3D MODELLING AND MANUFACTURING RESEARCH ACTIVITIES AT THE TEI OF CRETE

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1. ABSTRACT

CNC Machining and Prototyping Laboratory works under joint partnership schemes, bringing together business as well as academic institutions. This approach aims at maximizing results, with the understanding that targeted research is an expensive exercise which requires access to research facilities and highly specialized researchers that may exist only in an academic environment. It aims in adding value to a number of selected thematic areas, such as 3d modelling, reverse engineering and micro mechanics. Laboratory carries out projects and activities mainly within research programmes framework. This paper aims at presenting the operational abilities as well as the research achievements of this laboratory and its staff.

Keywords: 3d printing, 3d modelling, 3d scanning, computer aided design, computer aided manufacturing, computer aided engineering, computer numerical control machining

2. INTRODUCTION

Since its inception in 1983 the Technological Educational Institute (TEI) of Crete [1] has grown exponentially both in terms of size, academic achievement and ranking, and is now playing an important role both in higher education as well as in research for industry. The TEI of Crete intends to work in partnership with academia and industry to develop and implement high quality higher education programmes both at an undergraduate and a postgraduate level, as well as to develop technologies that will unite the people from the European Union together with our neighbouring countries in the east Mediterranean area.

The CNC Machining and Prototyping Laboratory of the Mechanical Engineering Department was established in 2008 by the TEI of Crete in partnership with European and private funding.

The facilities it has in the TEI of Crete cover an area of 500 m^2 (Fig. 1), and its equipment are the most recent in their field. The vast majority of them were acquired in 2008. It has a facility with 30 computer stations to design and develop products, which run specialized computer aided design (CAD) [2], computer aided manufacturing (CAM) [2] and computer aided engineering (CAE) [3] professional applications. On top of that, the laboratory has all the necessary facilities to support various research and business projects.

Figure 1.
The laboratory main room

In brief the research technology areas that can be supported are:

- Design and development of new products
- Support any activities in the “3d scanning – 3d modelling – 3d printing – rapid tool making” processes chain
- High precision mechanical processes

Most of the potential users of this lab's services fall into one of these categories:

- Medical engineering
- Industries, which require the production and copying of prototypes, the manufacture of metal casting moulds for plastic and metal parts, jewellery, souvenirs etc or the production of precision parts, items and spare parts with complex geometries and axisymmetric geometries
- Work in large scale research and development projects in areas where there is a competitive advantage and added value opportunities.

This work is focusing on the research activities and achievements of the laboratory, which are in three, interacting with each other, areas, described in detail below.

3. LABORATORY RESEARCH AREAS

3.1 Three dimensional geometric modelling

This research activity provides support to all of the laboratory's activities, as it processes the necessary digital data necessary for its works. It employs several advanced industrial design techniques, which ensure the conformity of three dimensional design models to the requirements of international standards (ISO, EN, DIN, etc.), the application of geometric, functional and aesthetic limitations, and the use of advanced materials technologies together with the necessary cost estimation for each designed part or product. This is achieved using the necessary software tools for computer aided activities, such as designing and manufacturing (CAD, CAM), which have strong design and simulation capabilities.

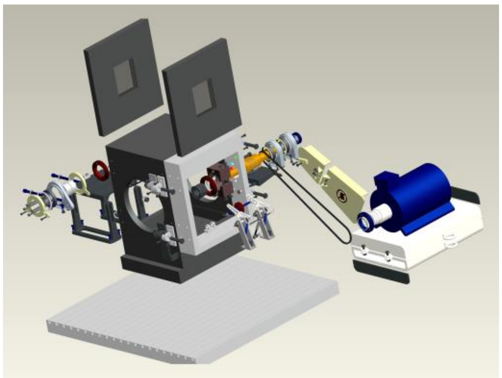


Figure 2.
3D geometric model of a device developed by the laboratory for a research project related to the characterization of porous materials (student Froudarakis Kostas research project)

Advanced numerical techniques (computer aided engineering – CAE) are also employed to simulate the functional behaviour of parts with the finite element analyses (FEA) method [4]. These software tools can model any field, such as mechanical stresses, deformations, plasticity, fatigue, crash conditions, aerodynamic behaviour, hydrodynamics, electromagnetic fields, thermal conditions etc. In addition to the above it has the ability to document and protect the intellectual work arising from such research and development activities. In this context, it can provide the necessary documentation (drawings, descriptions) in the appropriate form for patent applications. It is the most important stage in documenting development, as the researchers or inventors are not familiar with the intricacies of such procedures.

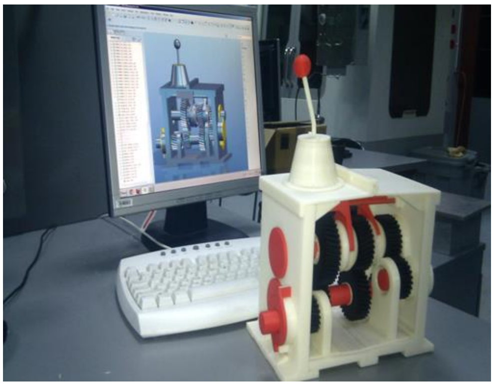
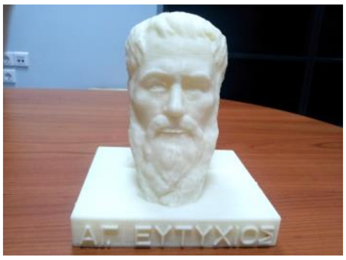


Figure 3.
CAD 3d geometric model and 3d printing prototype of a fully functional gear box (student Papadopoulos Alex diploma project)

3.2 Reverse Engineering

Reverse engineering [3] combines the technology necessary under which an existing product or device can be used to design and manufacture an identical, similar or completely different prototype. The geometry of an existing physical item is scanned by a laser scanner creating a cloud of points in space. Using the appropriate software for reverse engineering, this cloud of points is transformed into a digital file and then is processed with a CAD programme to make a copy of the original, a modified version of it or a completely new version of the item. Following this the digital geometric model can be downloaded to the 3d printer to make an identical copy to the original (Fig. 3). The prototype that the 3d printer makes is a fully functioning prototype, and can to be used straight away as the final product. In addition, it can be used for casting, therefore producing products in small quantities, or from different plastic materials (Fig. 4). This technology supports a wide range of plastic materials, from soft to very hard ones. Additionally, it can produce an item in different colours. Depending on the requirements of the application it may need to have a few more steps that those described here. For example, one product may need just a single prototype to validate the design, for functional verification or using it as the final product, while another product may need to produce castings for production.



(a) 3d printed model

(b) Silicon mould

(c) Plastic model

Figure 4.
Vacuum casting Saint Eutuxios project

3.3 Leptomechanics

Numerical control [5] is the basis of many modern engineering processes and machinery. It provides the ability for the operator to communicate with the machine and control it using a programme, i.e. a sequence of letters and numbers. This code replaces the individual manual processes done by the operator, with software that is done automatically, with the greatest accuracy possible and the ability to continuously produce the same items. The numerically controlled machines can produce products of complex geometries with very good tolerances and surface finish. The multi axis movement can produce complicated surfaces in 3D space. For example, a CNC milling machine can make [6]:

- Flat surfaces, product outlines, inlets, grooves, hollow surfaces, threads, gears, helical surfaces, freeform surfaces, among others

These capabilities make milling machines ideal for the making of

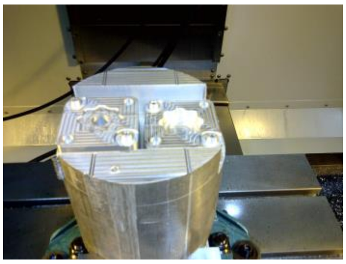
- Parts, customized machinery, tools, moulding casts

The wider the number of the milling machine's axis, the more complex geometry it can mill, therefore reducing the number of necessary fixed points.

Similarly, in a CNC lathe items that can be produced are [6]:

- Axisymmetric objects, flat and hollow surfaces, grooves, holes, conical surfaces, threads and other geometries

(a) Spearfishing gun handle mould
(student Kargatzis Nikos diploma project)



(b) Knob mould (student Kotrogiannis Dimitris diploma project)

(c) Robotic arm part (student Roza Gkliva research project)

Figure 5.
CNC parts manufactured in the laboratory

The Leptomechanics section of the laboratory can produce high precision items using a 4 axis manufacturing centre. This advanced machine works together with a 3 axis CNC milling machine centre. These machines can make extremely complex items for teaching, research or production purposes with the precision of a few micrometres (Fig. 5). This section can also make high quality items by turning, using a CNC lathe centre with two plus two axes. This can provide high added value in teaching and research activities, as it can produce axisymmetric items with the necessary high tolerances necessary in difficult applications, such as high vacuum devices (eg in laser applications, in ceramic coatings) or extremely high vacuum device used in physical or chemical processes.

(a) Small size 3d printed parts

(b) Large size 3d printed part

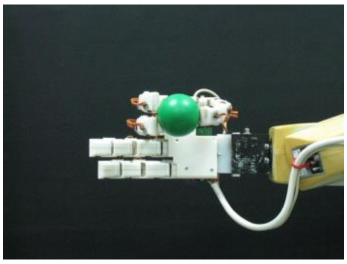
Figure 6.
From small to large parts; they are all build with the same 3d printing method and machine in the laboratory

4. LABORATORY RESEARCH PROJECTS AND ACTIVITIES

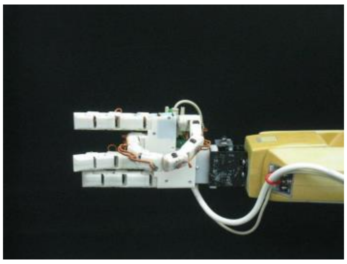
Laboratory research projects and activities in most cases combine 3d geometric modelling with either reverse engineering or leptomechanics. Most of the projects so far are in the areas of developing and manufacturing mechanisms for research projects, the laboratory is participating. Most of the parts in the mechanism shown in Figure 1. were manufactured in house.

Most of the parts the laboratory develops nowadays are manufactured with the use of the 3d printing technologies and only the metal parts are manufactured with the CNC machines. This is because of the ease of use of the technology, which doesn't require codes programming, specialized tools and significant technical knowledge, to build a part.

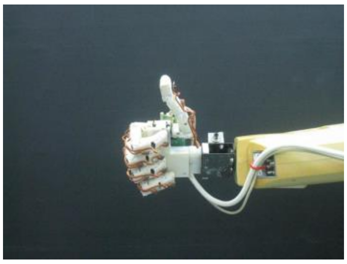
Also, 3d printing technology is capable of providing the part faster than any other method in most cases, as the build time is related mainly on the part size and not on its complexity, which is the main parameter for increasing the manufacturing time in any conventional production method. For these reasons it has been used for the build of very small to very large parts (Fig. 6).



(a) 3d printed robotic hand grasping test



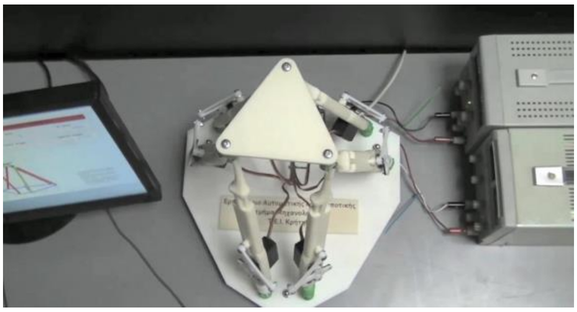
(b) 3d printed robotic hand accuracy test



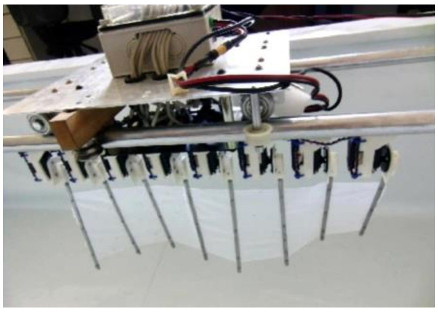
(c) 3d printed robotic hand gesture test

Figure 7.
3d printed robotic hand
(students Konstandoudakis Ioannis, Kritsotakis Nikos diploma project)

The 3d printing technology started as a technology to build prototypes of products, as the fully functional gear box shown in Figure 3., which is entirely build with this technology and has about 170 parts in total. Nowadays the technology has been used also to build fully functional parts for products and mechanisms. Several functional 3d printed parts have been built in the laboratory, most of them related to the robotics technology. Figure 7. shows a fully functional robotic hand, in which all the mechanical parts in the fingers and the palm are 3d printed. In the 3d printed plastic parts, the motors and the electronics are hosted. The major challenge of this project, was to design parts that can be assembled and have a size as closed as possible to the real thing and on the same time have the adequate shape to host the robotic hand mechanism and adequate strength to support the developed on the hand operating loads. This challenge is the most common on projects employing 3d printing as a technology for the manufacturing of the final product.



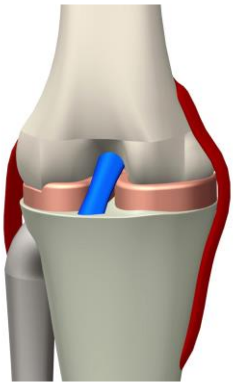
(a) 3d printed Steward Platform
(student Kalatzis Spiros diploma project)



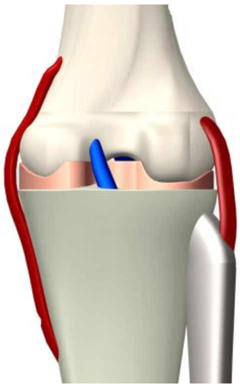
(b) 3d printed parts on a robotic boat
(Prof. Sfakiotakis Michalis research project)

Figure 8.
3d printed functional parts in laboratory robotic applications

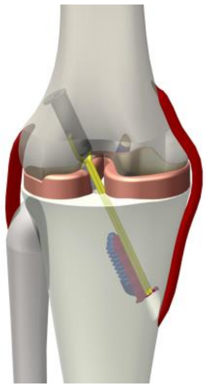
Figure 8a shows a fully functional 3d printed Steward platform. Steward platform is a robotic platform used in vehicle and airplane simulators. All the mechanical parts were built in the 3d printer. 8b shows a device developed for a research project. This device is robotic boat employing a propulsion system based on the locomotion mechanisms of sea organisms such as cuttlefish and rays. The advantage of such a propulsion system is its remarkable maneuverability, by propagating undulatory waves along their laterally placed elongated flexible fins. Such systems are employed mainly in unmanned underwater vehicles. The most complex parts of this mechanism were built with the 3d printing technology saving time and cost. The designers had the ability to experimentally test different design solutions a few hours after the geometrical model of each design solutions was completed.



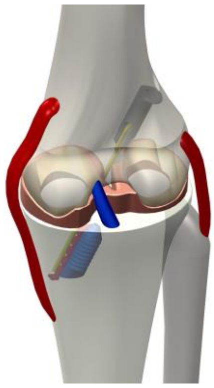
(a) Healthy human knee joint geometric model



(b) Healthy human knee joint geometric model



(c) Reconstructed human knee joint geometric model



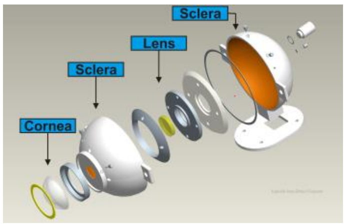
(d) Reconstructed human knee joint geometric model

Figure 9.
Human knee joint geometric model developed in the laboratory

Laboratory is highly involved in the biomechanics area, mainly with two different types of research activities. The first is the modelling and simulation of human joints in the computer, in order to study their kinematics and their mechanical behaviour. Figure 9. shows a human knee joint geometric model, developed to study its mechanical behaviour with the Finite Elements Analysis method. The purpose was also to study the mechanical behaviour of an ACL deficient human knee joint and a human knee joint reconstructed with a device developed and patented by the laboratory researchers. This FEA model is now experimentally verified.

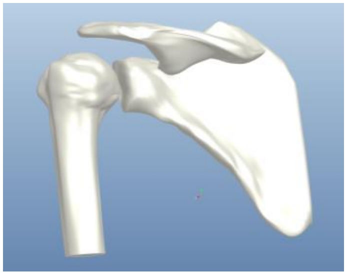
The second biomechanics research area is related with the 3d printing of the three dimensional geometrical models developed, so the doctors involved in each project can acquire information, not been able to validate with the geometric models in the computer. Figure 10. shows three different biomechanics projects and their 3d printing models.

Laboratory biomechanics research is focusing also to the anatomy of the human face. For the development of the 3d geometric model, patients are scanned with the laboratory 3d laser non contact scanner. Scanned data are converted to a geometric model in the computer and then in suitable 3d printing model. The 3d printing models are employed by the Plastic Surgeon for the evaluation of each surgical case and the design of the required surgical procedure. Figure 11. shows three different human face 3d printing laboratory projects.



(a) Human eye 3d geometric model

(b) Human eye 3d printing model



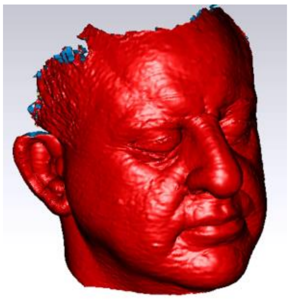
(c) Human shoulder 3d geometric model

(d) Human shoulder 3d printing model

(e) Human knee joint ACL deficiency reconstruction patented device

(f) Human knee joint 3d printing model

Figure 10.
Biomechanics 3d modelling and 3d printing models



(a) Visualization of the laboratory director Prof. Vidakis Nectarios (3d geometric model)

(b) Visualization of the laboratory director Prof. Vidakis Nectarios (3d printing model)

(c) Patient with nose abnormality 3d geometric model

(d) Patient with nose abnormality 3d printing model

(e) Patient with Parry Romberg syndrome (chick bone abnormality) 3d printing model

(f) Patient with Parry Romberg syndrome (chick bone abnormality) plastic mould model

Figure 11.
3d printing human face medical projects

5. DISCUSSION – CONCLUSIONS

Laboratory research activities are in different technological areas, but all have the same focus and content; developing parts and devices, study their behaviour, manufacture them and acquire information for them no other method can provide. Laboratory research activities usually support greater technology areas, but can also be the main result on each research project.

As it was shown in the presented projects, nowadays 3d modelling has been extended far beyond the idea of modelling in a drafting software tool, with the 3d scanning technology being able to provide geometries impossible to model with conventional modelling methods. Software tools nowadays are available for different modelling applications and can support almost any type of modelling project.

Working in research projects, customized parts and products development is always required, as well as taking into account specialized requirements, parameters, issues and technology. Each area has different parameters, to be considered. 3d modelling of a part that will be manufactured with 3d printing requires different design parameters to be taken into account from a part that will be manufactured with conventional methods.

In any type of project the only common parameter is the development of the 3d geometry, which is the most important parameter for a project to succeed.

6. REFERENCES

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