Case Study

ADDITIVE MANUFACTURING APPLICATION WITHIN INDUSTRY 4.0 IN HEALTHCARE

Keywords: *Additive Manufacturing, 3D printing, Industry 4.0, Healthcare*

Background to Case Study

Additive Manufacturing (AM), also called 3D printing (3DP), is a general term for a set of technologies that can build three-dimensional objects from a digital file by adding material layer after layer. It is a vital component and enabler of Industry 4.0. that allows SMEs to improve cost-efficiency of unique parts or low-volume production, to manufacture very complex object shapes, to easily customise their products, to offer advanced services, etc. Some characteristics of AM are particularly beneficial for SMEs granting them the ability to grow within Industry 4.0 and to enter highly rewarding markets, such as healthcare industry.

There is an increasing need of 3D printed products in healthcare industry, in order to provide doctors and patients with medical devices such as patient-specific 3D models, surgical guides and custom implants. SMEs can deliver these in a fast and cost-effective manner by taking advantage of the developments in AM technologies and materials.

This case study presents a SME that leverages AM in order to produce customised medical devices.

Introduction to the Case Study and it's growth within Industry 4.0.

The application of AM supports the growth of the SME under study (3Dific, www.edific.it) by enabling it to produce customised 3D printed models of human organs from patient's medical data imagery. These models are used by surgeons for training and surgical preoperative planning and intraoperative guidance in surgery.

The healthcare sector is currently transformed by Industry 4.0 and its underlying technologies. Among these, AM can be employed to manufacture unique and very complex objects, in a short time and at reasonable costs. 3D printers are an important part of the data flow that may include digital medical imaging equipment (i.e., radiography (X-rays), magnetic resonance imaging (MRI), computed tomography (CT), etc.), CAD/CAM software, data processing instruments, and simulation tools.

This case study shows how a SME is using digital medical data and AM technology to offer valuable services in the healthcare sector.

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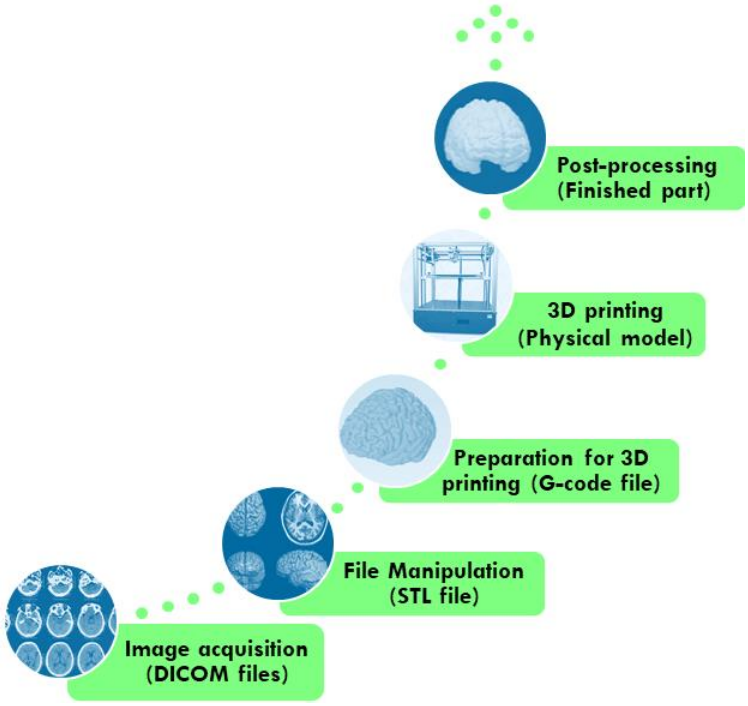
The Case Study and Industry 4.0 Elements: A Pictorial Overview

Patient-centred preoperative planning is needed to achieve precise knowledge of the target anatomy and to help surgeons during critical steps and potential complications. AM is a very useful tool for this planning as it can produce exact replicas of the relevant anatomy, based on patient's medical imaging information.

Digital Imaging and Communications in Medicine (DICOM) is the international standard to transmit, store, retrieve, print, process, and display medical imaging information [1]. In order to 3D print DICOM images, it is necessary to perform a series of data manipulations, such as segmenting the anatomical structure of interest from surrounding structures, noise removal, hole correction and conversion to a 3D printing file format.

The workflow for additive manufacturing of medical models includes the following steps:

1. *Image acquisition. DICOM files from Magnetic resonance imaging (MRI), Computed tomography (CT), etc.*
2. *File manipulation*
   - *Image segmentation*
   - *DICOM to STL file conversion*
3. *Preparing the model for AM – check and repair the STL file, model positioning, parameters setting, addition of support structures (if necessary), model slicing and generation of the G-code file*
4. *Additive manufacturing*
5. *Post-processing of the model*



The AM workflow. Image source: Ludor Engineering

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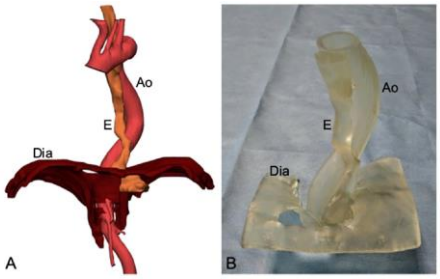
ADDITIVE MANUFACTURING APPLICATION WITHIN INDUSTRY 4.0

The Element Explored within Industry 4.0 Application.  *Image source: https://www.edific.it/*  *Image source: [3]*	*3Dific (www.edific.it) is an Italian innovative small enterprise, founded on 2015, specialised in research and development related to medical 3D imaging and 3D printing. It produces replicas, patient-specific devices and personalized tools using digital medical image data (DICOMs) obtained from MRI, CT, etc. The company works with some important Italian hospitals and it is also involved in medical research.* *3Dific receive DICOMs from the hospitals or doctors and manipulate them in order to reconstruct the 3D shape of the area of interest. The process is called data segmentation and it is completed using specialised software and skills. The final result is a printable 3D model.* *The 3D model is manufactured on a 3D printer. The company uses several AM technologies for the production of medical models, including Stereolithography (SLA) and MultiJet Printing (MJP).* *The 3D printed models are then delivered to the hospitals and the doctors are using them for various purposes: training, surgical planning, better communications with patients about their condition, intraoperative guidance in surgery, etc. The models can also be used to design the post-operative care and to evaluate the possible issues that the patient may have longer term.*
Application Target Audience	*The results of the case-study are intended for use by SMEs and entrepreneur subjects.*
Resources Used:	*https://www.edific.it/* *https://www.linkedin.com/company/3dific/*
Further Reading:	*1. https://www.dicomstandard.org/* *2. Kamio, T., Suzuki, M., Asaumi, R. et al. DICOM segmentation and STL creation for 3D printing: a process and software package comparison for osseous anatomy. 3D Print Med 6, 17 (2020). https://doi.org/10.1186/s41205-020-00069-2* *3. Marano L, Ricci A, Savelli V, Verre L, Di Renzo L, Biccari E, Costantini G, Marrelli D, Roviello F. From digital world to real life: a robotic approach to the esophagogastric junction with a 3D printed model. BMC Surg. 2019 Oct 25;19(1):153. doi: 10.1186/s12893-019-0621-6.*

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