Chapter 1

Introductory Chapter: Integration of Computer-Aided Technologies in Product Lifecycle Management (PLM) and Human Lifecycle Management (HUM)

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Additional information is available at the end of the chapter

http://dx.doi.org/10.5772/66202

1. Introduction

The major objectives of computer-aided technology (CAx) are to simplify and to improve human's work (engineer, architect, physician, surgeon, etc.), by using the computer as an indispensable tool to solve a problem in a certain field (engineering and production, medicine, architecture, business, teaching, economy, etc.) [1].

The advanced computer-aided technologies (CAx) are focused on solving specific problems by increasing human's creativity and innovation obtained through collecting, using, and sharing information between interdisciplinary teams.

Computer-aided technologies in X field are general terms to define a technology, from a specific field of work, which is computed-aided. The substitute for X includes engineering (CAx-E), medicine (CAx-M), natural science (CAx-S), education (CAx-Ed), etc.

Nowadays, computer-aided technologies are not islands of automation, being integrated in general context of **Lifecycle Management in X field**. The concepts used to define the lifecycle management in engineering and medical field are the following (see **Figure 1**):

- **Product lifecycle management (PLM)** in the industry field
- **Human lifecycle management (HUM)** or **health management across the human lifecycle**

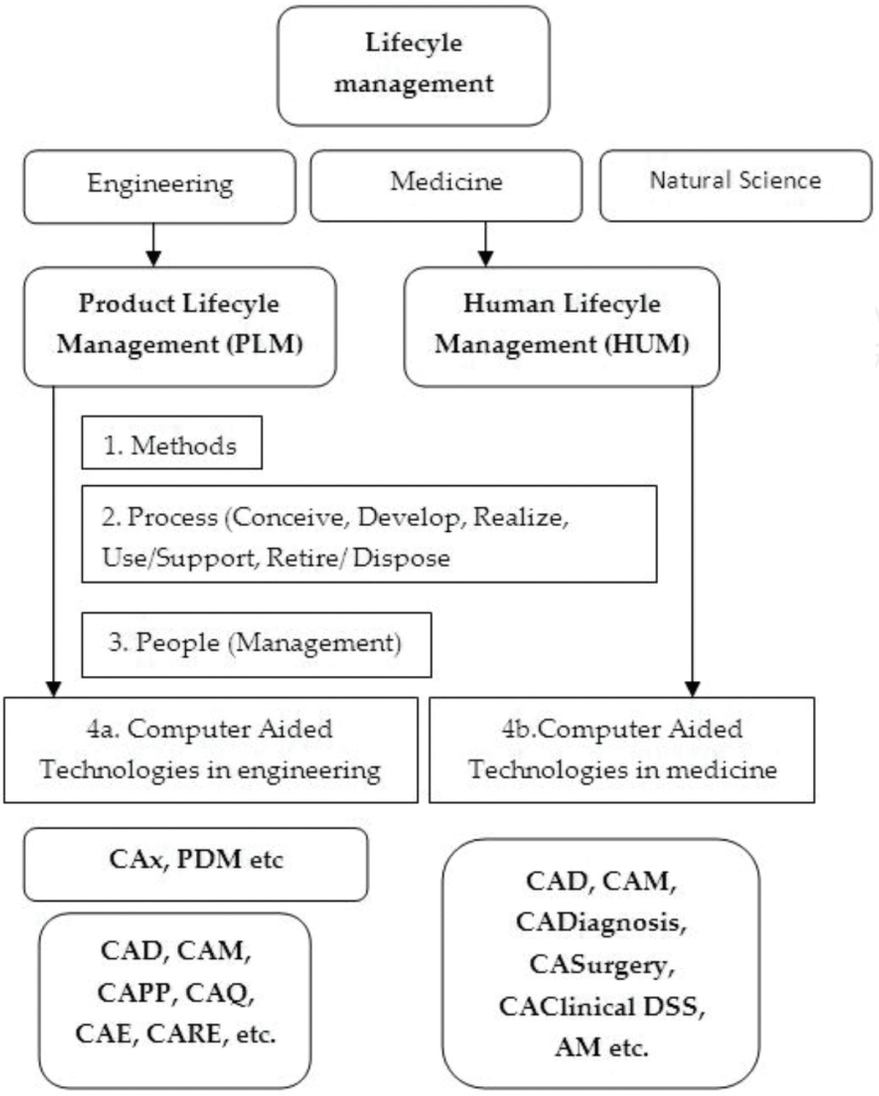

Figure 1. Schematic representation of lifecycle management in industry, medicine, and natural science.

2. Computer-aided technologies in product lifecycle management

Product lifecycle management (PLM) is the process of managing the entire lifecycle of a product including conception, design, manufacturing, quality control, use, service, and disposal of products, having integrated people, data, methods, CAx tools, processes, and business systems [2, 3]. PLM is a digital paradigm, products being managed with digital computer, digital information, and digital communication [3].

The main benefits of product lifecycle management (PLM) for the industry field are faster time-to-market, improved productivity, better product quality, decreased cost of new product introduction, improved design review, and approval processes, identifying potential sales opportunities and revenue contributions and reducing environmental impacts at end-of-life.

http://dx.doi.org/10.5772/66202

PLM emerged from tools such as CAD, CAM, and PDM, being viewed as the integration of these tools with innovative technologies (e.g., additive manufacturing, reverse engineering), methods, people, and the processes through all stages of a product's life [4].

To improve the product lifecycle management, a lot of methods and techniques are used [3] such as concurrent engineering, bottom-up design, top-down design, both-ends-against-the-middle design, design in context, design for X (DFX), TRIZ, lean production, design for six sigma (DFSS), total quality management (TQM), and failure mode effects analysis (FMEA).

Concurrent engineering [5, 6] or simultaneous engineering is a workflow that, instead of working sequentially through stages, carries out a number of tasks in parallel.

The most used design for X method is design for manufacture and assembly (DFMA) that is the combination of two methodologies: design for manufacture (DFM) and design for assembly (DFA), which mean the design of the parts for ease of manufacturing and the design of the product for ease of assembly.

Product data management (PDM) is the business function often within product lifecycle management (PLM) that is responsible for the management and publication of product data.

The tools used to access the information and knowledge regarding the product data are the computer-aided technologies (CAx). Computer-aided technologies (CAx) [7, 8] are the use of computer technology to aid in the design, analysis, production planning, manufacture of products, etc.

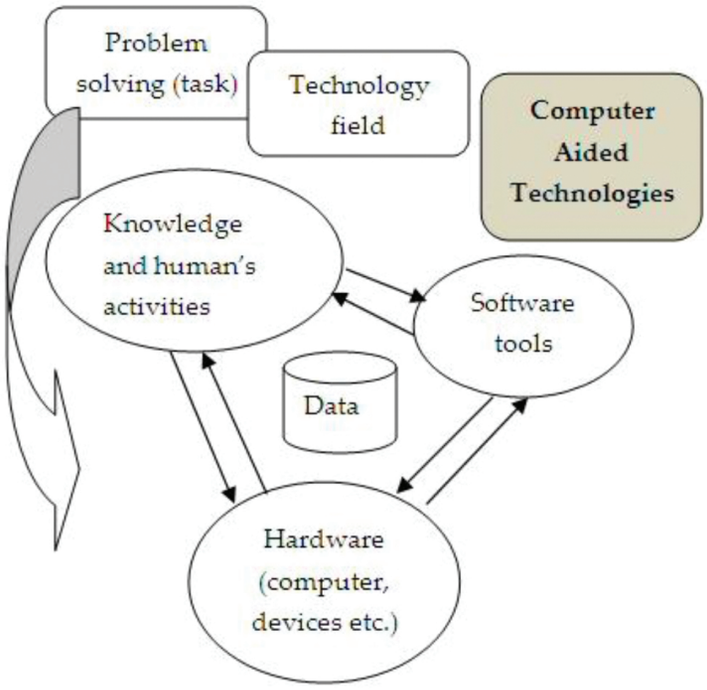

Figure 2. The main components of computer-aided technologies (CAx).

A CAx system can work like an "island of automation" or it can be integrated in the PLM system, interacting with other "islands of automation". Thus, the advanced CAx tools merge many different aspects of the product lifecycle management, including design, manufacturing, etc. CAx can be integrated, also, with other computational systems of management and planning of trials and output, such as MRP (material resource planning), ERP (enterprise resource planning), EDM (electronic document management), and PDM (product data management).

A CAx system may be defined, in generally, having the following main components (see **Figure 2**):

- Hardware component consisting in computer and interactive devices
- Software packages
- Data
- Knowledge and human's activities

Computer-aided design (CAD), computer-aided engineering (CAE), computer-aided manufacturing (CAM), computer-aided process planning (CAPP), and computer-aided quality assurance (CAQA) are the most known and mature computer-aided technologies.

Computer-aided design [1, 6, 9–12] is the computer-aided technology that involves the computer to assist in the creation, modification, analysis, and optimization of a design and design documentation.

Computer-aided engineering (CAE) [6, 9–12] is the computer-aided technology that involves the computer to analyze, simulate, and optimize the CAD geometry. CAE tools are available for a wide range of analyses: stress analysis, deformation, heat transfer, fluid flow, magnetic field distribution, kinematics, and dynamic analysis, etc.

Computer-aided manufacturing (CAM) [6, 9–12] is the computer-aided technology that involves the computer in planning, control, and management of manufacturing of any product. The most mature areas of CAM are the numerical control (NC) of the machine tools and programming of industrial robots that perform tasks as assembly, welding, etc.

The following are the most known commercial software tools for computer-aided technologies:

- CATIA by Dassault Systemes, Creo by PTC, NX by Siemens, PowerShape/ PowerMill by Delcam etc., in the field of CAD/CAM
- Materialise Magics and Netfabb Studio, in the field of 3D-printing/ additive manufacturing
- RapidForm and Geomagic in the field of computer-aided reverse engineering
- Ansys, Abaqus, COMSOL Multiphysics, Adams, LMS Virtual.Lab are focused on CAE

The computer-aided technology tools used in the engineering field are presented in **Tables 1** and **2**.

Computer-aided technologies	Remarks
CAx in engineering field	X=design, analysis, process planning, manufacturing, quality, innovation, etc.
CAD	Computer-aided design [6, 9–12].
CAM	Computer-aided manufacturing [6, 9–12]. *Software to control machine tools and related machinery in the manufacturing of workpieces*.
CAPP	Computer-aided process planning [9–12] *system is the bridge between CAD and CAM*.
CAE	Computer-aided engineering. *Software to aid the simulation of mechanical, strength, temperature, pressure, etc*.
FEA	Finite element analysis *is the practical application of the finite element method (FEM), which involves the use of numerical methods in structure analysis, dynamics, thermal analysis, etc*.
CFD	Computational fluid dynamics *uses numerical analysis and algorithms to analyze problems that involve fluid flows*.
MBDS	Multibody dynamics simulations.
CAQ	Computer-aided quality.
CAQA	Computer-aided quality assurance.
CAInsp	Computer-aided inspection.
CAI	Computer-aided innovation [13] *is an emerging domain in the array of computer-aided*.
CARE	Computer-aided reverse engineering [14] *has the aim to capture the geometry of an existing physical model, through digitization, and to create a 3D virtual model that is used then in different applications*.
CATAM	Computer-aided technologies for additive manufacturing. *Supporting the design, simulation and process planning for additive manufacturing*.
RapidX	RapidX [15, 16] *is a generic term for rapid technologies, e.g., rapid prototyping (RP), rapid tooling* (*RT*), *and rapid manufacturing* (*RM*) [17].
CADComposite	Computer-aided design in composite material technology.
CAMComposite	Computer-assisted manufactured composite [18].
CAMT	Computer-aided manufacturing technologies.
CAPE	Computer-aided production engineering [19].
CAMaintenance	Computer-aided maintenance.
CAMSE	Computer-aided manufacturing system Engineering [20]. *CAMSE is defined as the use of computerized tools in the application of scientific and engineering methods to the problem of the design and implementation of manufacturing systems*.
CAT	Computer-aided techniques for tolerance analysis computer-aided tolerancing [21].
CAAD	Computer-aided architectural design

Computer-aided technologies	Remarks
CAID	Computer-aided industrial design [22].
CAW	Computer-aided welding.
CAWFD	Computer-aided welding fixture design.
CAFD	Computer-aided fixture design [23].
CAMAP	Computer-aided mechanical assembly planning.

Table 1. Computer-aided technologies in engineering – terminology 1.

Integrated Cax in engineering field	Remarks
CADM	Computer-aided design and manufacture.
CAD/CAM/CAQ	Integrated CAD/CAM/CAQ system.
CIM	Computer integrated manufacturing [9–12] *has the purpose to tying "the separate islands of automation" together, including the computer-aided design, computer-aided planning, computer-aided manufacturing, and computer-aided quality assurance into an efficient system*.

Table 2. Computer-aided technologies in engineering – terminology 2.

The most known standards used in the product data exchange between computer-aided technologies systems are presented in **Table 3**.

CAD geometry translator standards	The neutral file format allows to exchange files containing 2D/3D product data models between different CAx software: **STEP** (standard for the exchange of product model data) is an ISO 10303-21 standard IGES (initial graphics exchange specification) DXF (drawing exchange format) **STL** (stereolithography, standard triangle language, or standard tessellation language) VRML (virtual reality modeling language) AMF (additive manufacturing file format) is an ISO/ASTM52915 standard [24]

Table 3. Standard exchange of product data used in computer-aided technologies.

Some terms, connected to computer-aided technologies, are shown in the **Table 4**.

Concepts	Remarks
PLM	Product lifecycle management [2, 3].
PDM	Product data management [2, 3].
PPLM	Product and process lifecycle management.
ERP	Enterprise resource planning.
DM	Digital manufacturing.
DF	Digital factory *is the foundation of the factory of the future, consisting in a digital mock-up of the factory*.
MPM	Manufacturing process management.
CPD	Collaborative product development.
DMU	Digital mock-up *is a concept that allows the description of a product, usually in 3D, for its entire life cycle*.
ICT	Information and communication technologies.

Table 4. Processes of managing and terms connected to computer-aided technologies.

3. Computer-aided technologies in health management across the human life cycle (human lifecycle management)

Medical technology is the type of technology which is used to extend and improve human life. Medical technology is used to diagnose infections, treat diseases, and to make research on diseases affecting humans. Computer-aided technologies play an important role in health management across the human life cycle. The main applications of computer-aided technologies in the medical field are the following:

- Computer-aided design (CAD)
- Computer-aided detection and diagnosis
- Computer-aided medical interventions or computer-aided surgery
- Computer-aided clinical decision
- Computer-aided simulation

CAD systems play an important role in medical applications, allowing to simulate and analysis, prosthesis design, surgical implant design, blood flow analysis, preoperative planning for surgical operations, and computer-assisted surgery [25].

Virtual reality (VR) enables physicians and surgeons to interact, manipulate, and simulate the geometric 3D CAD models of anatomical structures directly in a virtual environment, with 3D displays and haptic devices.

Rapid prototyping (RP), 3D printing (3DP), and additive manufacturing (AM) technologies allow us to obtain a real copy of anatomical structures, before a medical implant is inserted or a surgical procedure is performed.

The computer-aided technology tools used in the medical field are shown in **Table 5**.

Computer-aided technologies	Remarks
CAx in medical field	X=design, diagnosis, detection, surgery, manufacturing (RP, 3D printing), etc.
CADMF	Computer-aided design in medical field [25–27].
CAMD	Computer-aided manufactured devices [26–28].
CAL	Computer-aided learning [29].
CADiagnosis	Computer-aided diagnosis [30].
CADetection	Computer-aided detection *is a technology designed to decrease observational oversights of physicians interpreting medical images* [31].
CAMS	Computer-aided modeling and simulation.
CAClinical DSS	Computer-aided clinical decision support systems [32].
DSS	Decision support systems.
CAMI	Computer-aided medical interventions.
CASurgery	Computer-aided surgery [33] *is focused on surgical planning and simulation, and for guiding or performing surgical interventions*.
CAOSurgery	Computer-aided orthopedic surgery [29].
CATSurgicalG	Computer-aided technology of surgical guide.
CATE	Computer-aided tissue engineering or computer-aided technologies in tissue engineering *applies many CAx techniques including computer-aided design, medical image processing, reverse engineering, finite element analysis, computer-aided manufacturing, and additive manufacturing for multiscale biological modeling, biophysical analysis and simulation, and design and manufacturing of tissue and organ substitutes* [34].
CAO	Computer-aided orthodontics.
CAR	Computer-aided reconstruction.
AM	Additive manufacturing [15].
RP	Rapid prototyping [11, 15, 17].
CARE	Computer-aided reverse engineering.
CT	Computed tomography.
MRI	Magnetic resonance imaging.
PET	Positron emission tomography.
SPECT	Single photon emission computed tomography.
CAT	Computerized axial tomography.

Table 5. Computer-aided technologies in medicine – terminology.

Table 6 shows some computer-aided technology tools used in other fields.

Computer-aided technologies	Remarks
CAx in other fields	
CAS	Computer-aided technology in sport training [35] *is such a scientific training method that will improve athlete's training level when it is applied in athletics training*.
CAT3DAnim	Computer-aided technology applied in 3D animation.
CATDecorD	Computer-aided technology applied in decoration design.
CATArt	Computer-aided technology in art.

Table 6. Computer-aided technologies in other fields – terminology.

4. Conclusion and new trends

Nowadays, some computer-aided technology systems have reached the maturity, especially in engineering, and other CAx systems in medicine field are areas of research. The future of computer-aided technologies is focused on their integration in the smart factory, which is part of the fourth industrial revolution, Industry 4.0 [36] (**Figure 3**). The fourth industrial revolution supposes the introduction of the Internet of Things and Services into the manufacturing environment [37]. A sketch of Internet of Things is shown in **Figure 4**. The new concepts related to Industry 4.0 are presented in **Table 7**.

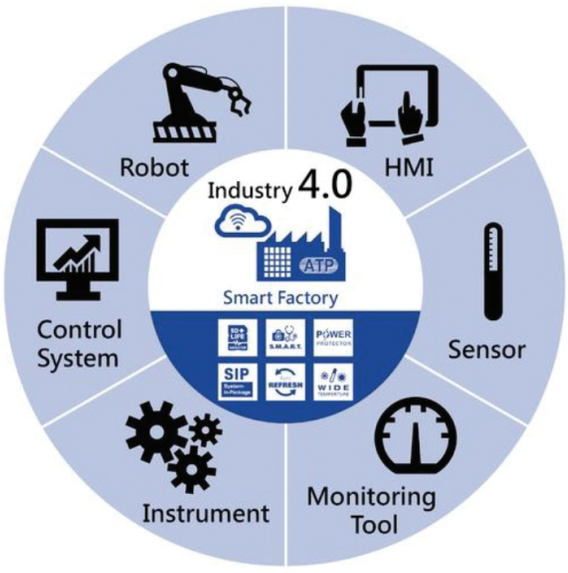

Figure 3. A generic Industry 4.0 [37].

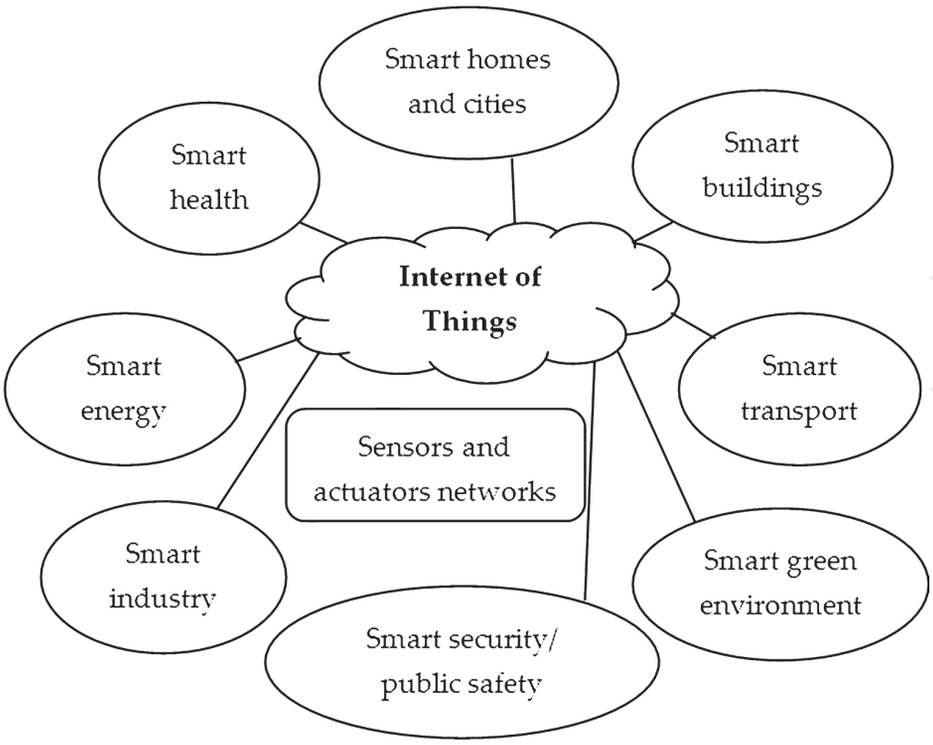

Figure 4. Internet of Things.

New concepts	
Virtual reality (VR)	Virtual reality [39] *refers to computer technologies that use interactive software and hardware to generate a realistic and immersive simulation of a three-dimensional environment controlled by movement of the body*.
Virtual enterprise (VE)	Virtual enterprise *consists in "a group of people who work together on a project, communicating mainly by phone, e-mail, and the internet, rather than regularly going to a central office to work providing operations as competitive as those in a traditional enterprise"* [40].
Factory of the future	Factory of the future *is the combination of virtual and real in order to get a full view of the complete value chain that it will allow factories to produce more rapidly, more efficiently and with greater output using fewer resources* [41].
Smart factory	Factory of the future.
Industry 4.0	Industry 4.0 *or the fourth industrial revolution* [37, 42] *creates a virtual copy of the physical world called "smart factory" including cloud computing, cyber-physical systems that communicate and cooperate with each other and with humans in real time, via the Internet of Everything and Services*.
Cloud computing	Cloud computing *store, manage, and process data, rather than a local server or a personal computer by using a network of remote servers hosted on the Internet*.
CMfg (Cloud manufacturing)	Cloud manufacturing [43] *uses cloud computing, the Internet of Things, service-oriented technologies, and high performance computing for solving manufacturing applications. CAx software can be supplied as a service on the* Manufacturing cloud (MCloud).

New concepts	
Cyber-physical production systems	Cyber-physical production systems "*comprise smart machines, warehousing systems, and production facilities that have been developed digitally and feature end-to-end ICT-based integration, from inbound logistics to production, marketing, outbound logistics, and service*" [37].
IoT (Internet of Things)	Internet of Things *comprises an intelligent interactivity, via Internet, sensors and actuators, etc., between human and things to exchange information and knowledge*.
IoTS (Internet of Things and Services)	Internet of Things and Services [38] *comprises the infrastructure, technologies, and applications that connect the real world and the virtual world. IoTS interconnects via the Internet, human, things, and services*.
IoE (Internet of Everything)	Internet of Everything joins *people, process, data, and things*.
Industrial Internet	Industrial Internet "*is the integration and linking of big data, analytical tools, and wireless networks with physical and industrial equipment, or otherwise applying metalevel networking functions to distributed systems*" [42].

Table 7. New concepts.

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References

[1] Li, Y., Hedlind, M. and Kjellberg, T. Usability evaluation of CADCAM: State of the art. Procedia CIRP. 2015;36:205–210.

[2] Kurkin, O. and Januška, M. Product Life Cycle in Digital factory. In Knowledge management and innovation: a business competitive edge perspective. Cairo: International Business Information Management Association (IBIMA). 2010; pp. 1881–1886.

[3] Stark, J. Product Lifecycle Management. Volume 1, 21st Century Paradigm for Product Realization, Springer International Publishing Switzerland, 2015, DOI 10.1007/978-3-319-17440-2.

[4] Teresko, J. The PLM Revolution. Industry Week, 2012.

[5] Udroiu, R. Concurrent systems engineering. Acad JManuf Eng. 2005;3(1):69–74.

[6] Udroiu, R. Integrated CAD/CAM system the core of concurrent engineering. Bull Transilvania Univ Braşov. 2004;11(46):161–168.

[7] Fagali De Souza, A. and Bodziak, S. Advanced Free Form Manufacturing by Computer Aided Systems—Cax. In: Mechanical Engineering. M. Gokcek (Ed.), InTech, Rijeka, Croatia, 2012, p. 555–586, DOI: 10.5772/36324.

[8] Werner Dankwort, C., Weidlich, R., Guenther, B. and Blaurock, JE. Engineers' CAx education—it's not only CAD. Comput Des. 2004;36(14):1439–1450.

[9] Chang, T.C., Wysk, R.A. and Wang, H.P. Computer Aided Manufacturing. Pretince Hall, Upper Saddle River, New Jersey, 1998.

[10] Kalpakjian, S. and Schmid, R. Manufacturing Engineering Technology. Pretince Hall International, London, New York, Tokio, Paris, 2001.

[11] Lee, K. Principles of CAD/CAM/CAE Systems. Addison Wesley Longman, Inc., USA, 1999.

[12] Groover, P.M., Enrory, W. and Zimmers, J.R. CAD/CAM Computer Aided Design and Manufacturing. PTR Pretice Hale, Englewood Clifts, New Jersey, 1984.

[13] Noel, L. Computer Aided Innovation. Comput Industry. 2009;60(8): 539–550.

[14] Bere, P. and Neamtu, C. Methodology for evaluate the form deviations for formula one nose car. Cent Europ J Eng. 2014;4(2):148–154.

[15] Udroiu, R. and Nedelcu, A. Optimization of Additive Manufacturing Processes Focused on 3D Printing. In: Rapid Prototyping Technology—Principles and Functional Requirements. M. Hoque (Ed.), InTech, Rijeka, Croatia, 2011, p.1–28, DOI: 10.5772/21433.

[16] Udroiu, R. and Ivan, N.V. Rapid-X using 3D printers. Supliment Acad J Manuf Eng. 2008;2:199–205.

[17] Udroiu, R. Rapid Prototyping and Rapid Manufacturing Applications at Transilvania University of Braşov. Bulletin of the Transilvania University of Brasov-Series I: Engineering Sciences, 2010.

[18] Udroiu, R. Composite materials. Technology and application in aviation. Transilvania University Press, Braşov, 2006.

[19] Novak-Marcincin, J. and Kuzmiakova, M. Computer aided production engineering. Proc Int Conf Manuf Syst–ICMaS. Bucuresti, 2009;4, p.311–314.

[20] McLean, C. Computer-aided manufacturing system engineering, in `Proceedings of the IFIP TC5/WG5.7 International Conference on Advances in Production Management Systems, APMS '93, 1993.

[21] Anselmetti, B. and Mawussi, K. Computer aided tolerancing using positioning features. J Comput Inf Sci Eng. 2003;3(1):15.

[22] Dönmez, S. Computer aided industrial design software selection in industrial product design education at Turkey using expert choice program. Procedia-Soc Behav Sci. 2013;106:682–689.

[23] Wang, H., Rong, Y. (Kevin), Li, H. and Shaun, P. Computer aided fixture design: recent research and trends. Comput Des. 2010;42(12):1085–1094.

[24] ISO/ASTM52915-16, Standard Specification for Additive Manufacturing File Format (AMF) Version 1.2, ASTM International, West Conshohocken, PA, 2016, www.astm.org [Accessed: 2016:09:20].

[25] Knopf, G.K. and Johnson, J.A. Computer Aided Design. Wiley Encyclopedia of Biomedical Engineering, 2006.

[26] Bilgin, M.S., Baytaroğlu, E.N., Erdem, A. and Dilber, E. A review of computer-aided design/computer-aided manufactures techniques for removable denture fabrication. Eur J Dent. 2016;10(2):286–291.

[27] Rustemeyer, J. Reconstruction of Maxillofacial Osseous Defects with Computer-Aided Designed/Computer-Aided Manufactured Devices, In: A Textbook of Advanced Oral and Maxillofacial Surgery Volume 2, Prof. Mohammad Hosein Kalantar Motamedi (Ed.), InTech, Rijeka, Croatia, 2015, p.733–746, DOI: 10.5772/58955.

[28] Lee, K.H., Yeo, I.S., Wu, B.M., Yang, J.H., Han, J.S. and Kim, S.H., et al. Effects of computer-aided manufacturing technology on precision of clinical metal-free restorations. Biomed Res Int., 2015. 5p, Hindawi Publishing Corporation, DOI: 10.1155/2015/619027.

[29] Rosenberg, H., Posluns, J., Tenenbaum, HC., Tompson, B. and Locker D., Evaluation of computer-aided learning in orthodontics. Am J Orthod Dentofacial Orthop. 2010;138(4):410–419. DOI: 10.1016/j.ajodo.2008.11.030.

[30] Li, Q., Nishikawa, R.M. Computer-Aided Detection and Diagnosis in Medical Imaging, CRC Press, Taylor & Francis Group, 2015, 454p.

[31] Castellino, R.A. Computer aided detection (CAD): an overview. Cancer Imag. 2005;5(1): 17–19.

[32] Holstiege, J., Mathes, T., and Pieper, D. Effects of computer-aided clinical decision support systems in improving antibiotic prescribing by primary care providers: a systematic review. J Am Med Informatics Assoc. 2015;22:236–242.

[33] Ellis, E. Computer-aided surgical planning for orthognathic surgery. J Oral Maxillofac Surg. 2016;74:1302–1303.

[34] Sun, W., Starly, B., Nam, J., and Darling, A. Bio-CAD modeling and its applications in computer-aided tissue engineering. Comput Des. 2005;37(11):1097–1114.

[35] Lai, C. The application of computer aided technology in the sport training (CAS). Appl Mech Mater. 2014;644–650:5753–5755.

[36] Hermann, M., Pentek, T. and Otto, B. "Design Principles for Industrie 4.0 Scenarios," 2016 49th Hawaii International Conference on System Sciences (HICSS), Koloa, HI, 2016, pp. 3928–3937. DOI: 10.1109/HICSS.2016.488.

[37] Kagermann, H., Wahlster, W. and Helbig, J. Recommendations for implementing the strategic initiative Industrie 4.0: Final report of the Industrie 4.0 Working Group. 2013.

[38] Langnau, L. Tips on designing for the Internet of Things. 2015, Available from: http://www.designworldonline.com/tips-on-designing-for-the-internet-of-things/#_ [Accessed: 2016:09:26].

[39] Virtual reality, 2016. Available from: http://www.dictionary.com/browse/virtual--reality [Accessed: 2016:09:26].

[40] Virtual enterprise, 2016. Available from:http://dictionary.cambridge.org/dictionary/english/virtual-enterprise [Accessed: 2016:09:28].

[41] Factory of the future, White Paper, International Electrotechnical Commission, Geneva, Switzerland, 50p., Available from: http://www.iec.ch/whitepaper/pdf/iecWP-future-factory-LR-en.pdf [Accessed: 2016:09:26].

[42] Techopedia, Industrial Internet, 2016. Available from: https://www.techopedia.com/definition/30044/industrial-internet [Accessed: 2016:09:26].

[43] Zhang, L., Luo, Y., Tao, F., Li, B. H., Ren, L., Zhang, X., Guo, H., Cheng, Y., Hu, A. and Liu, Y. Cloud manufacturing: a new manufacturing paradigm. Enterprise Inform Syst. 2014;8(2):167–187.