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WEB PLATFORM FOR COLLABORATION AND MEDICAL CASE DOCUMENTATION

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Abstract:
Creating medical applications of additive manufacturing (AM) is a complex multidisciplinary process. There is a need to examine this process in more detail to understand it better, which is crucial for its further development. The objective of this study was to investigate the design and production process of medical applications of AM and to develop an online platform for the documentation and planning of medical application of AM cases. The study was motivated by the fact that the medical applications of AM field is lacking a comprehensive classification standard and a process model which depicts the design and manufacturing process. A web platform would enable professionals to collaborate meaningfully on this complex and multidisciplinary subject. The online platform was developed by using Drupal content management system and PHP programming. The result was a dynamic web platform where users can view and document case studies using the designed matrix framework and communicate and collaborate with other professionals in the field.

Key words:
Additive Manufacturing
Medical Applications of Additive Manufacturing
Web Platform
Multidisciplinary Collaboration
Medical Case

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1. Introduction

Additive manufacturing (AM) was developed from industrial setting to produce implants, prostheses, tools and other medical applications. The production process has many steps requiring multidisciplinary expertise, and many actors are involved in the process. It draws resources from medical imaging, information technology, design and manufacturing, tooling, biomaterials and bioengineering. (Marciniec & Miechowicz, 2004) (Abbaszadeh et al., 2010)

Currently there are not many resources available where one can find well-documented information about medical applications of AM. Best practices in many cases are not known and technologies that could be used for medical applications are continuously developing. A global platform where professionals can find historical case information and be introduced to the newest technologies in the field would make it possible to bring out new ideas to a broader audience and these ideas could then be developed further collectively.

Also, communication between medical professionals and AM professionals is an undeveloped area, which limits the possible novel innovations of AM for medical applications. One main goal of this paper is to introduce the reader to the web platform and process framework developed by the Integrated Design and Manufacturing (IDM) research group. It is a platform for documentation and communication of medical applications of AM. If communication can be increased and developed it will hopefully enable better collaboration between various actors in the field. Also, when AM becomes more popular in medical applications, this web platform works as a tool to recognize the processes that are involved in different medical cases and it can help the involved professionals to realize more clearly the potential of medical applications of AM.

2. Methodology

This study applied a constructive research approach involving an innovative solution to a real-world problem. Even though the general steps in the process were known, it was not clearly known how different technologies used in each step would affect the production process and the application quality in general. Our aim was also to create clear definitions for each process step and to find out the critical information to be documented in each phase of the project.

3. Classification for Medical Applications of Additive Manufacturing

Medical applications can be divided into five categories in additive manufacturing context. (Tuomi et al., 2009)

3.1 Preoperative Models
Already since 1980s preoperative models have been used for Maxillofacial, Ear Nose and Throat, and Orthopedic applications when manufactured using the five-axis CNC machines. These systems have limitations for example in terms of undercuts and thin cross sections. Introduction of additive manufacturing (formerly called as rapid prototyping) eliminated these shortcomings. (Hieu et al., 2005)

Preoperative models are anatomically correct representations of a region of the human body, and they are most commonly used in complex surgical procedures to ease the planning process. An actual, haptic model facilitates the diagnosis of the problem and simplifies the study of the shape, location and size of an anatomic structure. Different qualities of the model such as anatomical accuracy, material characteristics or haptic response of the implants can become important depending on the application. Further, these models can be used in many phases of surgery. They make it possible to examine the defected area from any angle which reduces ambiguity, and makes communication of the problem and its solution easier. (Marciniec & Miechowicz, 2004) (Tuomi et al., 2009)

3.2 Medical Aids, Supportive Guides, Splints & Prostheses

Improvements in Computed Tomography (CT) technology have enabled more precise imaging. In addition, the reduction in costs of imaging and AM processes have made it possible to produce patient-specific devices that enhance the management of trauma, anomaly or tissue defect. In this class AM technology is utilized for personalization of a device or corresponding element. One example is the manufacturing of prosthetic sockets which is a labor intensive task using traditional methods but can be accomplished in less than 4 hours using CAM systems and AM (Ng et al., 2002). Examples of this class are external prostheses and prosthetic sockets and personalized splints. (Tuomi et al., 2009)

3.3 Tools, Instruments & Parts for Medical Devices

Surgical tools are important to enhance the surgeon’s skills during the operation. Drill guides are an example of these tools as they can increase safety, reduce operation and overall costs, and enhance the outcome of the surgery. (Hieu et al., 2005) Operation specific instruments, tools and hardware for medical applications belong to this class. (Tuomi et al., 2009)


3.4 Inert Implants

The possibility to manufacture anatomically accurate implants before operation not only make it possible to have extremely well fitting implants but it may also decrease operation time significantly. (Marciniec & Miechowicz, 2004)

Traditionally, implants have been manually bent and shaped with the help of anatomic solid models. With medical imaging data and CAD/CAM software it is now possible to design accurate, patient specific, implants prior to operation. An example, which also is found on the present web platform, is an orbital wall reconstruction case where a patient specific orbital implant (titanium reconstruction plate) was designed and manufactured prior to operation. (Salmi et al., 2012)

3.5 Biomanufacturing

Research efforts in tissue engineering have been accumulating during the past years. In the future, it may be possible to regenerate or replace damaged tissue with laboratory grown tissue components. At the moment, applications in this class include biologically compatible parts and components to be used in manufacturing these targets. Examples are AM produced scaffolds that can be used as a skeleton and as an optimal 3D structure on which cells can grow. (Hutmacher, 2005) (Hieu et al., 2005) (Tuomi et al., 2009)

4. Introduction to Process Phases

The general process of AM for medical applications is well known but each process phase should be examined and described in more detail. This study defines each process step and investigates which technologies can be used in each step of the process. This will enable finding all the relevant technologies for each process phase and understanding which information should be documented. Documenting relevant information, such as technologies and technology specific attributes/parameters, will also help to examine medical application cases, to compare them, to find best practices and to make the process of producing medical applications more efficient.

4.1 Medical Imaging & 3D Digitizing

In order to design and manufacture a model of human anatomy its digitization has to allow computers to process the information. A number of scanning technologies can be used ranging from imaging machines in the radiology department to laser scanners in laboratories, doctors’ offices or bedside. (Bibb 2006) Imaging technologies, especially CT, seem to be the most common way to acquire anatomical, three-dimensional information in medical cases.

We can group Medical imaging & 3D digitizing technologies in three categories: (modified from Galantucci, 2010)
- Based on transmission  
  o For example, conventional X-ray, Magnetic Resonance Imaging (MRI), Computed Tomography (CT)
- Based on contact  
  o For example, Coordinate Measuring Machine (CMM)
- Based on reflection  
  o For example, laser scanner

Second subcategory in Medical Imaging & 3D Digitizing process step is commercial machines, which could mean, for example, Philips CT 64-Channel Scanner. Documenting this information is important because imaging machines may have crucial variations depending on the manufacturer and machine type.

Third subcategory, attributes/parameters, documents most critical input information of the machine. For CT scanners, the information that is documented includes slice thickness, voltage, tube current, overlap, field of view and matrix size. All this information might not be available when documenting a medical case but more information can be gathered along the process.

4.2 3D Modeling

3D modeling is a process of creating 3D surface models from 2D imaging slices. Documented information in this step includes reconstruction software, Hounsfield (HU) value and CAD/CAM software. Reconstruction usually means thresholding and region growing after which three-dimensional images of the selected data can be produced (Bibb 2006). Hounsfield scale is a quantitative scale describing radiodensity. After reconstruction and having the file in STL format, it can be imported into CAD/CAM software where additional adjustments can be made to the 3D image.

4.3 Additive Manufacturing

AM process step describes technologies, materials and actors that are involved in production of a physical piece. The documented information are AM technology, AM commercial machine, AM supplier, AM material type, AM commercial material and layer thickness.

4.4 Finishing

After the physical piece is manufactured it might need finishing. This can include actions, such as removal of supporting structures, or polishing of the surface. In medical applications the surface treatment methods or sterilization methods used are of special interest.
4.5 Clinical Application

The last step in the process flow is the **Clinical Application** which describes the desired purpose of the application.

5. The Web Platform

A web platform was designed in accordance with the aforementioned classifications and process steps. The purpose of this web platform is to be a source of information and to enable connectivity, collaboration and communication. It can also be regarded as an educational tool that can be used when trying to understand the production of medical applications of additive manufacturing.

Practical examples of applying this platform:
- Representative case studies aid as example cases in the beginning phase of designing and developing medical applications of AM.
- Researchers can promote their research and innovations and get feedback.
- Information about medical applications is quite scattered. Various disciplines might find abbreviations and field specific vocabulary confusing. A Unified terminology can be developed to tackle this problem.
- A comprehensive database of professionals and companies working in this field will enable easier regional or global collaboration on new cases.

5.1 Structure of the Web Platform

The site can be divided roughly in four sections. Information about the process and classification matrix (1); case, article and content search (2); case, article and content creation (3); forum and collaboration tools (4). Figure 1 shows the front page of the platform.
5.2 Case Modeling

The medical case pages are the core and the most valuable information on the web platform. The idea of the case modeling is to be able to present all case specific information in a logical one-page format that helps the user to understand the design and production process of medical applications. An example case is a 67-year-old patient who had a difficult facial trauma. The matrix framework depicted in Figure 2 shows the process steps implemented and the classifications for each application. In this case the patient needed an orbital reconstruction plate which was manufactured from titanium and implanted onto injured orbital wall of the patient. (Salmi et al., 2012)
The matrix shows that a preoperative model was manufactured by taking a CT scan of the patient’s orbital area (slice thickness 1.25mm), using reconstruction and CAD/CAM software (Osirix and VisCAM) to produce a 3D model and a piece was then manufactured by selective laser sintering (SLS). (Salmi et al., 2012) This physical model was used preoperative to plan the implant and the surgery.

After planning, a model of the titanium implant was designed using CAD/CAM software (3Data Expert and Rhinoceros) and manufactured using direct metal laser sintering (EOSINT M270). Finally, the orbital reconstruction implant was placed onto the inferior wall and fixed to the bone with two screws. (Salmi et al., 2012) More detailed information about technologies and in depth explanation of different process steps can be found on the web site.

Visualization was recognized as a key component in case presentation. Depicting the design and production process with relevant pictures of the different phases makes understanding the case explanation much better.
5.3 Medical Case Creation

The creation of medical cases is at the moment limited to the administrators of the web platform. However, as the target is to increase communication, content creation possibilities will be available as the next stage of the process. This will enable users to contribute to the community and have their work presented on the site.

5.4 Article Database and Search

Integrated Design and Manufacturing research group has compiled a reference list of articles related to medical applications of AM. These references are classified according to the aforementioned five classes and can be found using the search tools on the website. The idea is to grow the database of articles to serve as a practical way to find relevant and up to date information about medical applications of AM.

<table>
<thead>
<tr>
<th>Content type</th>
<th>Classifications</th>
<th>Search terms</th>
<th>Search by year</th>
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<tbody>
<tr>
<td>Article</td>
<td>1. Preoperative models</td>
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<td></td>
<td>2. Medical Ads, Supportive Guides, Splints &amp; Prostheses</td>
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<td></td>
<td>3. Tools, Instruments &amp; Parts for Medical Devices</td>
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<td>4. Inert Implants</td>
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<td></td>
<td>5. Biomanufacturing</td>
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Percutaneous cochlear implant drilling via customized frames: An in vitro study

Otolaryngology-Head and Neck Surgery (2010) 142-426

Rapid development of medical imaging tools with open-source libraries

Caban, J J, Joshi, A, Nagy, P.

[Keywords]: Image processing, Open source, Programming language

Fig. 3. Article search page.

6. Future and Collaboration Possibilities of the Web Platform

At this point the website serves in distributing information about medical applications of AM to medical professionals and engineers. The growing awareness of the presented website has potential to increase the real-time connectivity of this specific community. Gathering more case data and relevant research content will increase the attractiveness of medical applications of AM and aid building a global online community.

The next phases of this development include productivity tools that help users to present innovative ideas and share research data. The ultimate goal is to transform the site to a knowledge-based-system. Moura, Bártolo and Almeida (2010) define a knowledge-based-system as a computational tool that uses human knowledge and computer power to solve complex decision making problems that normally require human intelligence and expertise. This system could guide the team making medical applications of AM through the process and give further guidelines. Therefore, a
large database including different cases, best practices, best materials and technologies for specific tasks is needed. Also, there are quite significant regional differences in regards of AM resources and clinical techniques which will affect the applicability of some case approaches.

To create global impact we need to build active dialogue and transparency in the AM community to build trust and to enhance collaboration. We invite an open discussion in the development of the presented platform acknowledging the needs of the community. This is a truly interdisciplinary field with many challenges that need to be addressed, as the range of medical applications of AM continues to accumulate.

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8. References


