortly describe the relation between the Turing's (1937) concept of a clerk and our vision of a scribe. The subsequent parts will present the idea of the model conceived by Kenneth Craik (1943) and a prototype of a complete model of scribe's mentality. The paper will be concluded with a summary containing a plan of further tasks and literature.

2. The nature of bibliophilic book design process

A book designer's work, although fulfilling and gratifying in its results, can also be, and often is, very tedious. While contemporary computer tools have dramatically improved some aspects of graphics design and typesetting, they have left other parts of the process neglected or even outright untouched. It is not the goal of this article to discuss these tools nor their effects in detail, but it aims to provide its reader with at least a hint of the overall situation.

The gain of digital technologies applied to the area of book design is largely a speedup of selected design-related activities. This speedup, in turn, is possible, thanks to the implementation of well-established physical tools and work practices as software components. These tools and practices are identifiable and intelligible by means of an observation of designer's external actions, so the nature of this observation is purely behaviouristic. Partly because of that, readily available automation in contemporary design tools is limited to the implementation of very specific and rigidly defined scenarios like, for example, page numbering. Such automation is sufficient and beneficial as long as the design requirements match the assumptions on which a piece of software was built, but as soon as these assumptions are exceeded, the designer is forced to fall back to manual methods, even though an automated solution seems to be within reach.

Automation, in the context of book design, can be perceived merely in the categories of sheer speed and convenience, but also – and even more importantly so – in terms of a delegation of the designer's creative competencies to an automated system. This delegation is exactly what the designer does when, for example, he or she lets computer software place numbers on pages without his or her direct supervision. The more parts of design process are ceded to software, the less strain is put on a human designer, who can then focus on *designing* itself rather than on *tedious chores*. At the extreme, a properly crafted system could even be able to act as a kind of virtual intelligent designer in lieu of a human specialist who, in turn, would assume a different role as a source of general suggestions and requirements if he were to act at all.

Just as we expect a human designer to produce a beautiful book, so we should expect, and even require, the same from an intelligent design system. Our aim is not a system able to design (in an assisted or fully autonomic way) simply *some* book (indeed, such systems are already there) but a system capable of yielding truly beautiful results. One way to tackle this challenge would be to follow the previously mentioned behavioural analysis. Despite the fact that ever more sub-scenarios of the design process, suiting ever different cases, could always be observed and then implemented, it would lead us only as far as to a kind of an elaborate template-based, grid-driven system. Although products of such a system are not inherently unimpressive or aesthetically unpleasing (The Grid, 2016), they are most certainly quite heavily constrained by something we could call a form-oriented paradigm, that is a design methodology treating composition as a set of rigidly defined fields filled-in with separate content fragments. Making a comprehensible framework, it also promotes a sort of aesthetic inflexibility – designs looking basically *the same* regardless of their content. This unidirectional influence of composition on the content can only be broken by a human intervention, for example, by designing a new template.

Another, very recent and already somewhat controversial, example of an attempt to turn a computer into an artist is The Next Rembrandt (2016) project. Although at the time of writing only some general information was available, still, thanks to what is known, it is possible to make some assumptions about the project. In contrast to the previously mentioned The Grid (2016), The Next Rembrandt seems to be, to a degree, freed from the form-based regularity, which is in fact a necessity for a system oriented on the art of painting. For our purposes, the most interesting aspects of the project (apart from the components responsible for the process of painting itself) were how Rembrandt's artistic style was extracted from his paintings and how it was represented. Unfortunately, as former undertakings, The Next Rembrandt project appears to be heavily behaviouristic, focusing on an elaborate statistic of paintings and their features, while disregarding their deeper contents and meaning represented in facial expressions, eyes or poses. This is good enough to produce a very impressive feature-based portrait (which is deemed to be the statistically most probable subject of the next Rembrandt's painting, if he was still alive), but not good enough to fulfil a commission of a person who would like to be painted by Rembrandt or to have *a biblical scene* newly made by the Dutch master. The problem is the system that does not know how to pose a subject, what does a biblical scene mean or, in fact, how to use a real brush and paints, let alone how to mix them for the desired effect. Other potential problems and unknowns are the methodology of digitalization (the colour space of the input device is prone to lose portions of the original colour information perfectly perceivable by the human eye), the colour model and the working space in which the data was handled and, finally, the exact print technology. However, while being potentially very important, these are, as of yet, unknown details.

Although the image presented on the project's official website bears noticeable marks of being digital art (like tell-tale signs of non-painterly blurs in the shadow under the nose, on the right cheek or in the transition between the left side of the beard and the collar), it still should be considered a very successful example of an important and applaudable effort (Figure 2). Let this remark serve as a well-deserved counterweight to the otherwise critical assessment of The Next Rembrandt project we present here.

Figure 2: A portrait from The Next Rembrandt (2016) website

Once again, it appears that to be successful in mimicking an artist, we need to go much deeper than statistics and a purely behaviouristic analysis. It is not enough to know how something was made technically; we also have to know, understand and be able to recreate the whole inner, mental story behind it.

Since the human factor seems to be essential, we should ask the question: *How does one design a beautiful book?* and try to answer it in a much broader sense than just behavioural. It takes more to design than to fill-in predefined placeholders it takes to understand the content and the entirety of the design process happening both in a human mind and in the environment which contains, surrounds and influences this mind.

Here we are due a few words about what does the adjective *beautiful* mean in our context, why do we use it and what criterions are we to apply to recognize a *beautiful book*. While it may never be possible to express in scientific terms what is *beautiful*, the very existence of the word proves that there is such thing as *beauty* and, what follows, some features determining its elements in a work of art – a book, for example. Recognizing beauty is somewhat similar to recognizing civilisation. About the latter Kenneth Clark (1977), a renowned art historian, aesthetician and art connoisseur, said: *What is civilisation? I don't know. I can't describe it in abstract terms. Yet. But I think I can recognize it when I see it and I'm looking at it now.* These words were spoken on the banks of Seine with a sight of a medieval cathedral in the background. While we may have trouble with defining *beauty* in less than a few tomes of a philosophical treatise, it's hard to imagine anybody would judge Michelangelo's David, for example, as anything less than beautiful. The same can largely be said of many medieval manuscripts. Subjectivity of the judgement itself doesn't make it altogether useless. What is more, in relation to the established examples of art widely deemed *beautiful* it gives us a kind of comparatory criterion, according to which products of our own system could be evaluated.

By stating explicitly that we expect *beautiful* results from our automatic and autonomic book design system we also hope to gain a certain psychological effect. The name itself doesn't allow the researcher to forget about the scale and goal of his/her enterprise. It is noteworthy that J.C.R. Licklider (1963), one of the ARPA (Advanced Research Projects Agency) directors and researchers, called his concept resulting in the emergence of ARPANet (which could be seen as a proto-Internet) *Intergalactic Computer Network*. Were we to settle on anything less than *beautiful*, we would fall into the same trap of ambiguity we just described without gaining anything in return. On the extreme we could lower our ambitions and skip any adjective altogether but that would simply mean construction of an automatic and autonomic system producing books. That in turn would mean re-inventing another TeX, DSSSL (Document Style Semantics and Specification Language), CSS (Cascading Style Sheets) and the like.

To explain and understand how a beautiful book is made (Tymms and Wyatt, 1860; Putnam, 1896; Johnston, 1906; Frutiger, 1989; Tillotson, 2016), we have to take a look at what is inside the designer's mind and build a model of it. This insight will give us a far better grasp of what is essential to the design process as a whole and will be a crucial step on the way to the construction of an intelligent book design system. First, however, we need to select a fitting designer to investigate. We could try to take a look into the mind of a contemporary designer but with the multitude of inspirations, styles, stimuli and tools available and present nowadays we are at a serious risk of being overwhelmed by details before we would even start to notice any desirable patterns in the workings of his/her mind. We need an example of a designer relatively isolated to make his/her inspiration sources limited and emotions ordered and therefore more feasible for analysis. At the same time our designer should be able to produce works reaching far beyond simplistic banality – works which could be considered beautiful. Incidentally we find all of these characteristics in a person of a medieval scribe.

3. The scribe

Before we proceed to construct a prototype of a mental model for a medieval scribe, it is crucial to get to know who he was, what he did and how he did it in all the necessary historical and cultural contexts. Only then we will be able to decide what the term *medieval scribe* will mean to us.

Firstly, we should clearly state what is to be considered medieval in temporal, geographical and cultural meanings. Although the equivalently used term *Middle Ages* suggests only the first kind of interpretation, it is worth noting that in historiography the *medieval period* is inseparably connected with Europe, understood mostly as a sphere of a specific culture. This notion is also reaffirmed by the choice of historical events marking the beginning and the end of the era. In the contemporary view of the world, we can say that the sphere of the European culture expanded from the territories of both the Western and Eastern Roman Empires, North Africa and the westernmost parts of the Middle East to what is now known as the European continent (including Great Britain, Ireland and Iceland along with Scandinavia). As a consequence of slightly different Roman and Greek heritages, European culture grew in two stems, an Eastern and a Western one – each prevalent in basically its own respective *half* of Europe. For our purposes, we will consider the Western one because of its rich scribal traditions, art, forms of expression and artefacts of which are still relatively easily accessible today.

Having crudely established the cultural frame of our interest, we should now do the same time-wise. The medieval period is considered to span about 1 000 years – from the 5^{th} to the 15^{th} or even early 16^{th} century. The dates of the boundary events marking the period are not universally agreed upon, as are the events themselves; however, they all point at the given centuries. This fact combined with the knowledge that the process of the cultural change from antiquity to medieval and from medieval to Renaissance was evolutionary and not revolutionary in its nature allows us to settle on this very loose time frame, even though it may be rough for many other uses. Before we further continue our description, a word should be said about the purpose of the trade of scribe. It can be asserted that the main impulse driving its development was the spreading of Christianity. Missionary work called for a reference and support in the form of liturgical, biblical and other religious texts. At that time, the only practical way of providing them was copying by hand. Because of the profile of the copied works and the demise of secular literacy, the bulk of the medieval pieces of scribal work are products of monastic societies. Most notable of these societies are the Benedictines (Oliver, 2016) (with their famous monastery of Monte Cassino), Cistercians (Oliver, 2015) and Carthusians (Girard, 2016).

Although the Christian religion was the main focus of medieval research and publication, it does not mean that the earlier, pre-Christian works were altogether discarded; on the contrary, many of the great works of pagan antiquity were preserved and copied in medieval monasteries, thus saving them for the generations to come. If it had not been for that, they would have been almost certainly lost forever in the tumultuous years of the medieval period.

Apart from the preservation and transmission of the already existing texts, mostly religious in their nature, monastic life was also a rich source of original works dealing with almost all aspects of the contemporary world. Their reach beyond the boundaries of a simple recapitulation allowed for the further development of philosophical ideas, leading to the subsequent onset of the Renaissance. Generally, monasteries remained the main centres of scribal activities, and of culture itself, for almost all of the Middle Ages, giving way to secular scriptoria (and later to print shops) only at the end of the period.

So far we can assume that our scribe is a western European monk, living between the 5^{th} and the 15^{th} century. Let us also take the liberty of arbitrarily setting his interests and competencies to the copying work, illumination and illustration, especially since it is often very hard to distinguish between the two latter forms. It seems to be a quite practical and justifiable choice in the light of this paper's goals.

Moving forward from the broad view presented so far, we shall take a look at the environment our monk scribe lived in and, more specifically, at his craft and art.

The living environment can be considered as a direct source of inspiration, a source of the ideas which transpire into the results of a scribe's work. This inspiration can be immediate (simple mimicking of solutions seen in other works) or more elaborate, based on personal experiences, both physical and mental ones. All kinds of inspiration can be used in the process of producing a copy of another book. Here we have to note that the word *copied* refers, for the most part, to the text of the book. It was really the text that was copied; other aspects of the book, like its form, page composition, illustration or illumination were frequently questions at the scribe's own discretion. His *choice*, in turn, is another point of interaction between the scribe's own creativity and the environment, because the scribe's *choices* can be influenced by, for example, his superiors or collaborators (who are also a part of the environment). This type of interaction is an assumption; however, it appears quite reasonable to assume that some kind of *control* over the work of scribes had to be exerted. Otherwise, the likelihood of introducing some serious doctrinal or technical errors into the copied works would have been so high that such occurrences would be easy to spot in the surviving examples of medieval books and such cases would be well known. If such a kind of control had been in place, then it is almost natural that its role would not have ended only on a meritorious verification, but it would also have spread to the area of the work's aesthetics.

Before we move on, we have to clarify a couple of potentially problematic subjects. The first one is a matter of scribe's living environment, that is: chiefly his monastery. Undeniably all of the religious orders mentioned before – Benedictines, Cistercians and Carthusians – sought some kind of isolation from the outside world. This isolation however, immediately noticeable in its material manifestation of thick, closed walls, should be primarily seen as an attempt to isolate the monastic family from the world's dangers, turmoil and *spiritual toxicity*, not from the nature or populace. The former becomes almost self-evident in places like, for example, Grande Chartreuse or Monte Cassino. This kind of isolation is in fact very opportune for our needs because it allows us to narrow down potential sources of scribal inspiration and shorten the probable reasoning path from an idea to its expression on the pages of a book.

Another interesting aspect of a medieval scribe archetype we have to take into account here is his will and choices he makes in relation to his vows of obedience. It is not inconceivable to think that obedience of a monk to his superior meant a total submission of the former to the latter in the every aspect of life. Religious sources however do not treat obedience as total, that is, precluding any activity unless it was sanctioned by the superior. Monastic obedience did not prevent free will, human artistic creativity or conscience to work. Perhaps the most elegant and clear explanation on the matter of obedience is given by St. Thomas Aquinas in his *Summa Theologica* (1920, Q. 104, Art. 5). He writes that the vows of obedience are not binding when a superior requests of a subordinate an action which is contrary to God's Commandments and Gospel. In the same text it is expressed that the obedience should be complete but in the things that are due to the specific authority. Obedience was treated as a voluntary and limited submission of one's own will grounded deeply in Christian theology and directed towards one's personal path to salvation guided by a more spiritually experienced person. In general, obedience is to be understood as a tool of spiritual guidance not an absolute and unquestionable control. While superior had an objective authority over a monk-scribe it doesn't mean that it placed the latter in the role of a mere desultory automaton micro-managed by the former.

In this quick sketch of the scribe's environment and condition, there is one last element to describe: the technological process of producing a manuscript. Historical sources tell us that it consisted of many stages: from preparing parchment, coloured inks and golden leafs, through using all of these in the actual act of writing, painting and illumination of a book, up to binding the pages and introducing the cover. Each of these stages required a very specific set of knowledge, experience and predispositions, so most often they were performed by different persons purposely delegated to one of these tasks. There were, however, cases when a single man was able to (or was compelled to) do multiple of these activities in person. Even if the scribe himself was not involved in all of the preparations of a book and materials, still he must have been conscious of his medium and tools – their specificity, abilities and shortcomings – to properly plan his actions and to execute them successfully.

When mentioning the medium and tools, we should once again take a look at the scribe's environment; this time, as an instructive source of information about the new or perfected methods of work. After all, our scribe had to learn and keep improving his trade. He must have been able to discover some of its secrets by himself, but he had to learn other skills, most probably in person, from more experienced scribes. There were almost no *manuals* on the craft and art of calligraphy, as well as book decoration, illustration and illumination. *Almost* does not mean *none*; there is one noteworthy example of this type work, but it was written only in the late Middle Ages and its existence even more vividly supports the claim about the rarity of *scribal handbooks*. Besides, not all of the knowledge could be efficiently passed using the written media; some had to be presented firsthand and then practiced in controlled conditions to achieve the desired level of proficiency.

Researchers studying old manuscripts noticed that there are certain similarities (be it similar motifs, aesthetic forms or technologies) between books authored in different centres of scribal culture. This palaeographical clues allow us to conclude that there existed not only an exchange of the *raw* material in the form of textual content to be copied but also an exchange of methods of work. Findings based on an inspection of unfinished manuscripts and illuminations are even more valuable for our purposes. While being quite common, they present a unique opportunity to infer the order in which the work progressed and how it had been planned beforehand.

So far, we have constructed, in a very brief and concise manner, an image of a medieval scribe and the world he lived in. Unfortunately, for the sake of the above mentioned brevity, many details had to be omitted. Such omission would be an unforgivable act, should this paper aspire to the status of an achievement in the fields of palaeography or historiography, but in our case some, even serious, simplifications can be made. After all, we aim for the comprehensibility of a prototypical model of a medieval scribe's mind and mentality we are about to present in this article, and not for full historical accuracy.

Having sketched our subject person in the specificity of his times, we should now think about the way we can turn the knowledge we have gained up to this point into a model of a scribe's mind. To that effect, we can take a look at the story behind the famous Turing Machine as a source of inspiration. Therefore we shall now follow Turing's clerk in his relation to the machine developed upon him, parallelly use this relation to find out what are the characteristics of a successful automaton and identify similar characteristics in our scribe. Since we want to use scribe's model as a basis for the *virtual scribe*, this knowledge will be very important for us, even though the purpose and abilities of Turing Machine are very different.

4. Clerk vs. scribe

If we will compare Alan Turing's clerk-mathematician (Turing, 1937) and a medieval scribe, we will find astonishing similarity. The clerk-mathematician by definition had to be an outstanding mind, but Figure 3 shows how his office environment was trying to make him automate. Even today, some mathematicians underline the discipline of mathematical thinking. Thus, for Alan Turing it was natural to replace a mathematician with an automaton in a formal way. The same applied to a medieval scribe (see Figure 4): his outstanding mental abilities did not release him from the monastery discipline and work discipline when copying and illuminating books. However, the nature of this discipline is quite different for each of them. The authority the discipline holds over the clerk is absolute. He cannot escape or contest it. He also cannot do anything outside of the regime he is subjected to. Consequently, his work is devoid of his own invention, which can be as much a blessing as it can be a liability, especially in the context of book design, where artistic invention is always desired, even if it is in the smallest of matters.

Whereas the clerk's discipline is, by design, an inseparable part of his *mentality*, it plays more of an auxiliary role for the scribe. It surely is there and cannot be simply ignored, but it does not mean that its lines cannot be crossed or broken. It is, after all, something the scribe had to accept on his own and by his own free will. The grounds on which he based his acceptance, whether they were physical or metaphysical, remain a different matter. Anyway, the structure and authority of the discipline (disciplines) the scribe accepted still left him much room to think and act as he pleased, which was enough to keep him *creative* while guarding him from being heretic. So, both the clerk and the scribe are subject to some kind of a discipline but in a different sense and to an unequal degree.

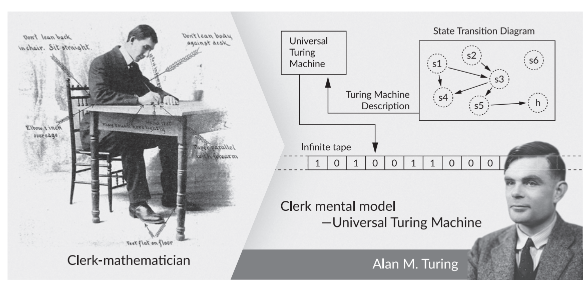


Figure 3: From clerk-mathematician to Turing Machine; authors' composition based on the photograph from The Business Educator, January 1909 (Leslie, 1909)

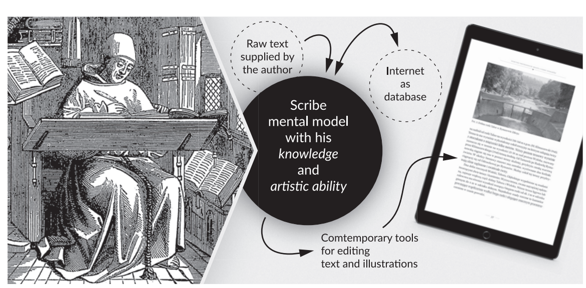


Figure 4: From medieval scribe to engine for future intelligent book design system; authors' composition containing illustration of a scribe from Lacroix (1875, p. 432)

Another point of tangency when it comes to the clerk and the scribe are their minds, or rather states of their minds. The clerk's *state of mind* is treated simply as a *state* of the automaton he is being turned into, an indivisible and opaque entity, denoted by a discretionary symbol. The function of this *state of mind* could be summed up as a kind of *scratch-memory* for the operations carried over the paper tape and for that purpose it is quite sufficient. However, it ceases to be so for our scribe, because his mind is expected to hold an internal *image* of the world around him and, specifically, of the piece of art he is working on. It is next to impossible to try to denote such a very detail-rich scene of imagination with a single symbol (the required number of such discrete symbols would have a tendency to quickly explode to infinity without bringing anything useful into the picture). Besides, we need to be able to manipulate this scene and its components, so we must steer clear of any temptation to assume its immutability, which would be implied if a symbol was used to denote it. For that intent, we have to devise our own way to represent the scribe's mind and its inner workings. Again we are confronted with a similarity between clerk and scribe, which also proves to be a crossroad leading us on a rather different path from the one Turing took in his work.

From the comparison of the clerk's and the scribe's minds, let us move to another issue: the objects and means of both the clerk's and the scribe's work. While the clerk's only imprint on the world can be symbols from a well-defined, finite set, the scribe's arsenal of expression is by comparison virtually infinite. What is more, the clerk does not even have to *understand* the symbols he is using. It is enough for him to be able to recognize, delete and write them. While this makes the clerk-machine quite straightforward to make at the same time it raises a barrier between the concepts used by this machine and the concepts which are natural for its controller, i.e. a human being. This is a barrier which as yet is somewhat lowered, but has not been not removed completely.

Symbols used by the clerk are by their nature and due to the clerk's abilities indivisible. It is very different with the scribe's objects of work, which are pages of parchment filled with letters and embellished with ornaments and pictures. In a very general and low-level sense, we could say that as the clerk writes symbols, the scribe puts areas of colorants, but while for the clerk these symbols are devoid of any meaning, for the scribe it is the contrary: it is the meaning that dictates the specific shape and composition of all the areas marked with ink or paint. Meaning, however, does not exist on its own and by its own. It requires a mind. Thus, everything the scribe does to the page is to some degree a reflection of the concepts in his mind. What is more, these concepts (or, as we will identify them later, *mental models*) are not monolithic. They can be (and indeed, often are) deconstructed and reconstructed again between themselves for some novel effects. Old manuscripts are abundant with proofs for that. To be convinced of that, it is enough to look at fantastic beasts guarding the wisdom contained within the pages. While none of them existed or exists in reality, we can often recognize elements of dogs, lions, birds of prey, fishes and the like in them, all mixed-up in a splendid creature: an amalgam of concepts. This is not to say that everything the scribe does is chaotic and unstructured. Quite the opposite, each of the cross-concept combinations mentioned is seamless and well ordered, which means that even such constructs are guided by something, perhaps other more general or abstract concepts.

Before we move on to consider the clerk's and the scribe's respective means of work, we should take note of two important consequences of the freshly introduced *concepts of mind*. First, the sheer fact that they can be decomposed and re-composed again allows us to conclude that they must consist of *lower-level* concepts. Additionally it is possible that each of these *lower-level* concepts could be shared by two or more other concepts, thus, in great simplification, providing a kind of information *compression* method for the mind (Schmidhuber, 2009). The second consequence is that we cannot in all honesty describe the work of the scribe as *creative*. If the verb *to create* is to be understood as an act of bringing something previously non-existent into being, in part or as a whole, i.e. making something to exist out of nothing, then we cannot use it in relation to the scribe's work. Such was the meaning of *to create* in the Middle Ages. The only thing we can say about the scribe's efforts is that they are a kind of mimicking of proper creative ability.

Now, we have to consider the means by which both the clerk and the scribe do their work. For the former, it is enough to be able to read, write or erase a symbol as a whole and to move between cells containing the said symbols. All that is neatly represented in the Turing Machine by movements and abilities of a header and the paper tape. This straightforwardness is again a bliss for any potential implementer interested in purely computational advantages of the clerk analogy but a serious nuisance for anyone trying to directly utilize this model to simulate work of the scribe. The scribe cannot let himself compartmentalize elements of his work in quite the same manner the clerk can. Firstly, these elements relate to meaningful internal concepts which on the page of a book are separated not so much spatially (as the clerk's symbols) but semantically. Secondly, concepts can be connected between themselves both internally in the scribe's imagination and externally as their graphical representations. Simple, undividable symbols are not up to that task. Thirdly, the scribe cannot focus only on particular elements of his design; he has to be able to consider it once as a whole, the other time as a sum of its parts and finally as separate elements requiring special attention. To do that, he needs much more than *reading/writing head*: he needs quills, brushes, special blades, inks and paints with which he can operate on virtually unrestricted area of a page (any restriction is of his choosing and serves the purpose of a comprehensible layout). Only with these tools the scribe is able to visually encapsulate a scene of his imagination and do his work. A silent consequence of stating this is that apart from physical tools the scribe also has to have their *models* in his mind. To sum up, comparing the clerk's and the scribe's tools of expression (understood as tools by which they can influence the outside world) is like comparing a set of rubber stamps to a whole spectrum of artistic means.

As we discuss the differences and similarities between the clerk and the scribe, one more thing needs our attention. It is an answer to the question of what propels actions of our protagonists. In the case of the clerk, we can say that the motor of everything he does is a table of instructions together with a kind of arbitrary *clock* forcing ceaseless execution of the said table. It is completely sufficient for his type of activity. Unfortunately for us, this also means that the clerk does not have any autonomy. Autonomy (at least partial) in turn is a condition *sine qua non* for any system striving to provide as mature and sophisticated results as the art of a medieval scribe. Without any autonomy our system would simply execute a program, which inevitably leads us to the conclusion that such a system is not intelligent and represents at most a behavioural stimulus-response model. Therefore, we cannot simply follow the clerk's case and we have to come up with another solution respecting the scribe's autonomy but at the same time not allowing for stagnation in the face of an abundance of different paths of action to take. In other words, we need something that will allow our scribe to more or less autonomously set his goal, and a facility allowing him to reach it. A quite natural and intuitive candidate for the role of the latter seems to be a *narrative*. After all, *internal narrative* accompanies every thought process we can recall and it appears to run continuously throughout our conscious hours and even beyond them. Now, if we give specific parts of the scribe's psyche an ability to take over the narrative, we should have a recipe for a psychological motor for the scribe's thoughts and actions (which can be pictured as an external projection of thoughts through the means of the body).

To sum up our comparison, we will compare the most important characteristics of the clerk and the scribe in Table 1.

Table 1: Comparison of clerk and scribe

Aspect	**Clerk**	**Scribe**
State of mind	Single, indivisible, opaque state	A living stage populated with models, governed by the narrator
Subject of actions	Symbols on a tape – opaque and immutable, like the state of mind	Pages of the book (the book itself)
Motor of actions	A table of instructions, external to mind, constructed from predefined sets of symbols, states and elementary actions over a tape	A narrator, internal to mind
Basis of personality	Disregarded	Built by experience
Ability to learn/change	Indirect – a clerk may potentially create another, better clerk if the results of his work are to be interpreted this way	May enhance and change his mental models, both consciously and unconsciously

5. What is a mental model?

In the previous section we used the terms *model* or *concept* to denote an internal representation (an image) of reality or its parts in the scribe's mind. Now, we shall elaborate on this matter and introduce another term, *mental model*, which from now on will replace the ones used before.

A mental model is a term originating from the fields of psychology and philosophy (Thagard, 2010; Johnson-Laird, 2004; Kurzweil, 2012). In short, it can be explained as a description of the way one thinks about the reality by means of *small-scale models* (Craik, 1943) representing this reality. The term is popular especially in psychology, sociology and, cognitive sciences, but its use is not restricted only to them. Mental models are also used in marketing and – more recently – in web design industry, where they serve as a way to understand clients' needs and wishes. Another area where mental models are extensively utilized is the field of human-computer interaction studies. In all of these disciplines, however, mental models are made to be used directly by a human, while we intend to use our model as a basis for an automatic and autonomic system. In other words: we want to turn our model, as directly as possible, into a machine. We don't seek to create another design tool with more refined user interface but an *artificial designer* itself.

It is widely believed that the term *mental model* was first coined by a Scottish philosopher and psychologist Kenneth Craik in his work "The Nature of Explanation" (Craik, 1943). Although some earlier works bare traces of similar concepts, they fall short in comparison to Craik's work in completeness and clearness of the proposition. Craik says: *If the organism carries "small-scale model" of external reality and of its own possible actions within its head, it is able to try out various alternatives, conclude which is best of them, react to future situations before they arise, utilize the knowledge of the past events in dealing with the present and the future, and in every way to react in a much fuller, safer, and more competent manner to the emergencies which face it.*

This sentence, regardless of its undisputed, and often explicitly noted, vagueness, provides a powerful idea. Despite the strongly emphasized predictive and improving role of a *small-scale model*, a clear image of a mind as a *sandbox for testing different alternative lines of action* emerges from it. Its vagueness can also be a blessing in disguise, because, thanks to it, there is much potential for exploring different architectures of the *model*, while the idea itself remains a clean launchpad for such exploration, without any cruft which would have to be stripped from it beforehand.

In the light of the earlier comparison between the Turing's clerk and the medieval scribe, it does not take a big leap in reasoning to realize that Craik's idea is a good starting point for a journey into a book designer's mind. It should not be too hard, especially for those who, at least once, had to design a book, or any other thing, to perform an auto-examination of their mind at the time of *designing*. Any *design* begins its life not so much on a drawing board or a piece of paper, but in one's imagination as an entity being a *small-scale model* of a portion of reality, or, more strictly speaking, potential reality. So is the case with a book and it is only natural to take a mental model concept and expand upon it.

6. A mental model prototype

Before we attempt to describe our prototype of the scribe's mental model, we have to distinguish between two different meanings we use the word *model* in. The first meaning relates to the whole of the scribe's mentality which we are attempting to postulate here. The second one is reserved for any small-scale *imprint* of reality in the scribe's mind. As such a *model* in the second meaning is only one of a whole set of elements within the first *model*. This information, along with the context the word *model* appears in, should be enough to disambiguate the word.

Now it is time for us to introduce a diagram (Figure 5) illustrating our proposition of the scribe's mental model.

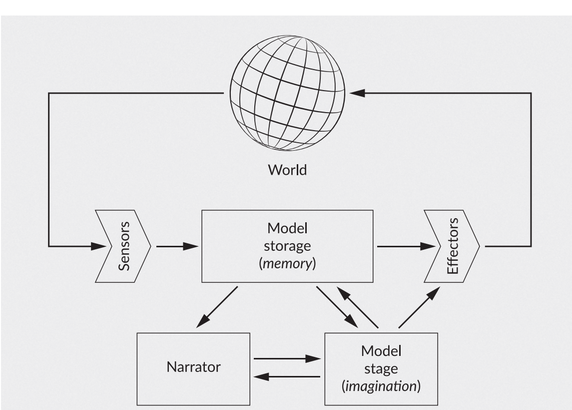


Figure 5: Scribe's mental model

Even though it may seem a bit crude and overly simplistic for such a formidable task as making a beautiful manuscript, it has a potential to account for a quite surprising variety of real life scenarios including, above all, scribal artisanship.

One thing to note is that although the world is presented here as a separate entity, the scribe's mentality, along with the body containing it, is actually also a part of this world, which is of consequence for self-consciousness as the world can affect us directly not only mentally but also corporally.

First, let us take a general look at the parts of the diagram. We may start with the *sensors*. Unsurprisingly, they represent senses, both in the classical, like sight or smell, and a more contemporary meaning, like balance. By being immersed in the world, they detect specific physical phenomena and translate their observations into other phenomena, proper and *understandable* for the rest of the system. It is roughly equivalent to a head reading signs from a tape in the Turing Machine.

Moving on, we now step into the next block, designated as *model storage or memory*. We could also call it *modelling fabric* because it is used to form and retain models. Its responsibility is twofold. As the name itself suggests, it serves as a storage place for all the mind's models (small-scale models or concepts) but its task is also to detect patterns (regularities) in sensory information and in whatever happens in imagination (this ability is marked by arrows pointing towards the block). Any pattern previously experienced is noted, possibly by *activation* of the model and by informing the narrator about its detection, and refined. Any new regularity, on the other hand, will be used in an attempt to formulate a new model. From the *memory storage* we skip along one of the arrows to another block called *effectors*. These are representatives of the muscles. They can be thought of as a kind of *reversed* sensors. While sensors convert an observation of phenomena to internal signals, effectors do the opposite: they translate internally recognized signals to muscle contractions. Sensors observe the world, effectors act upon it. In more general case, effectors can be much more than just muscles, but since the scribe is a human being, we hold this analogy.

Right now, it should be pointed out that the diagram construction between the sensors and the effectors allows for a formulation of something analogous to reflexes, including the ones acquired with time. In such a case, the stimulus goes straight from being noticed to triggering a reaction. Such a reaction could have a varying degree of complication depending on the complexity of the models involved, which perfectly reflects real life observation.

The next element of the diagram to be considered now is the narrator. It is the motor of our mental model, or a master narrating the inner story. This is the part responsible for pulling models from the model storage, placing them onto the model stage (imagination) and putting action on this stage into motion. We will soon explain more specifically what *putting into motion* means; meanwhile, another thing we can say about the narrator is that, in addition to placing models on *stage*, narrator can also be notified about *models* detected by sensors in physical world and it has the ability to observe the *stage of imagination*. The first property is crucial for simulating all the situations which interrupt our inner narrative in real life, like dangerous situations or external calls for attention (e.g. verbal addresses).

The second one is almost self-explanatory: to direct, the narrator has to know what it is directing and how the action unfolds. Although *stage*, *narrative*, *movement* and *action* are useful terms when we are trying to explain the narrator's role, it should be said that in our mental model they are not restricted to their traditional, theatrical meaning. The *action* could be, for example, a running deer or a process of combining models of a lizard with a snake and a bat to create an image of a dragon. Therefore, the narrator's area of expertise is also a combination of the models. Following this line, we can now see that imagining the said running deer can also be viewed as a combination of a model of running with a model of a deer. Another thing to notice is that models in imagination do not appear in all their details at once. Details (or more specific models) appear only when they are needed. It is another task for the narrator to allow for this by a kind of *shifting* its focus between models of differing generality. Combining models, in turn, can also account for the ability to use rules (however were they acquired) in reasoning. In that case, every rule is a model and by combining it with a *tested* model by means of a model of *testing* (binding the two together in comparison) the validity of the second model can be established, yielding a model of an answer in response.

The last element to describe is the model stage. This part is a scratchpad area for the narrator, which we could also call imagination. In this *sandbox*, models are combined together to form more complex structures representing real-life objects or actions. The model stage is also constantly observed by the narrator allowing him to fetch proper models from the model storage, and by the storage itself. This enables the latter to emphasize the known regularities and find new ones within the *scenes* in imagination. It is crucial, for example, for improving methods of work or making scientific discoveries, which can also be viewed as noticing similarities between observed events and other models deemed abstract, like mathematical expressions. Noticing similarity is in fact finding a pattern.

Having described our proposition of the scribe's mental model, we can now use this description as a basis for an attempt to define such terms as *model* and *intelligence*.

When it comes to a model, we could say it is a record of regularity (pattern) or a conjunction of other models which can be used in a narrative. Much of this definition could be supported when we think about how a model could come to life in one's mind. To do that, we should start at the very beginning of human mental development, i.e. at a healthy baby's mind. It could not be a complete *tabula rasa* because from the first hours of their lives, babies are able to express their needs and emotions, even if it is done in a basic way, and have some reflexes specific to them which later in life subside. At the same time, we cannot hope to communicate with them verbally as we would otherwise do. Also, we cannot be sure what thought processes are taking place in their heads because of the said lack of communication and because nobody can remember it from their own infancy. What we can be sure of is that their brains are fed by information coming from their senses. In time, this information gets clustered when a specific kind of stimulus appears again and again. It is the time when the first models are shaped and also the first memories may appear. When this happens it is enough for the brain to remember that a specific model was noticed at a specific time and only a handful of extra, contextual information has to accompany it (possibly as models, too). This is consistent with the brain's extraordinary ability to *compress* information and could be an explanation why our memories start only at a certain age. Further down the line of development, different clusters are connected together like the word *green* spoken by a mother with the perception of the green colour. This time communication skills are formed and an internal narrative gets enough models to start to work with them. So we start with almost completely sensory information building the first models and follow to develop more complex models with the first ones as a basis. Then we move towards more and more abstract models (ideas), but we still can trace their origins to the first sensory experiences, even if sometimes it is hard to notice it at first. Just as we construct models of our body and the rest of the world using senses, so we create models we could call *expressive* by which we learn to control the motoric abilities of our bodies. By connecting them with sensory models, we establish a critical corrective and coordinative loop allowing us, for example, to learn to walk, talk or do any other activities, including how to make a beautiful book.

We also have to mention such things as emotions, conscience, instincts, preferences and, above all, free will. For now, our model attempts to treat all of them as yet another models, however it is not inconceivable that in the future some of them will have to become independent components. Since we have defined what a memory retained model means to us, we could now attempt to define another term, namely intelligence. A definition of intelligence based on the concept of a model could be as follows: intelligence is an ability to formulate, detect and refine models, store them and combine them to achieve a given goal (also stated as a model). This definition in turn allows us to derive three different kinds (aspects) of intelligence:

- perceptual intelligence – the ability to create a new model if a given situation has not been experienced before, or detect and refine a pre-existing one,
- combinatorial intelligence – the ability to combine known models to achieve a given goal,
- expressional intelligence – the ability to express the desired model with effectors; it could be also called *communicative intelligence*. This expression is by no means limited to verbal skills. It could as well present itself as an ability to work on a manuscript, which can be seen as a manifestation of the scribe's internal mental process.

All these types of intelligence are interconnected in a kind of chain. As everyday observation confirms, an impairment of any of its links impairs intelligence perceived as a whole. On the other hand, it is hard to apply the term *intelligent* to a behaviour based exclusively on one of the said aspects of intelligence. With this final observation, we conclude the description of our proposition of the scribe's mental model.

7. Conclusion

It should be noted that because of the sheer size of the project this paper should be viewed as a starting point of a long and laborious road ahead. In this case, however, any amount of work is balanced by the potential benefits the main of which is the construction of an intelligent book design system even if not matching, then at least aspiring to match the beauty of the old manuscripts. This in itself would be a groundbreaking achievement opening many possibilities.

7.1 Potential applications outside of book design

Although an intelligent book design system is the ultimate goal of this work, it is not hard to notice that the mental model postulated in this paper is not inherently and exclusively bound to the scribal tasks and competencies and has many more potential applications. Since it operates on models and a model is a universal and capacious term, we could imagine it used, for example, as an apparatus translating natural language. The idea does not seem very original until we realize that there are many texts, either poetry or prose, which first have to be well understood within their historical and cultural context to be translated correctly, again, within a proper context. Our mental model places received information on the scene of imagination from which it can be further described, this time using words of a different language and meanings of a different culture. It is much like two persons observing the same situation and relating it in their own tongues.

Another application of this style of a mental model (or a *mental machine*) would be programming. From the beginning of the art and craft of programming, people have been trying to close the gap between the spoken language, which is the most natural tool for the man to use, and an internal language of machines. Despite these efforts, new programming languages which have been developed do not change much in that regard. Our mental model may provide a framework by which a machine could be able to *understand* the task described in a natural language and propose a solution. If this solution is not satisfactory, it will be corrected using the very same language. That kind of programming would be similar to explaining to another person what we want them to do. Natural, spoken or written, language would not be the only type of *language* available; as in the real-life situations we would be able to pass the necessary information using, for example, gestures or drawings.

Possible applications of the scribe's mental model are plenty. To enumerate them would be too much for this paper, but we could say that it could help to realize things like some psychological simulations, provide life-like gaming environments with intelligent virtual players, allow for the on-the-go creation and modification of computer graphic user interface, making it a breeze to match to personal preferences, or to be used to prepare a beautiful map shading, worthy of the name of a piece of art.

7.2 Relation to other work

Our work is not the only one in the field concerned with human mind inner workings in relation to the tasks a human being performs. One of such works is the work by Shao and Terzopoulos (2007), which presents a very detailed and complex simulation of human behaviour in an urban environment such as a train station. It builds a virtual world consisting of a train station filled with people. Each of the *persons* in the simulation is given their own simplified *mind* which is to guide their actions. The said mind keeps track of such human-like attributes as being curious, tired or thirsty. It contains a person's knowledge, memory, motion repertoire, and allows the senses to gather information about the environment and the *motor interface* to facilitate the movements in it. It also plans each person's actions adapting them to the situation at hand, which is crucial in a scenario when the simulated person has to, for example, move through a crowded hall to reach a ticket line. It can also make a person sit when they are tired or seek a drink when they are thirsty. All of that makes for a stable and quite life-like simulation of a train-station.

Impressive results of the Shao and Terzopoulos' simulation are matched by the equally impressive effort put into its preparation. The most interesting part of it, for our purposes, is the pedestrian model devised for the simulation. This model is presented in a quite sizeable diagram from Figure 10 in Shao and Terzopoulos' (2007) paper. Originally this diagram, which we use as a basis for our Figure 6, depicts components of both pedestrian model and world model along with their interdependencies and interactions. All of these are used in a single time step of a simulation designed by the two researchers. Such step is called HSS or *human simulation step*. In it all of the components are visited and used in a specific order to update pedestrian and world states. *Memory* on the diagram represents a list of pedestrian goals – like: wait for somebody, get a drink, etc. *Knowledge* corresponds to an internal image of the pedestrian's world with its objects, topography and events. *Cognition* binds memory and knowledge together for the sake of planning actions by the *Cognitive Control* component. *Cognition* influences *Behavioural Control* that is a component responsible for issuing general commands to *Motor Control Interface* (like: look at the clock, sit down, etc.). *Motor Control Interface* in turn tunes down unrealistic commands taken from *Behavioural Control* (e.g. the latter commanded the pedestrian to move with a speed physically unattainable by a human being) and manages pedestrian's body by selecting one of the options from the so called *Motion Repertoire* (predefined movements). Movements of the pedestrian's body are registered in an updated *World Model* and influence *Sensing. Sensing* then perceives current situation in *World Model* and allows *Knowledge* to be updated accordingly. *Sensing* also acts as a kind of transducer for so called *Internal States*, which represent pedestrian's condition by the use of parameters like tiredness, thirst or curiosity and may influence *Cognition*.

After a while it is not hard to notice interesting similarities between Shao and Terzopoulos' diagram and our own diagram from Figure 5. The big difference, however, is the complexity. All of the separate abstractions used to build the pedestrian model relate more or less directly and precisely to one of the abstractions used in our model of the scribe's mentality. These relations are presented in Figure 6, which contains the original diagram from the Shao and Terzopoulos' article connected to our own diagram from Figure 5. Knowledge, memory, motion repertoire and partially internal states can be mapped to our model storage. Behavioural control and some aspects of internal states find their counterparts in the model stage. *Sensing* and *Motor Control Interface* are pretty much directly equivalent to our sensors and effectors, respectively. *Cognitive Control*, in turn, is quite similar to the narrator used in our case to build the course of actions. *World Model* and *Rendering* are roughly the same as our *World*.

The similarities and differences between the two diagrams allow us to hope for two things. Firstly, if there is a working model, based on assumptions similar to our own, it makes future practical implementation of our model all the more probable. Secondly, since much of the complexity of the pedestrian model can be potentially *compressed* in our model, it lets us be cautiously optimistic about our model's spectrum of applicability and universality.

7.3 Plans for the future

Plans for the nearest future consist of further development of the mental model and its parts presented here. Such parts in need of further investigation are models themselves and ways in which they can be combined by the narrator. We have to look more closely on how the models can be represented, what are their attributes and how they relate to each other. The narrator and its role also has to be more fully understood and described. The next step would be a system complete with examples of models realizing a scenario in which a page of a book is designed. This hopefully will allow us to properly assess the soundness of the whole project, identify problems and decide on the next course of action to take.

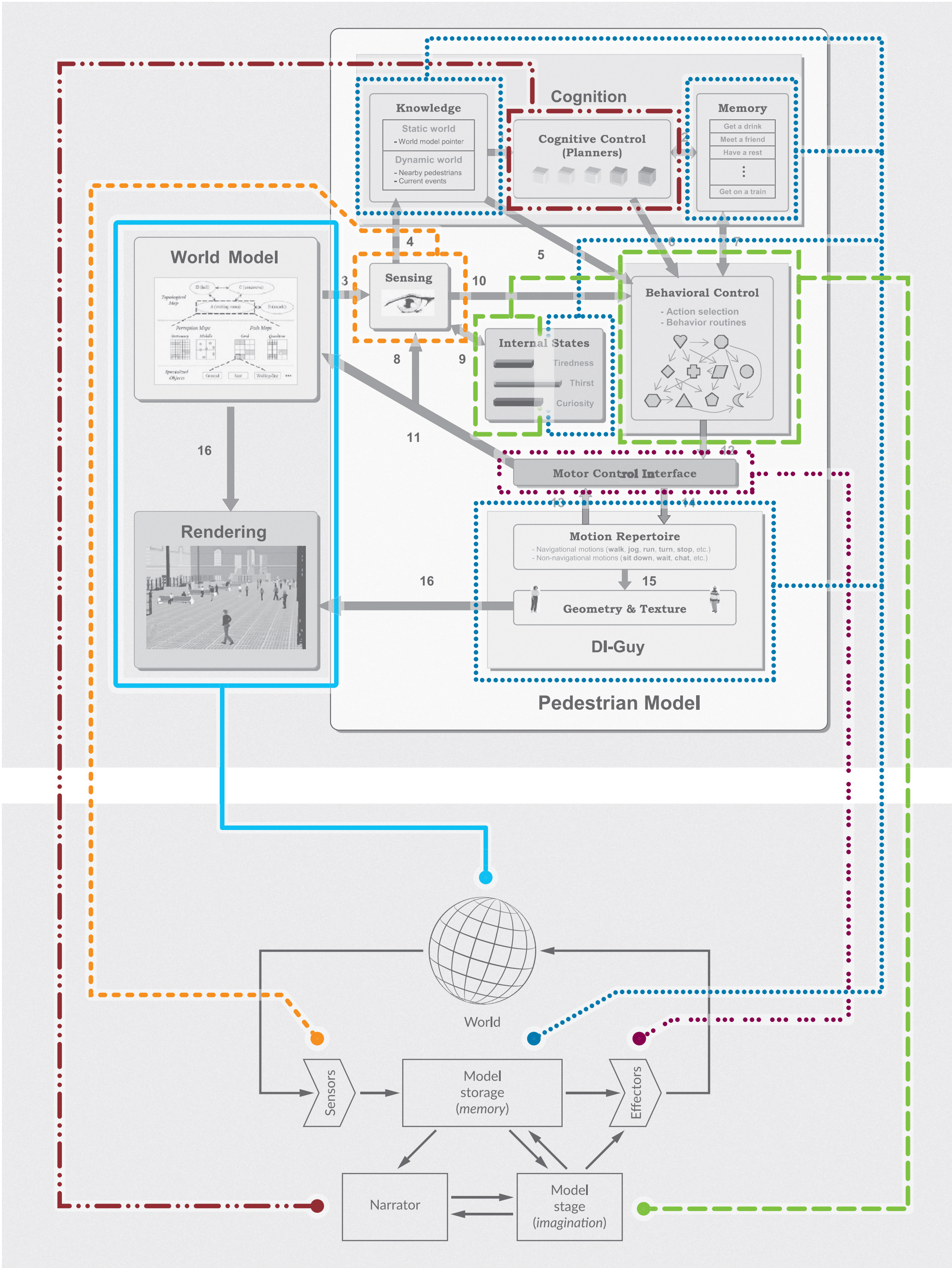


Figure 6: Scribe's mental model in relation to the diagram from the article by Shao and Terzopoulos (2007, p. 258)

Endnotes

This paper presents State of Art of Mr. B. Szczurek PhD dissertation under T. Szuba supervision. Paper also fulfils PhD program requirements of Computer Science Department at Faculty of Computer Science, Electronics and Telecommunications, AGH University.
B. Szczurek works as a book and graphic designer and an illustrator at Ruthenus Publishing House.

References

Adobe, 2016. [online] Available at: < http://www.adobe.com/products/catalog.html> [Accessed September 2016].

Aquinas, T., 1920. *The "Summa Theologica" of St. Thomas Aquinas, Part I QQ I.-XXVI.* (Literally translated by Fathers of the English Dominican Province). London: Burns Oates and Washbourne.

Clark, K., 1977. *Civilisation, Chapter 1: The Skin of Our Teeth*. London: British Broadcasting Corporation.

Craik, K.J.W., 1943. *The Nature of Explanation*. Cambridge: Cambridge University Press.

Frutiger, A., 1989. *Signs and Symbols: Their Design and Meaning*. (Translated from German by A. Bluhm). New York: Van Nostrand Reinhold.

Girard, A., 2016. *The Carthusian Order*. [online] Available at: <http://www.chartreux.org> [Accessed September 2016].

Johnson-Laird, P. N., 2004. The history of mental models. In: K. I. Manktelow and Man Cheung Chung, eds. 2004. *Psychology of Reasoning: Theoretical and Historical Perspectives*. New York: Psychology Press. pp. 179–212.

Johnston, E., 1906. *Writing & Illuminating, & Lettering*. New York: Macmillan.

Kurzweil, R., 2012. *How to Create a Mind: The Secret of Human Thought Revealed*. New York: Viking Penguin.

Lacroix, P., 1875. *The Arts in Middle Ages and at the Period of The Renaissance*. London: Chapman and Hill.

Leslie, S.E., 1909. Lessons in business writing. *The Business Educator*, 14(5), p. 9.

Licklider, J.C.R., 1963. *Memorandum for: Members and Affiliates of the Intergalactic Computer Network*. [online] Available through: Kurzweil Accelerating Intelligence website <http://www.kurzweilai.net/memorandum-for-members-and-affiliates-of-the-intergalactic-computer-network> [Accessed 15 March 2016].

Microsoft, 2016. [online] Available at: <https://www.microsoftstore.com/> [Accessed September 2016].

Oliver, R., 2015. *The Cistercians*. [online] Available at: <http:// http://www.osb.org/cist/> [Accessed September 2016].

Oliver, R., 2016. *The Order of Saint Benedict*. [online] Available at: <http://www.osb.org> [Accessed September 2016].

Putnam, G.H., 1896. *Books and Their Makers During the Middle Ages*. New York: G.P. Putnam's Sons.

QuarkXPress, 2016. [online] Available at: <http://www.quark.com/Products/QuarkXPress/> [Accessed September 2016].

Schmidhuber, J., 2009. Driven by compression progress: a simple algorithmic theory of subjective beauty, novelty, surprise, interestingness, attention, curiosity, creativity, art, science, music, jokes. *Journal of SICE*, 48(1), pp. 21–32.

Shao, W. and Terzopoulos, D., 2007. Autonomous pedestrians. *Graphical Models*, 69, pp. 246–274.

Splendor, 2016. *Pro Deo et Ecclesia: Proclaiming the Beauty, Grandeur and Majesty of the Church*. [online] Available at: <http://thesplendorofthechurch.com/2016/09/06/refuting-the-born-again-arc-heretic-on-bible-history-and-private-interpretation-by-splendor1618/> [Accessed September 2016].

Thagard, P., 2010. How Brains Make Mental Models. In: L. Magnani, W. Carnielli and C. Pizzi, eds. 2010. *Model-Based Reasoning in Science and Technology*. Berlin, Heidelber: Springer. pp. 447–461.

The Grid, 2016. *The Grid*. [online] Available at: <https://thegrid.io> [Accessed 20 March 2016].

The Next Rembrandt, 2016. *The Next Rembrandt*. [online] Available at: <https://www.nextrembrandt.com/> [Accessed 12 April 2016].

Tillotson, D., 2016. *Medieval Writing*. [online] Available at: <http://medievalwriting.50megs.com/writing.htm [Accessed 12 March 2016].

Turing, A.M., 1937. On computable numbers, with an application to the Entscheidungsproblem. *Proceedings of the London Mathematical Society*, ser. 2, 42(1), pp. 230–265.

Tymms, W.R. and Wyatt, M.D., 1860. *The Art of Illuminating as Practised in Europe from the Earliest Times*. London: Day and Son.

Topicalities

Edited by Markéta Držková

Contents

News & more

Recent activities of CIE

To engage scientists in building the knowledge supporting the developments in lighting technology and application, CIE (International Commission on Illumination) has released the CIE Research Strategy document in August 2016, listing the topics judged by the CIE as needing immediate attention by the research community. Relevant publications in the peer-reviewed literature are needed to form the solid basis enabling the CIE to keep providing consensus-based technical reports and standards that help to ensure high safety and quality of respective technologies.

As the top priority topics are identified: (i) Recommendations for healthful lighting and non-visual effects of light, (ii) Colour quality of light sources related to perception and preference, (iii) Integrated glare metric for various lighting applications, (iv) New calibration sources and illuminants for photometry, colorimetry, and radiometry, (v) Adaptive, intelligent and dynamic lighting, (vi) Application of new CIE 2006 colorimetry, (vii) Visual appearance: perception, measurement and metrics, (viii) Support for tailored lighting recommendations, (ix) Metrology for advanced photometric and radiometric devices, and (x) Reproduction and measurement of 3D objects.

CIE S 025/E:2015 – Test Method for LED Lamps, LED Luminaires and LED Modules

This standard provides requirements to perform reproducible photometric, colorimetric, and also electrical measurements on lamps, modules, and luminaires employing LEDs, together with the advice for the data reporting. Measurements performed in normalised conditions should ensure the consistency, reliability and accuracy of the photometric data for LED devices between different laboratories, enabling to compare different products on the same basis. The photometric and colorimetric performances of LED devices with different geometry and/or colour are considered individually. The standard was prepared by the corresponding technical committee of CIE Division 2, Physical Measurement of Light and Radiation, and deals in particular with measurement methods for testing the compliance with the photometric and colorimetric requirements of LED performance standards issued by IEC/TC 34 (Lamps and related equipment).

The standard covers measurements of total and partial luminous flux, luminous efficacy, luminous intensity distribution, centre beam intensity and beam angles, luminance, correlated colour temperature (CCT), colour rendering indices (CRIs), and angular colour uniformity, along with measurement uncertainties. It takes into consideration operation with AC or DC supply voltages, possibly with associated LED control gear. The standard does not cover LED packages and products based on organic LEDs.

CIE S 017-SP1/E:2015 – ILV: International Lighting Vocabulary –Supplement 1: Light Emitting Diodes (LEDs) and LED Assemblies – Terms and Definitions

This supplement summarizes the terms and definitions in the field of lighting by inorganic semiconductors that are used in CIE documents and intended to become part of the International Lighting Vocabulary.

Update on Ghent Workgroup Releases in 2016

After the new version of Ghent Workgroup PDF Specification GWG2015 for heatset and coldset printing, based on PDF/X-4:2010 and finished in November 2015, specification guidelines explaining the differences between the GWG 1v4 and 2015 specifications have been published in the beginning of 2016. This document goes through specification variants for different workflows, their consistent reliance on PDF/X, switching from PDF/X-1a to PDF/X-4, as well as the way of treating colour information, file size, optional content, OpenType fonts, 16-bit images, total ink coverage, output intent and ICC profiles, and single image pages. The changes are always described together with their reasons and consequences. As the change is major, a transition period and sufficient testing of workflows, applications and procedures is recommended when going from 1v4 to 2015.

In May 2016, GWG2015 PDF/X Workflow document was published, further explaining the differences in workflow needed when switching from GWG 1v4 to 2015 specification and how to take advantage of the new specification. It provides schematic diagrams of GWG2015 workflow, the way of processing PDF today, tomorrow and in the future, PDF limitations necessary for prepress data creation, and a guide which Ghent Workgroup specification to use. Moreover, the document describes the Ghent Workgroup example page, contrasts process-specific and media-neutral image editing, gives advices on process-specific preparation of vector-illustrations, configuring layout applications for new as well as existing documents, live preflight in InDesign, design, layout, and its optimization using transparency, explains differences between so called early, intermediate and late binding colour management, and PDF/X creation in InDesign and QuarkXPress.

GWG2015 – Packaging

In addition to the 2015 version of specification intended for heatset and coldset printing, the new specification for packaging based on ISO PDF/X-4 standard was released in April 2016, addressing the specific issues relevant to package and label production. In the main part, the terms and definitions are detailed, and then the individual requirements are described. In the last part, an overview of requirements is given for each of the three variants – for offset, gravure, and flexographic packaging printing.

Storing Processing Step Data in PDF

This GWG specification published along with corresponding white paper in May 2016 describes a standardized method for storing additional objects and metadata that will not be used for printing, but e.g. for die cutting, in a PDF. The implementation should avoid interoperability problems in the packaging and other segments of the printing industry. The derived standard is still under development as ISO/DIS 19593-1 Graphic technology – Use of PDF to associate processing steps and content data – Part 1: Processing steps 2016.

Ghent PDF Output Suite 5.0

Finally, in October 2016, Ghent Workgroup released its PDF Output Suite 5.0, offering new ICC-based test patches for colour-managed PDF output workflows to support their testing and adjusting in order to be fully compliant with PDF/X-4. This GWG package is now divided into three categories – CMYK with test patches using Device CMYK colour only, featuring one new 16-bit image, SPOT with test patches using Device CMYK and a spot colour, including the updated Spot to CMYK Overprint patch, and CMS with brand new test patches using ICCbased colours and testing colour management.

At present, instructions for the successful output of the Ghent PDF Output Suite 5.0 are available for the following PDF workflow systems: Agfa Apogee Prepress 9.2, Dalim ES and Dalim Twist, several EFI Fiery servers, Esko Software Platform, Kodak Prinergy Workflow, and Océ PRISMAsync print server.

CIE 217:2016 – Recommended Method for Evaluating the Performance of Colour-Difference Formulae

This is the first technical report published by CIE in 2016; it was prepared by the committee for Uniform Colour Space for Industrial Colour Difference Evaluation working under CIE Division 1, Colour and Vision. First, perceived and measured colour differences are described, followed by the indices for testing colour-difference formulae. The recommended method to evaluate the strength of the relationship between visually-perceived colour differences in a given set of colour pairs and their corresponding predictions made by a colour-difference formula is based on the standardized residual sum of squares (STRESS) index. It tests whether the two colour-difference formulae are statistically significantly different; in addition, it can be used to compute intra- and inter-observer variability in visual experiments. Finally, the report examines the performance of different formulae for selected visual datasets. The results indicate that it is not possible to recommend a more uniform colour space with a Euclidean colour-difference formula that is statistically significantly better than CIEDE2000.

CIE 220:2016 – Characterization and Calibration Methods of UV Radiometers

Corresponding committee established within CIE Division 2, Physical Measurement of Light and Radiation, has recently finished this technical report describing quality indices for UV radiometers, creating a common basis for instruments characterisation by both manufacturers and users. The quality indices in this document relate to those described in ISO/CIE 19476:2014 Characterization of the performance of illuminance meters and luminance meters; references are provided where applicable. Because UV radiometers may be designed for various actinic spectra and different spectral ranges, three reference-spectrum sources are proposed in CIE 220:2016 to support the generic spectral characterization of UV radiometers for various applications and their spectra are provided.

In respect to the properties of UV radiometers, the report covers their initial adjustment, effective responsivity against a reference-spectrum source, spectral matching, short- and long-wavelength range response characteristic, directional response, linearity, display unit, fatigue, as well as temperature dependence, humidity resistance, modulated radiation, polarization, spatial non-uniformity response, and range change. Further, source-based and detector-based approaches for the calibration of UV radiometers used for laboratory as well as industrial applications are described, along with measurement conditions and limiting boundary conditions.

CIE 221:2016 – Infrared Cataract

This technical report, prepared by the Infrared Cataract committee formed under CIE Division 6 (Photobiology and Photochemistry), reviews the recent progress in the research on the dose response curve, action spectrum and mechanism for the production of infrared cataracts, studying whether the damage mechanism is purely thermal, or if it could be photochemical. In the former case, the ambient temperature as well as the spectral content of the infrared irradiation becomes important, whereas a strong wavelength dependence in the near infrared spectral region would be present in the latter case, with great impact on lamp safety, medical devices, occupational exposure limits and the design of industrial eye protection. A conclusive laboratory study of the action spectrum for infrared cataract is enabled by the advanced infrared radiation sources (high-power LEDs and diode lasers as well as wavelength-tuneable lasers). The available results suggest the thermal nature of the mechanism.

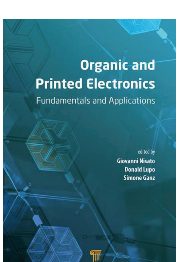
Bookshelf

Organic and Printed Electronics: Fundamentals and Applications

This book was written for students and engineers with a motivation to provide them with a preliminary reference guide, useful also for teachers. The book is contributed by a number of respected specialists and edited by the experts with solid background in the field, combining experience in industry and academia; two of the editors are active in the Organic and Printed Electronics Association (OE-A). Being aware that the intended book cannot cover all related topics in detail, the editors have focused on those with a certain level of maturity. Further, they have decided to deal in particular with printing and solution coating, while vacuum processing is presented only briefly. Special attention has been paid to the handling of liquid deposition and understanding the underlying physics. Similarly as vacuum deposition, the chemistry of organic and printable semiconductors, as well as the flexibility and mechanical properties of thin films, are mentioned only where important for context.

The introduction is followed by three chapters dedicated to materials and techniques. The chapter on organic semiconducting materials explains their functionality and optical properties. The next chapter on printing and processing techniques starts with a formulation of printable functional materials, their properties such as viscosity and surface tension, suitable solvents, and fluid dynamics of printed liquid films – wetting properties, the lubrication limit, surface-levelling time and Marangoni effect. Then, the general printing process sequence is detailed, from conditioning of the printing fluid and substrate pretreatment, through fluid acquisition, predosing, dosing, and transfer, up to relaxation and drying, curing or sintering. Finally, there are described principles, characteristics of print equipment, and processes of the four main printing techniques, namely flexography, gravure printing, screen printing, and inkjet printing, along with related practical experiences, applications, and current research. Presented coating techniques include spin coating, slot-die coating, and blade coating. In addition, laser patterning of thin films and other coating and structuring techniques are briefly mentioned – evaporation deposition, photolithography, pad printing, offset printing, nanoimprint lithography, microcontact printing, aerosol jet printing, laser transfer printing, xerography, plasma printing, and hot embossing. The fourth chapter brings an overview of characterization techniques for printed electronics.

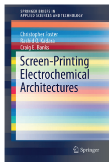
The following six chapters deal with selected groups of devices – organic field-effect transistors, the basics of organic light-emitting diodes, organic solar cells, batteries and supercapacitors, printed sensors and sensing systems, and hybrid printed electronics; encapsulation of organic electronics is also included. Three chapters then discuss environmental aspects, innovation management, and market perspectives. The final chapter refers about four experiments, namely with organometallic light-emitting diode, RFID tags, applications of µPlasma printing, and manufacturing a piezo single-nozzle drop-on-demand device. The text is complemented by abbreviations, glossary of printing terms and a number of exercises.



Organic and Printed Electronics: Fundamentals and Applications
Editors: Giovanni Nisato, Donald Lupo, Simone Ganz
Publisher: Pan Stanford
1st ed., March 2016
ISBN: 978-981-4669-74-0
604 pages, 227 images
Hardcover
Available also as an eBook

Screen-Printing Electrochemical Architectures

Authors: Christopher W. Foster, Rashid O. Kadara, Craig E. Banks



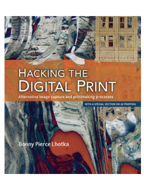
Publisher: Springer
1st ed., November 2015
ISBN: 978-3319251912
56 pages, 31 images
Softcover
Also as an eBook

This tiny book from SpringerBriefs in Applied Sciences and Technology introduces screen printing to readers who are not familiar with this printing technique or want to advance their technical knowledge and skills further. Screen printing is presented as a process allowing the mass production of novel and useful electrochemical architectures in a cost effective and highly reproducible way while yielding significant electrical benefits.

First, the basics and history of screen-printed electrodes are briefly introduced. The next chapter explains screen-printing process and recommends how to select screen-printing equipment. Then the reader is guided through successful design and fabrication of screen-printed electrochemical architectures. The last chapter presents the methods for the quality evaluation of electrochemical screen-printed sensors.

Hacking the Digital Print: Alternative image capture and printmaking processes with a special section on 3D printing

Author: Bonny P. Lhotka



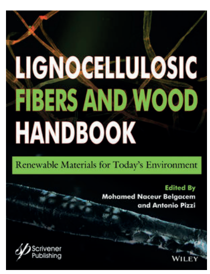
Publisher: New Riders
1st ed., February 2015
ISBN: 978-0134036496
312 pages
Softcover
Also as an eBook

The author is a co-founder of the Digital Atelier, whose members apply digital imaging in fine art. This book offers various projects with a clear step-by-step description and visuals; it is a good choice for those who wish to experiment to find out how to express their ideas through photography, but for others the technical instructions might be too complicated. A number of related resources can be found online.

Lignocellulosic Fibers and Wood Handbook: Renewable Materials for Today's Environment

The handbook summarises current knowledge on lignocellulosic fibres, an important raw material, which is the major constituent of wood – a natural, renewable source. After the opening pages of the first part, two chapters introduce the main characteristics of wood and wood fibres, i.e. the moisture content, distribution and influence on wood properties, biological and thermal characteristics, treating with fire retardants, weathering, and chemical composition and properties, going from cellulose through hemicelluloses and lignins to wood extractives. Next, recycled fibres are described, with sections discussing, among others, recycling and deinking lines, deinking efficiency control, influence of ink formulation and paper grade on deinkability, stickies, optical and strength properties of recycled pulp, recycling rejects, and the limits of paper recycling. The first part continues with chapters on deinking of recovered papers by froth flotation, high-yield pulps, kraft pulping, and sulphite pulping.

The second part of the handbook offers seven chapters covering various aspects related to the production of composites and panels. The third part, reserved for paper, explains rheology, papermaking and wet-end chemistry, paper winding, surface treatments of paper, calendering of papers and boards, and colour and colour reversion of cellulosic and lignocellulosic fibres. The final part deals mainly with the assessment of wood and fibres properties, including a section on paper characterization and testing.

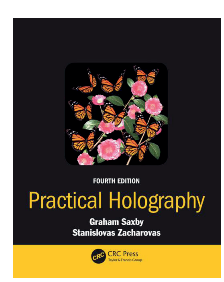


Lignocellulosic Fibers and Wood Handbook:
Renewable Materials for Today's Environment
Editors: Mohamed N. Belgacem, Antonio Pizzi
Publisher: Wiley-Scrivener
1st ed., April 2016
ISBN: 978-1-118-77352-9
704 pages
Hardcover
Available also as an eBook

Practical Holography

The fourth edition of this comprehensive and valued book is co-authored by Stas Zacharovas. It brings new information on colour holograms, sensitive materials, and modern processing techniques, consolidates information on digital holography, adds an appendix on the methods of non-holographic 3D imaging, updates the glossary, and more. The book including intelligibly presented in-depth information is since its first edition in 1988 considered a solid resource for everyone involved in practical holography at all levels, from basic applications to advanced holographic systems. The content is organised into 26 chapters in three sections – principles of holography, practical display holography, and applied holography, accompanied by appendices A to G.

Practical Holography
Authors: Graham Saxby, Stanislovas Zacharovas
Publisher: CRC Press
4th ed., October 2015
ISBN: 978-1-4822-5157-9
642 pages, 473 images
Softcover
Available also as an eBook



Design for the Mind:
Seven Psychological Principles of Persuasive Design

Written primarily for web designers and developers to teach them how to get beyond aesthetics and engage users, this book covers seven principles of psychology, which the author considers relevant to design and proven, yet simple – planned behaviour, prospect theory and heuristics, Fogg's behaviour model, influence, social influence, framing communication, and persuasion. They are grouped into two sections; the first one in three chapters explores how to create and change behaviours through design, and the second one in the next four chapters explains the design for influence and persuasion. Before that, the examples of design ignoring and respecting psychological principles are provided, as well as the discussion on understanding the meaning of persuasion, summarised in this claim: "Persuasion is not a dirty word; this book covers persuasive techniques meant to create a better user experience, not trick users into doing something they don't want to do." The last part of the book presents a case study and concluding recommendations. The book examines many factors and options worth to consider to make good designs work, demonstrated on examples of real websites and supported by the exercises.

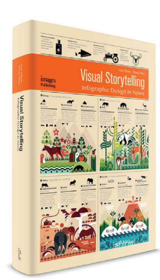
Design for the Mind:
Seven Psychological Principles of Persuasive Design
Author: Victor S. Yocco
Publisher: Manning
1st ed., July 2016
ISBN: 978-1-61729-295-8
240 pages
Softcover

Visual Storytelling:
Infographic Design in News

Infographics and data visualisation help to clearly communicate the message, regardless its complexity or tediousness, and hence became highly important in today's media. Data journalism works with the vast amount of data to discover patterns and relationships in order to offer more in-depth, visually engaging insight. This richly illustrated book demonstrates many opportunities to creatively utilise various kinds of graphics and illustrations.

First, the volume briefly presents the origin of news data, characteristics of data journalism and its forms, followed by the case studies on data journalism in the media – The Guardian, The New York Times, and Bloomberg News. The next part deals with data journalism design, its basic elements and design methods ranging from the traditional ones to multidimensional and interactive data news design. Finally, the main part is dedicated to the case studies on various topics, going through finance and economy, sport, politics and military, entertainment news, and society and science.

Visual Storytelling: Infographic Design in News
Editors: Liu Yikun, Dong Zhao
Publisher: Images
1st ed., January 2016
ISBN: 978-1-86470-649-9
240 pages
Hardcover



Min:
The New Simplicity in Graphic Design

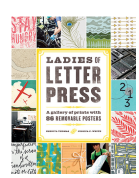
Author: Stuart Tolley

Publisher:
Thames & Hudson
1st ed., May 2016
ISBN: 978-0500292198
288 pages, 500 images
Softcover

Minimalism, putting the stress on the relationship between form and function of graphic design, have recently gained ground with a new strength. This volume presents the work of 162 contemporary minimalist designers produced in the past three years. Reduction, the first section, introduces graphic designers who create original compositions by applying restraint and reduced methods. It is opened by an interview with designers of Cereal, a travel and style magazine, and concluded by two essays, one on social revolution and the other on the grid. "Print production used as a replacement for graphic design as a method for communication" is explored in the second section – Production. It is framed by an interview with BVD, a brand and graphic design agency, and another two essays – 'Excess meets less', and 'Simplification today'. Geometry, the third section, presents design simplified to its purest graphic form using shape and abstract compositions and starts with the last interview about Erased Tapes Records, an independent record label.

The Ladies of Letterpress

Authors: Jessica White, Kseniya Thomas

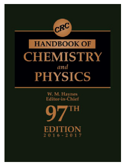


Publisher: Princeton Architectural Press
1st ed., April 2015
ISBN: 978-1616892739
192 pages, 350 images
Softcover

This book showcases the best work of the members of an international organization of the same name. Presented pieces range from greeting cards to broadsides and posters, printed in a variety of type and illustration styles. For each one there are provided technical details of paper, inks, and press used, together with a profile of its printer.

CRC Handbook of Chemistry and Physics

Editor: William M. Haynes

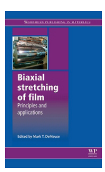


Publisher: CRC Press
97th ed., June 2016
ISBN: 978-1498754286
2 652 pages
Softcover
Also as an eBook

The current 97th edition of this iconic reference as always includes several new or updated tables along with other updates and expansions. Among others, colorimetry and refractometry are now covered within basic instrumental techniques of analytical chemistry, and new compounds were added to the table on surface tension of common liquids.

Biaxial Stretching of Film: Principles and Applications

Editor: Mark T. DeMeuse



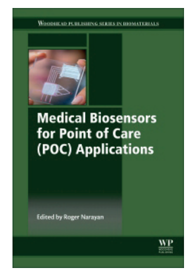
Publisher: Woodhead Publ.
1st ed., August 2016
(Hardcover August 2011)
ISBN: 978-0081016923
288 pages, Softcover
Also as an eBook

This is another paperback edition of recently published book from Woodhead Publishing. Part I deals with the fundamental principles of biaxial stretching – the production equipment, processes and materials, structures and properties of films, and their post-production processing. Part II presents the applications of biaxial stretched films in fresh-cut produce and snack packaging, as well as in product labelling, including glue-applied labelling systems, pressure-sensitive, in-mold and thermal transfer self-adhesive labelling, shrink sleeves and stretch sleeves, and both thermal transfer and direct thermal tag labelling; label requirements by application are discussed. There is also a section on label design, printing and converting, listing the label properties suitable for individual processes, and varnishing or lamination possibilities. Remaining two chapters are dedicated to biaxial stretching of nanocomposite and multilayer films, and future trends for biaxially oriented films and orienting lines, respectively. Overall, this book is more descriptive than explaining.

Medical Biosensors for Point of Care (POC) Applications

Point-of-care diagnostic tools are becoming another field where printing techniques can be beneficially applied. To provide real-time and remote health monitoring, miniaturised and portable biosensors are designed to enable the use by untrained individuals wherever needed. This book, which is intended primarily for researchers and scientists active in biomaterials, imaging, and biomedicine, follows the recent advances in medical biosensors suitable for point-of-care use. The text is organised into three parts. The first one introduces basic concepts, necessary validation and regulation methods, and materials for *in vitro*, *in vivo* and *ex vivo* sensors. The second part starts with a chapter on screen printing and other scalable technologies, including flexography, gravure, microcontact, inkjet, wax-ink and 3D printing, and continues with lab-on-chip devices, wearable biosensors, and wireless ones. Finally, the third part presents biosensors for cancer detection and blood coagulation monitoring, as well as the use of nanomaterials, microfluidic platforms and electrochemical medical biosensors.

Medical Biosensors for Point of Care (POC) Applications
Editor: Roger J. Narayan
Publisher: Woodhead Publishing
1st ed., August 2016
ISBN: 978-0-08-100072-4
316 pages
Hardcover
Available also as an eBook

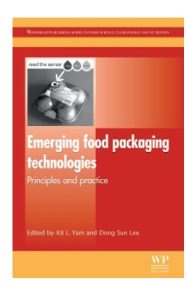


Emerging Food Packaging Technologies: Principles and Practice

Since August 2016, many books published in recent years by Woodhead Publishing are available in paperback edition, including this one on emerging food packaging technologies.

The book reviews the advances in available materials and technologies towards improved packaging sustainability, as well as food safety and quality. After an overview in the first chapter, six chapters of part I examine the developments in active packaging. Part II in five chapters deals with intelligent packaging and the consumer/packaging interface. This part presents basic concepts of intelligent packaging, describes a conceptual framework of intelligent decision support system designed to minimize microbial hazards, explains RFID systems, their benefits, technical functions and future, reflects on the advances in freshness and safety indicators in food and beverage packaging, introduces smart packaging for enhanced convenience, functionality and communication, and more. Next, five chapters of part III then summarise developments in packaging materials. Finally, various aspects of environmentally compatible food packaging are analysed in four chapters of part IV.

Emerging Food Packaging Technologies:
Principles and Practice
Editors: Kit L. Yam, Dong S. Lee
Publisher: Woodhead Publishing
1st ed., August 2016 (Hardcover March 2012)
ISBN: 978-0-08-101639-8
512 pages
Softcover
Available also as an eBook



Bookshelf

Academic dissertations

Automated CtP Calibration for Offset Printing: Dot Gain Compensation, Register Variation and Trapping Evaluation

Doctoral thesis – Summary

Author:
Shahram Hauck

Speciality field:
Media Technology

Supervisors:
Sasan Gooran
Björn Kruse

Defended:
9 September 2015 at Linköping University / Department of Science and Technology
Norrköping, Sweden

Contact:
shauck@beuth-hochschule.de

This dissertation deals with a number of issues in offset printing workflow, discusses various requirements for print quality control and offers corresponding quality control models. Namely, dot gain, register and trapping are examined, all being influenced by a complex of conditions and settings, both in prepress and press. Dot gain compensation is done in the Raster Image Processor (RIP). Register variation, causing tone value and grey balance variation as well as blurring the image details, is monitored and controlled during printing. Similarly, trapping effects have to be measured to avoid their negative influence on grey balance.

Two novel models to determine the register variation value, one based on spectrophotometry and the other one on densitometry, are proposed and verified by a comparison to the industrial image processing based model. Next, a novel spectral trapping model is suggested, quantifying the trapping effect by a colour difference metric. Very good correlations with the existing models have been found, showing also a bigger dynamic range of the proposed model. It was further extended to take into account the effect of ink penetration and gloss; however, these factors can be neglected in case of the tested high glossy coated paper. Finally, three different dot gain compensation methods are discussed. The most accurate and efficient one has been tested, evaluated and applied using many offset printing workflows. Moreover, the method is non-iterative, which is the feature important for an automated CtP (Computer to Plate) calibration. Finally, an automated CtP calibration system for offset printing workflow has been introduced and described. This method is a good solution to generate the needed huge numbers of dot gain compensation curves to have an accurate CtP calibration within the range recommended by ISO 12647-2.

Colour Local Feature Fusion for Image Matching and Recognition

Doctoral thesis – Summary

Author:
Tony Marrero Barroso

Speciality field:
Computer Vision Engineering

Supervisor:
Paul Francis Whelan

Defended:
6 November 2015 at Dublin City University / School of Electronic Engineering
Dublin, Ireland

Contact:
tony.marrero@gmail.com

Local invariant image features, being one of the most successful present solutions in developing a bottom-up saliency mechanism for representing the visual form in computer vision, are important in many applications. However, the most widely used local feature techniques very often disregard some unique image features since they operate only on greyscale image information. The research conducted within this thesis aimed to develop a method of local colour features extraction for the applications of feature matching and image recognition, while complying with the criteria important for local image features in general. That entails ensuring the necessary robustness to different imaging conditions and photometric variations, including changes in exposure, lighting direction or shading, and geometrical changes such as viewpoint, zoom, and orientation. Robustness to variations in the image quality and camera acquisition process was also of importance, as well as the applicability of the features for various computer vision tasks, especially for matching, retrieval and classification.

The text details the performed work on the colour invariant local image features and presents the results for feature detection and matching, as well as for object class recognition using a Bag-of-Words approach. In contrast to the majority of previous works, the local feature extraction in this thesis

uses colour in both the detection and description steps – specifically the Harris-Laplace algorithm with optimised parameters for interest region detection, and the Scale Invariant Feature Transform (SIFT) for characterising the detected region. Four different local image feature matching datasets covering the common imaging distortions (scale, viewpoint, blurring, JPEG compression and illumination) were employed to solidly validate the colour local features against the requirements mentioned above. The correlation analysis for feature matching has shown the level of redundancy in the features extracted by the colour and greyscale-based techniques, indicating a strong potential for developing an approach capable of jointly extracting the best information from both techniques. Two separate fusion approaches are implemented and evaluated, one for local feature matching tasks and another for object recognition. In the former case, it turned out that the standard Harris-Laplace ranking method that uses the cornerness energy doesn't sufficiently indicate the robustness of the point, failing to ensure a high probability of selecting the most appropriate set of points from either colour or greyscale feature types. In summary, the research showed that the majority of the colour invariants are not optimal to be used individually for the tested applications. Some colour features however did outperform their greyscale counterpart in numerous situations, and the research demonstrated that it is possible to obtain consistently better results once both colour and greyscale information is utilised appropriately.

Doctoral thesis – Summary

Author:
Mikko Nelo

Speciality field:
Electrical Engineering

Supervisors:
Heli Jantunen
Jari Juuti

Defended:
4 December 2015 at University of Oulu / Faculty of Information Technology and Electrical Engineering, Department of Electrical Engineering Oulu, Finland

Contact:
mikko.nelo@oulu.fi

Inks Based on Inorganic Nanomaterials for Printed Electronics Applications

The goal of this thesis was to develop novel low temperature curable composite inks with improved long-term storage capability, dispersion uniformity and high filler loading, while not sacrificing the quality and durability of printed layers to provide desired functionality for printed electronics devices. The inorganic materials were utilised mainly in the form of dry powders as almost all electrically interesting raw materials are typically available in powder form at a low price. The introductory chapters of the thesis describe the topic with relevant printing methods and ink formulations for magnetic, piezoelectric and memristive applications. Third chapter lists the materials and methods used. The main part, Chapter 4, then deals with the ink formulations and characterization of both inks and printed patterns. Key results and conclusions are summarized in final chapter.

Firstly, the research was focused on low curing temperature magnetic screen-printing inks based on dry cobalt nanoparticles for high frequency applications. After ink formulation and its process development, the multifunctional surfactant was utilised and then the inks for plastic substrates were developed. The maximum loading level of cobalt nanoparticles was 60 % (volume fraction). The resulting ink enabled the miniaturization of a patch antenna. Next, the formulation of inks based on piezoelectric ceramic powder with ferroelectric polymers as a matrix material was introduced and the printed inks and cured layers were tested with respect to their performance and quality. The utilisation of the printed piezoelectric layer in a pressure sensor is suggested. Finally, the inks for a memristor, i.e. a printed memory component expected to revolutionise the memory systems, were developed. A synthesis route for an organometallic precursor solution was successfully proposed. The solution was formulated into inkjet-printable form and based on the printing tests, the optimal layer thickness with memristive behaviour was determined. Further, it was shown that the prepared memristive patterns remained functional for up to 35 days, while the precursor solution remained usable for over a year. Up to 30 read/erase cycles were achieved. In addition, suitable heat treatments ensured the increase of the shift in resistance value by up to three orders of magnitude.

Events

SPIE Applications of 3D Printing 2017

San Francisco, California, USA
28 January to 2 February 2017

This symposium is one of the three applications tracks that highlight papers being presented during SPIE Photonics West and addressing technology solutions for some of the most promising new applications.

For 2017 edition, about a hundred papers representing more than twenty conferences are included. Almost a half of papers belong to the Laser 3D manufacturing IV conference, with topics such as the high-speed imaging and evolution dynamics of laser induced deposition of conductive inks, laser sintering of sol-gel derived ceramic materials, and micro and nano printing of carbon materials by pulsed laser deposition at atmospheric pressure, and Advanced fabrication technologies for micro/nano optics and photonics X conference, presenting e.g. 3D printing of high-resolution bioresorbable vascular stents, or strategies for rapid and reliable fabrication of microoptical structures using two-photon polymerization. In addition, Alberto Piqué will give a plenary speech on 'Printing hybrid electronics by laser direct-write'. The industry event discussing the new challenges and opportunities of 3D Printing is scheduled on 1st February.

EI 2017 – IS&T International Symposium on Electronic Imaging

Burlingame, California, USA
29 January to 2 February 2017

In 2017, the 29th annual symposium features 18 technical conferences. Participants can also join many short courses, exhibits, demonstrations, and special events, such as the EI Scientist of the Year award ceremony. Students can benefit from significantly reduced registration fees, apply for travel grants, and, first of all, showcase their projects and ideas while meeting the representatives of relevant companies and universities.

The program of Color imaging XXII: Displaying, processing, hardcopy, and applications conference begins on 30th January with the EI 2017 opening plenary lecture 'Giga-scale 3D computational microscopy' by Laura Waller, and a joint session focused on modelling and reproduction of surface appearance. The next day, the schedule consists of sessions on colour management, colour vision and deficiency, and then on display and display appearance – after the Gordon Wetzstein's plenary 'VR 2.0: Making virtual reality better than reality'. The morning of the third day is reserved for halftoning and printing, with the plenary lecture 'Designing VR video camera systems' by Brian Cabral and the special session 'Dark side of color' later in the day, dealing with image quality for visually impaired, metameric failure, what makes hue special, how to reveal the dark ages through erased manuscripts imaging, and, finally, what we see and what we know. The last day is dedicated to colour image processing, and spectral selection and separation, with the interactive workshop 'How can color imaging provide us with powerful insights?' in the afternoon, co-sponsored by Material appearance 2017. The program of the other conferences is rich as well.

3D Printing Electronics Conference

Eindhoven, Netherlands
24 January 2017

This conference is organised to explore how integrated devices with active, functional components – from rather simple sensors or switches to more complex electronics, can be produced directly, instead the usual assembly of individual elements, thus looking for new markets and applications.

Presentations announced so far for the 4th edition include application examples, such as the integration of 3D electronics in lighting products or printed primary batteries, as well as technology developments, presenting e.g. the special pastes for 3D printing, high-precision 3D printing, and 3D polymer printing combined with inkjet nanoparticle printing.

A week later, the related 3D Printing Materials Conference, also in its 4th year, will take place in Sittard-Geleen, Netherlands (2 February 2017).

C!print

Lyon, France
31 January to 2 February 2017

The two C!Print trade shows (the other one held in Madrid, Spain in autumn) encompass a broad range of digital-based solutions and technologies that can be utilised to add the value to printing in many ways, from design over printing and finishing to fully integrated services. With the expansion of wide-format printing, personalisation is not the domain of small formats anymore. On top of that, the sophisticated data management and development of new services, meeting the specific client and customer expectations, take personalisation to the next step and bring new business opportunities for existing production systems.

Inside 3D Printing Conference & Expo

Düsseldorf, Germany
2–3 February 2017

This professional 3D printing and additive manufacturing event is organised worldwide to present the latest 3D printers, software and services, as well as their business applications in various industries. In Düsseldorf, the program contains over fifty presentations in three tracks, panel discussions, and plenary keynotes – 'Insights in the history and drivers of the AM markets' by Fried Vancraen, 'Global value chains – How does AM influence the factory of the future?' by Nikolai Zaepernick, 'AM perspectives – Not bound to earth' by Tommaso Ghidini, and finally 'Function defines form – Increasing value through functional design' by Christoph Kiener.

The other Inside 3D printing events organised in 2017 by the Rising Media will take place in Istanbul (9–12 February), Singapore (14–15 February), New York (14–15 March), Melbourne (9–12 May), Paris (17–18 May), São Paulo (5–6 June), Seoul (28–30 June), Shanghai (in September), Tokyo (3–6 October), Mumbai (7–8 December), and San Diego (in December).

Sign & Print Scandinavia

Stockholm, Sweden
7–9 February 2017

The Easyfairs event for Scandinavian visual communications industry offers in 2017 several new topics, such as car wrapping, robotisation, 3D production, or digital signage, as well as Print Power initiative with Grafiska Företagen (Swedish Graphic Industries' Federation) and the online dispute resolution (ODR) with SWEDMA (Swedish Direct Marketing Association). During all three days, fair visitors can attend seminars and lectures at the management and creative stages.

Printable Electronics 2017

Tokyo, Japan
15–17 February 2017

This event is organised as a part of the Converting technology exhibition. The seminar focused on advanced printed electronics technology presenting e.g. materials for printed electronics applications or progressing from 2D to 3D printed functionality is scheduled on 15th February. The day before, the OE-A Asian working group meeting will take place.

The conference is complemented by the exhibition showcasing materials, devices and machines relevant for printable electronics products, such as conductive inks based on metal (nano)particles or polymers, insulating and other functional inks, suitable substrates, equipment for measurement and analysis, and all kinds of patterning and coating techniques.

Printable Electronics is co-located with many other events, including the 16th edition of Nanotech, this year offering special sessions e.g. on graphene or cellulose nanofibres. Further, the Advanced Printing Technology and 3D Printing exhibitions are held at the same time. The first one showcases printing machines, together with other equipment and materials for all printing technologies and markets, from editing and prepress over proofing to quality inspection systems. At 3D Printing, the exhibitors will present not only 3D printers and other rapid prototyping or manufacturing machines, but also a wide range of connected products and services, including 3D scanners, hardware for image processing, 3D modelling, etc.

VISIGRAPP 2017
12th International Joint Conference on Computer Vision, Imaging and Computer Graphics Theory and Applications

Porto, Portugal
27 February to 1 March 2017

In 2017, the 12th volume of this established event includes one conference more than its editions in previous years. Besides the three conferences focused on theory and applications of computer graphics (GRAPP), information visualization (IVAPP), and computer vision (VISAPP), the international conference on human computer interaction theory and applications (HUCAPP) will be co-located as the fourth one.

In addition, the participants can make use of tutorials, workshops and attend the special session focused on cultural applications. The tutorial program includes, among others, the sessions on 'Image quality assessment based on machine learning for the special case of computer-generated images' and 'Perception for visualization: From design to evaluation'. The doctoral consortium, providing graduate students within the field with an opportunity to discuss their research in an international forum, is organized as well. Moreover, the objectives and outcomes of both ongoing and past European research projects will be promoted within the European Project Space, along with new financing opportunities related to Horizon 2020, presented by the European Commission representatives.

Inkjet Engineering / Inkjet Ink Development Conference

Lausanne, Switzerland
14–16 March 2017

The IMI Europe spring technical event starts in 2017 with the conference focused on components and techniques for development and production of digital printing systems, and continues with the two-day conference on materials, equipment and techniques for digital printing ink development and manufacturing. This way, those who decide to register for both conferences (discounted fees are available) can acquire information on drive electronics, software, printhead choice, reliability and print quality, as well as how to create stable dispersions, which additives to use for ink formulation, and what to consider in respect to raw material quality and process stability, and more. The detailed programme is not available yet.

Earlier in 2017, the IMI Europe Inkjet Winter Workshop 2017 is offered in Barcelona, Spain from 23 to 27 January, featuring three courses in five days. The first course deals with the challenges of high-speed single-pass inkjet system design, namely with printer development, jetting, system integration and design processes, printhead and ink selection to match printing application, process development and testing procedures. The next one is focused on inkjet drop behaviour during printing, both in flight and when interacting with surfaces, including effects of inks, surfaces, fluid flows with particles, drops aerodynamics, drying and curing, and print quality assessment. The last course is dedicated to inkjet ink manufacturing, covering the issues of inkjet ink design, development and testing, scale-up for manufacture and manufacturing itself, not exluding ink plant design and commercial considerations.

TAGA 2017 Annual Technical Conference

Houston, Texas, USA
19–22 March 2017

After the TAGA student meeting in the morning, the main program of this year's conference starts on Sunday (19 March) with keynote sessions. Anthony Thirlby will present the outlook of the print and communications industry: how the transformation will happen, what the future shape of print companies will look like and how this will influence how business is done, with software seen at the centre of any successful communications business. Next, Gary Dispoto will compare and contrast the capabilities of both present and future 3D printers with conventional manufacturing methods and review important workflow considerations for 3D printing. John Seymour then will explain why 'Patenting a color' is not possible in the keynote of the same name, while providing useful information on what to do and what to avoid when considering a patent application. Finally, Steve Smiley will discuss the expected outcome of ISO standards on PDF/X, CxF/X-4 colour data exchange format, and spot colour tone value measurement and calculation, which can substantially improve the communication of colour and job intent, also enabling to print more vibrant spot colours.

In following two days, the presentations will traditionally cover wide range of topics – from inks with the expanded gamut for high-speed inkjet printing, advances in electron beam curing and barrier biofilms for packaging applications, through print layout optimised for manufacturing efficiency and possibilities to quantify subjective properties of graphic reproductions, up to recent developments in UV curing equipment, special ink formulations, as well as characterisation and evaluation methods, and many more.

GWG Meeting Prague

Prague, Czech Republic
15–17 February 2017

Although several important specifications and other documents has been released recently (see News & more section of this issue), the Ghent Workgroup (GWG) does not plan to slow down. The agenda of winter technical meeting includes the work on specifications on the first day and presentation of subcommittees for colour management, packaging, process control, documentation, compliancy testing, and marketing in the next two days, as usually.

Digiday Publishing Summit Europe

Lisbon, Portugal
21–23 February 2017

The main concern of this event is how to make the content distribution profitable. Besides networking and attending the lectures, the participants will split off into four working groups on the first day, each one focusing on a particular challenge that publishers face: social media, video, platform distribution or ad blocking. The groups will work throughout the summit and then present suggested solutions.

The Japanese edition of Digiday Publishing Summit takes place in Odawara City three weeks earlier (2–3 February), while the North American one in Vail over a month later (29–31 March). Further, two Digiday Brand Summit events are announced; the first one in Charleston (18–20 April) and the European edition in Berlin (3–5 May). The other related Digiday summits, so far scheduled for 2017, include Digiday Agency Summit in Nashville (1–3 March) and Digiday Moguls in Vail (27–29 March). Summer and autumn editions of Digiday Publishing Summit events will be organised in the upcoming months, as well as the Digiday Signal Awards for the outstanding media and marketing technology platforms.

High Security Printing Europe

Baku, Azerbaijan
27–29 March 2017

The High Security Printing™ Europe, as well as the Asian and Latin American editions of this event, focus on government-specified and issued documents and are held annually.

Expert speakers will present technical advances as well as some regional case studies. The event is complemented by trade exhibition of currency, e-passport, smart card, authentication and related industries.

Delegates can also gain professional knowledge in two pre-conference seminars combining presentations and discussions. Both of them are organised on 27 March and free for government delegates. The first one will provide practical considerations related to durable substrates for banknotes, covering all major products available today along with their benefits and challenges, while the second one will give a practitioner's perspective on combating document fraud and counterfeiting, offering a practical overview of the various methods and techniques used for altering, tampering with and counterfeiting of identity documents and passports using real-life cases, as well as their examination.

3D Printing Days

Kielce, Poland
28–30 March 2017

This event for 3D printing, hosting also 3D scanning industry and rapid prototyping sector representatives, is held since 2013 and biggest in Central and Eastern Europe. It gathers all major Polish printer manufacturers as well as foreign equipment distributors. In 2017, further expansion is expected, thanks to programmes under the new European Union financial perspective being now launched in Poland and providing the industry, research and educational institutes with the opportunities to implement new technologies.

SPIE Smart Structures / NDE 2017

Portland, Oregon, USA
25–29 March 2017

The 24th Annual International Symposium on Smart Structures and Material Systems + Nondestructive Evaluation and Health Monitoring organised by SPIE features 11 conferences, some of them split into two tracks, complemented by various special events and an introductory course on electroactive polymer actuators and devices. The course planned on the day prior to the technical conference covers ionic materials including gels, field activated electronic materials and torsional actuators, basic mechanisms responsible for the active behavior of these materials, as well as relevant analytical models, fabrication processes and characterisation methods. Moreover, it provides an overview of the currently considered applications, including actuators, robotics, or energy harvesting.

Interesting contributions can be found across the individual conferences, exploring e.g. printed sensor arrays for structural monitoring, novel textile and yarn actuators, development of sensing systems printed with conductive ink on gear surfaces, computer-controlled direct ink writing of conductive polyaniline transducers, spatial piezoresistivity of inkjet-printed carbon nanotube thin films for strain-state sensing, 3D printing of polyurethane/multiwall carbon nanotube composites for highly elastic strain sensors or ionic polymer-metal composites for soft robotics, 3D printing of lenses for structure-borne wave focusing and energy harvesting, or preference tests for zebrafish, comparing live stimuli and 3D-printed replicas. Most sessions dedicated directly to 3D printing and applications are scheduled within the Nano-, bio-, info-tech sensors and 3D systems conference. A number of contributions deal with dielectric elastomers based solutions – such as the integration of flexible high-voltage thin-film transistors to drive a matrix of dielectric elastomer actuators, surface texture change on-demand and microfluidic devices based on thickness mode actuation of dielectric elastomer actuators, drop-on-demand printing of dielectric elastomer actuator electrodes, dielectric elastomer pressure sensors for operation tools, and fatigue testing setup for dielectric elastomer membrane actuators.

LOPE-C 2017

Munich, Germany
28–30 March 2017

As each year, this international exhibition and conference for the printed electronics industry brings content for business, technical and scientific audiences. While the program for scientific and business conferences is still in preparation, some speakers for plenary sessions and technical conference are already announced.

Plenary lectures include 'Collaboration and the development of a flexible hybrid electronics ecosystem' by Melissa Grupen-Shemansky, 'Printed electronics in Korea and future prospect of organic electronics' by Sang Yoon Lee, 'Toward flexible future of electronics' by Jennifer Y. C. Lin, presenting the development of mass-production organic thin-film transistors technology (OTFT 2.0), and 'Fully printed organic sensors' by Jean-Yves Gomez. At the technical conference, e.g. the near field communication solutions for the Internet of everything, low-power electrophoretic displays, highly reliable solution-processed flexible organic thin-film transistors, haptic technologies, printed, skin-mounted system for electrocardiography measurements, or item-level data will be discussed.

Call for papers

The Journal of Print and Media Technology Research is a peer-reviewed periodical, published quarterly by iarigai, the International Association of Research Organizations for the Information, Media and Graphic Arts Industries.

JPMTR is listed in Index Copernicus, PiraBase (by Smithers Pira), Paperbase (by Innventia and Centre Technique du Papier) and NSD – Norwegian Register for Scientific Journals, Series and Publishers, ARRS, Slovenian Research Agency – List of Scientific Journals.

Authors are invited to prepare and submit complete, previously unpublished and original works, which are not under review in any other journals and/or conferences.

The journal will consider for publication papers on fundamental and applied aspects of at least, but not limited to, the following topics:

- Printing technology and related processes
  Conventional and special printing; Packaging; Fuel cells, batteries, sensors and other printed functionality; Printing on biomaterials; Textile and fabric printing; Printed decorations; 3-D printing; Material science; Process control
- Premedia technology and processes
  Color reproduction and color management; Image and reproduction quality; Image carriers (physical and virtual); Workflow and management
- Emerging media and future trends
  Media industry developments; Developing media communications value systems; Online and mobile media development; Cross-media publishing
- Social impact
  Environmental issues and sustainability; Consumer perception and media use; Social trends and their impact on media

Submissions for the journal are accepted at any time. If meeting the general criteria and ethic standards of scientific publishing, they will be rapidly forwarded to peer-review by experts of high scientific competence, carefully evaluated, selected and edited. Once accepted and edited, the papers will be printed and published as soon as possible.

There is no entry or publishing fee for authors. Authors of accepted contributions will be asked to sign a copyright transfer agreement.

Authors are asked to strictly follow the guidelines for preparation of a paper (see the abbreviated version on inside back cover of the journal). Complete guidelines can be downloaded from:

http://www.iarigai.org/publications/

Papers not complying with the guidelines will be returned to authors for revision.

Submissions and queries should be directed to:

journal@iarigai.org

Vol.6, 2017
Prices and subscriptions

Journal of Print and Media Technology Research
A peer-reviewed quarterly ISSN 2414-6250 (Online)

Starting newly in 2016, the journal is published in digital form.
A print version is available on-demand and at additional price.

Please, find below the prices charged for the Journal, as well as for a single paper. Use the opportunity to benefit from the Subscriber's discount price!

By ordering a publication, or by subscription a password will be provided to you for downloading. The password protection of every issue is active during a period of six months. After this period the publications will be available free of charge.

iarigai members will be given the download password free!

Regular prices

Four issues, digital JPMTR, (password protected)	300 EUR
Single issue, digital JPMTR, (password protected)	100 EUR
Single paper from JPMTR (pdf file)	20 EUR
Four issues, print JPMTR, (on-demand)	400 EUR
Single issue, print JPMTR, (on-demand)	100 EUR

Subscription prices

Annual subscription, four issues, digital JPMTR, (password protected)	240 EUR
Annual subscription, four issues, print JPMTR, (on-demand)	400 EUR

Prices for iarigai members

Four issues, digital JPMTR, (password protected)	Free of charge
Single paper from JPMTR (pdf file)	Free of charge
Four issues, print JPMTR, (on-demand)	400 EUR
Single issue, print JPMTR, (on-demand)	100 EUR

Place your order online at:

http://www.iarigai.org/publications (open: Order/Subscribe here)

or send an e-mail order to: journal@iarigai.org

Guidelines for authors

Authors are encouraged to submit complete, original and previously unpublished scientific or technical research works, which are not under review in any other journals and/or conferences. Significantly expanded and updated versions of conference presentations may also be considered for publication. In addition, the journal will publish reviews as well as opinions and reflections in a special section.

Submissions for the journal are accepted at any time. Papers will be considered for publishing if meeting the general criteria and ethic standards of the scientific publication. When preparing a manuscript for JPMRT, please strictly comply with the journal guidelines, as well as with the ethic aspects. The Editorial Board retains the right to reject without comment or explanation manuscripts that are not prepared in accordance with these guidelines and/or if the appropriate level required for scientific publishing cannot be attained.

A - General

The text should be cohesive, logically organized, and thus easy to follow by someone with common knowledge in the field. Do not include information that is not relevant to your research question(s) stated in the introduction.

Only contributions submitted in English will be considered for publication. If English is not your native language, please arrange for the text to be reviewed by a technical editor with skills in English and scientific communication. Maintain a consistent style with regard to spelling (either UK or US English, but never both), punctuation, nomenclature, symbols etc. Make sure that you are using proper English scientific terms.

Do not copy substantial parts of your previous publications and do not submit the same manuscript to more than one journal at a time. Clearly distinguish your original results and ideas from those of other authors and from your earlier publications - provide citations whenever relevant. For more details on ethics in scientific publication, please consult:

http:// www.elsevier.com/ethicguidelines.

If it is necessary to use an illustration, diagram, table, etc. from an earlier publication, it is the author's responsibility to ensure that permission to reproduce such an illustration, diagram etc. is obtained from the copyright holder. If a figure is copied, adapted or redrawn, the original source must be acknowledged.

Submitting the contribution to JPMTR, the author(s) confirm that it has not been published previously, that it is not under consideration for publication elsewhere and - once accepted and published - it will not be published under the same title and in the same form, in English or in any other language. The published paper may, however, be republished as part of an academic thesis to be defended by the author. The publisher retains the right to publish the printed paper online in the electronic form and to distribute and market the Journal (including the respective paper) without any limitations.

B - Structure of the manuscript

Title: Should be concise and unambiguous, and must reflect the contents of the article. Information given in the title does not need to be repeated in the abstract (as they are always published jointly).

List of authors: i.e. all persons who contributed substantially to study planning, experimental work, data collection or interpretation of results and wrote or critically revised the manuscript and approved its final version. Enter full names (first and last), followed by the present address, as well as the e-mail addresses.

Separately enter complete details of the corresponding author - full mailing address, telephone and fax numbers, and e-mail. Editors will communicate only with the corresponding author.

The title of the paper and the list of authors should be entered on a separate cover page (numbered as 0). Neither the title nor the names of authors can be mentioned on the first or any other following page.

Abstract: Should not exceed 500 words. Briefly explain why you conducted the research (background), what question(s) you answer (objectives), how you performed the research (methods), what you found (results: major data attained, relationships), and your interpretation and main consequences of your findings (discussion, conclusions). The abstract must reflect the content of the article, including all the keywords, as for most readers it will be the major source of information about your research. Make sure that all the information given in the abstract also appears in the main body of the article.

Keywords: Include three to seven relevant scientific terms that are not mentioned in the title. Keep the keywords specific. Avoid more general and/or descriptive terms, unless your research has strong interdisciplinary significance.

Abstract and keywords should be entered on a separate page, numbered as page 1. Do not continue with the main body of the text, regardless of the possible empty space left on this page.

Introduction and background: Explain why it was necessary to carry out the research and the specific research question(s) you will answer. Start from more general issues and gradually focus on your research question(s). Describe relevant earlier research in the area and how your work is related to this.

Methods: Describe in detail how the research was carried out (e. g. study area, data collection, criteria, origin of analyzed material, sample size, number of measurements, equipment, data analysis, statistical methods and software used). All factors that could have affected the results need to be considered. Make sure that you comply with the ethical standards, with respect to the environmental protection, other authors and their published works, etc.

Results: Present the new results of your research (previously published data should not be included). All tables and figures must be mentioned in the main body of the article, in the order in which they appear. Do not fabricate or distort any data, and do not exclude any important data; similarly, do not manipulate images to make a false impression on readers.

Discussion: Answer your research questions (stated at the end of the introduction) and compare your new results with the published data, as objectively as possible. Discuss their limitations and highlight your main findings. At the end of Discussion or in a separate section, emphasize your major conclusions, specifically pointing out scientific contribution and the practical significance of your study.

Conclusions: The main conclusions emerging from the study should be briefly presented or listed, with the reference to the aims of the research and/or questions mentioned in the Introduction and elaborated in the Discussion.

Introduction, Methods, Results, Discussion and Conclusions - as the scientific content of the paper - represent the main body of the text. Start numbering of these sections with page 2 and continue without interruption until the end of Conclusions. Number the sections titles consecutively as 1, 2, 3 ..., while subsections should be hierarchically numbered as 2.1, 2.3, 3.4 etc. Use Arabic numerals only.

Note*: Some papers might require different structure of the scientific content. In such cases, however, it is necessary to clearly name and mark the appropriate sections.*

Acknowledgments: Place any acknowledgments at the end of your manuscript, after conclusions and before the list of literature references.

References: The list of sources referred to in the text should be collected in alphabetical order on a separate page at the end of the paper. Make sure that you have provided sources for all important information extracted from other publications. References should be given only to documents which any reader can reasonably be expected to be able to find in the open literature or on the web. The number of cited works should not be excessive - do not give many similar examples. Responsibility for the accuracy of bibliographic citations lies entirely with the authors.

Please use only the Harvard Referencing System. For more information consult, e. g., the referencing guide at:

http:// libweb.anglia.ac.uk/referencing/harvard.htm.

List of symbols and/or abbreviations: If non-common symbols or abbreviations are used in the text, you can add a list with explanations. In the running text, each abbreviation should be explained the first time it occurs.

Appendix: If an additional material is required for better understanding of the text, it can be presented in the form of one or more appendices. They should be identified as A, B, ... etc., instead of Arabic numerals.

Above sections are supplementary, though integral parts of the Scientific content of the paper. Each of them should be entered on a separate page. Continue page numbering after Conclusions.

C - Technical requirements for text processing

For technical requirement related to your submission, i.e. page layout, formatting of the text, as well of graphic objects (images, charts, tables etc.) please see detailed instructions at http:// www.iarigai.org/publications/journal.

D - Submission of the paper and further procedure

Before sending your paper, check once again that it corresponds to the requirements explicated above, with special regard to the ethic issues, structure of the paper as well as formatting. Once completed, send your paper as an attachment to: **journal@iarigai.org**. You will be acknowledged on the receipt within 48 hours, along with the code under which your submission will be processed. The editors will check the manuscript and inform you whether it has to be updated regarding the structure and formatting. The corrected manuscript is expected within 15 days. At the same time the first (or the corresponding) author will be asked to sign and send the Copyright Transfer Agreement.

Your paper will be forwarded for anonymous evaluation by two experts of international reputation in your specific field. Their comments and remarks will be in due time disclosed to the author(s), with the request for changes, explanations or corrections (if any) as demanded by the referees. After the updated version is approved by the reviewers, the Editorial Board will consider the paper for publishing. However, the Board retains the right to ask for a third independent opinion, or to definitely reject the contribution. Printing and publishing of papers once accepted by the Editorial Board will be carried out at the earliest possible convenience.

4-2016

Journal of Print and Media Technology Research

A peer-reviewed quarterly

The journal is publishing contributions in the following fields of research:

- Printing technology and related processes
- Premedia technology and processes
- Emerging media and future trends
- Social impacts

For details see the Mission statement inside

JPMTR is listed in

Index Copernicus International
PiraBase (by Smithers Pira)
Paperbase (by Innventia and Centre Technique du Papier)
NSD – Norwegian Register for Scientific Journals, Series and Publishers
ARRS, Slovenian Research Agency List of Scientific Journals

Submissions and inquiries
journal@iarigai.org

Subscriptions
office@iarigai.org

More information at
www.iarigai.org/publications/journal

Publisher
The International Association of Research Organizations for the Information, Media and Graphic Arts Industries
Magdalenenstrasse 2
D-64288 Darmstadt
Germany

Printed in Slovenia by Collegium Graphicum, d. o. o. Ljubljana