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Modern Digital Manufacturing Technical Support Centers

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ABSTRACT

The article focuses on a novel solution to one of the key problems of modern mechanical engineering – the development of digital manufacturing in the field of engineering. This paper presents a project aimed at the development of technical support centers in the field of modern digital manufacturing. The article thoroughly analyses prerequisites for the establishment of such centers, the problems associated with the functioning of such centers, technology that can be used in the design and infrastructure development of the centers, as well as key characteristics of the courseware and equipment process. These solutions can be used in such fields of science and technology as virtual engineering, learning systems, e-manufacturing, education and engineering, digital products, digital manufacturing, rapid manufacturing, rapid product development, rapid prototyping and fully meet the objectives and goals of procedia engineering. The project of technical support centers development in the field of modern digital manufacturing, offered by the authors of the article, is aimed at the organization of functional bonds between educational, engineering and manufacturing innovative enterprises and at the development of laboratories in the field of innovative technologies training based on those enterprises.

KEYWORDS
Engineering education; Technical designs; Smart manufacturing process; Information and computer technologies; E-learning method

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Introduction

Rapid Prototyping (RP) Technologies are the most powerful instrument for boosting scientific and research work and launching new products onto the market. RP-Technologies are used in almost every field of manufacturing, but they have become most popular in knowledge-intensive and high technology fields: aviation, space exploration, automotive industry, power machinery engineering, electronic engineering, instrument making and medicine.

The problem, the solution to which this project offers, is that modern manufacturing requires training engineering staff for such manufacturing.

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The numerous FabLab laboratories (the first one was introduced by Massachusetts Institute of Technology Professor N.A. Gershenfeld (Gershenfeld, 1999; Gershenfeld & Fab, 2005) have definitely exerted great positive influence on the new perception of digital manufacturing and on basic education in this field. However, the occurrence of new technologies presupposes the necessity to further develop this idea (Botti, 2014; Fastermann, 2014; Basmer et al., 2015).

The processes taking place in the modern world, globalization, development of a knowledge-based economy, information society formation, bring new problems to the forefront. An explosive growth of information is happening, new research areas constantly appear, scientific priorities change rapidly and new technologies are being continuously created. Under the given circumstances, the role of the youth's scientific and engineering development during personnel training for an innovation economy becomes paramount.

Much attention is devoted to the development of industry-specific training and scientific and engineering creative work.

The youth's scientific and engineering creative work is a unique educational technology aimed at the search for, training and support of a new generation of young researchers with a practical experience of teamwork at the confluence of promising fields of knowledge.

In accordance with the education modernization strategy, its development is associated with differentiation, with industry-specific education being one of its mechanisms. At the contemporary stage of education development, the profession-oriented school becomes one of the key innovation priorities. Industry-specific training, first and foremost, allows taking into account the interests, dispositions and abilities of the trainee. It is an education differentiation means.

Education continuity and succession at all its levels and stages is one of the main priorities in its modernization strategy.

One of the implementation forms for this concept is the establishment of university centers, through which education continuity and succession have to be achieved.

The project of technical support centers development in the field of modern digital manufacturing, offered by the authors of the article, is aimed at the organization of functional bonds between educational, engineering and manufacturing innovative enterprises and at the development of laboratories in the field of innovative technologies training based on those enterprises.

The undeniable scientific novelty of the offered approach is the project authors' presentation of a complex solution to the relevant problem of education modernization in the field of innovative digital manufacturing.

The works (Degrigny et al., 1996; Degrigny & Gall, 1999; Degrigny, 2004; Degrigny & Witschard, 2006) present solutions that allow to locally increase the efficiency of this or that project. The works (Fantini et al., 2008; Schweizer & Witschard, 2007; Brinkmann, 2011; Wachowiak & Basiliki, 2009; Wolfe, Bouchard & Degrigny, 2010; Gershenfeld, 2011), even ones with an obviously efficient approach to the use of modern digital technologies, lack offers regarding a complex implementation of a model that would allow for a fullest unlocking of the digital laboratories' potential.

As part of the implementation of the project described herein, the authors offer to use the following technologies:

– Three-dimensional modeling – creation of 3D-files using modern graphics and technical software solutions;

– 3D-prototyping (Rapid Prototyping - RP) – an advanced technology, allowing a relatively short lead-time three-dimensional model, layout, sample casting or production of a small batch of a product based on 3D-files.

The unique feature of this technology is the ability to create arbitrarily shaped colored 3D-objects:

– 3D-scanning – to obtain an accurate three-dimensional computerized image of a real-life object;

– Three-axis surface milling based 3D-prototyping using programmable purpose-designed machines and composite and polymeric materials, as well as various metals;

– Diamond engraving application to a wide range of materials to manufacture souvenir gifts and premium award products using special photo printers.

Apart from teaching students the basics of spatial modeling, the abovementioned technologies will also provide insight into the fundamentals of prototyping, underlying the function of advanced computer-assisted production facilities, allow gaining knowledge and learning the principles of work with high-performance innovative equipment to evaluate the fruits of creative work as embodied in actual products (Mitrofanov, Drachyov & Kapitanov, 2011; Mitrofanov, Kapitanov & Popov, 2013).

Materials and Methods

The offered project is based on the FabLab laboratories operation experience, however, the obvious scientific novelty of the offered solutions is the use of a wider range of manufacturing equipment, as well as specialized software and procedural guidelines, targeted at senior secondary school students' training.

Similar projects have been executed and described in the works of the FabLab notion "founder" N. Gershenfeld (Gershenfeld, 1999; Fantini et al., 2008). His works provide the fullest development of the FabLab notion (Gershenfeld, 2011). However, the offered project considerably broadens the range of used equipment executing the 3D-prototyping itself and targeted at senior secondary school students.

The methods of system analysis, mathematic modeling and statistical analysis were applied as methods that allow integrating technological equipment into the training materials.

The principles described in works are also of interest (Greenberg, 2008; Botti, 2014; Fastermann, 2014). However, unlike the project offered in the given paper, the offered laboratories do not provide for the implementation of a complex approach to the solution of the task aimed at developing an educational complex to study modern digital manufacturing.

Results. Manufacturing equipment

The authors offer the given approach as an efficient solution during modernization of contemporary infrastructure of technical universities, educational centers at industrial enterprises of the mechanical engineering, car manufacturing, aircraft engineering and other industries.

The offered development project of modern digital manufacturing technical support centers is aimed at the development of functional relationships between educational, engineering and innovative manufacturing enterprises and at the designing of laboratories in the field of innovative technologies education, based on the enterprises that would be very beneficial for the industry.

3D-printer

A personal 3D-printer allows a higher than ever flexibility in making 3D models for visualization, collaboration and functional testing (Egorov, 2014b, 2014d). A 3D-printer is compact enough to be placed on the worktable, fairly simple to install and run and, most importantly, accessible for most users, regardless of their professional occupation or office size.

Figure 1. 3D-printer

Durable ABSplus thermoplastic

A production-grade thermoplastic, strong enough to replace the real item during test trials, serves as the modeling material for the printer. Models are printed from bottom to top with a modeling material and support material layer-by-layer deposition. No need to wait for anything - the support material can be removed from the component parts immediately upon completion of the formation process.

Models can be drilled, threaded, polished and painted, which makes the 3D-printer an ideal solution for the production of operational prototypes, molding, making of patterns or even custom tools and accessories:

– Fully functional ABS Plus (ivory-white) models;
– 8 additional colors;
– A more capacious working chamber;
– Higher build-up speed advantage.

FDM technology-based three-dimensional plastic printing

The 3D-printer operation is based on FDM (Fused Deposition Modeling) technology. The process is a molten plastic layer-by-layer deposition-based creation of a real-life object in accordance with the target object virtual model. The device allows obtaining industrial grade models right in the office within just a few hours.

Extended working chamber

The 3D-printer design area has been increased by 33% and is 203 × 203 × 152 mm in length, width and height. The device is enabled to create a greater variety of models of varying complexity within just a few hours. Besides, the user can keep the printing process under control in real time: the sealed working chamber is fully visible through a transparent window.

Two options of 3D printing resolution

The system is enabled to print using two resolution options: with a layer thickness of 0.254 mm and 0.33 mm. Simply select the desired thickness of the printed layer in the supplied software, which serves as a convenient tool to control the 3D-printer operation.

Increased prototyping speed

The use of a 0.33 mm printed layer thickness in prototypes production allows a 37% increase in the build-up process speed bringing it to 21.22 cm^3 / hour. This means that with a 3D-printer, the user can get simple formed industrial plastic prototypes even faster.

Two types of materials for prototyping

Two types of materials - modeling material and support material - shall be used in 3D-printer prototyping. These two materials differ in their physical properties. The ABSPlus is an industrial thermoplastic with high strength, elasticity and thermal conductivity. The support material used is a special SR-30 plastic, easily dissolved by a concentrated cleaning agent.

Automated support removal

Removing of the support elements formed from a soluble plastic has now become even easier by using a cleaning system. No need for complicated manipulations with the support material. Nothing needs to be broken off, washed, dried or processed. One only needs to place the freshly printed prototype into the system cart, add a concentrated cleaning agent and start the automatic cleaning process. The system has been designed specifically for office use and is completely safe for the environment and harmless to humans, as confirmed by the purification system certification in accordance with the WEEE and RoHS directives of the European Union.

Ivory and 8 additional color shades for modeling

In addition to basic ivory, a 3D-printer can print in eight other colors. The ABSplus thermoplastic is available in white, black, red, blue, gray, olive green, nectarine and fluorescent yellow. Using the same material of different colors simplifies the distinction of individual assembly components in the prototype.

Stable accuracy and production quality

A high precision surface construction, as well as excellent reproducibility of prototypes constitutes a most valuable asset for replication. A probable error in the prototype construction does not exceed 0.1-0.2 mm depending on the model geometry.

The 3D-printing process

Special software supplied with the device makes the operation of the 3D-printer simple and user-friendly. Upload your three-dimensional prototype model into the program in the STL format. The program will automatically generate support elements for the model and calculate the amount of required consumables and the time to produce the prototype. Meanwhile, the printer can be charged with modeling materials.

Pressing the software interface "Print" button starts the process of model creation that will be finished in a few hours. The modeling material shall be fed into the extrusion head of the printing unit and melted. Then, based on the virtual prototype model, a molten plastic monofilament will be extruded layer-by-layer through a nozzle onto the model table. Upon completion of the printing process, the finished prototype will be framed with supportive ribs incredibly easy to remove - to make the prototype ready for use, just place it into the purification system!

Convenient size and simplicity

Given the convenient size, the system can be easily placed on a worktable. The 3D-printer is 635 × 660 × 800 mm in length, width and height and weighs 76 kg. To make the device operational, just connect it to the mains (220V). No vents, air funnels or water purification systems are needed! A 3D-printer works whenever you need it and tolerates strong language and tobacco smoke!

Feeling is worth a thousand words

The special features of 3D-printers found application in various industries, styling design, designing consumer goods, as well as in small-scale production. Along with that, 3D-printers are the favorite device in contemporary art and all sorts of design applications. With the advent of prototyping and ready-to-use unique products, cheap to produce, exact 3D model-based replicas have become a reality.

Functional prototypes and ready-to-use products

The creation of rapid dynamic load resistant prototypes is a difficult task, but it can be easily done with a 3D-printer. Prototypes made using this device have bigger dimensions than the material copy of a three-dimensional model. The prototypes have been created for various manipulations and processing: gluing, polishing, external turning, drilling, cutting, surface treatment by painting or chromium plating.

Specialized high-precision engraving machine

Figure 2. Specialized high-precision engraving machine

A program-controlled milling machine supports both rotary axes and the 3D scanning head installation. A 3D-scanner allows digitizing three-dimensional objects, with their subsequent, circular and four-way processing made possible using a rotation axis. This makes the machine the most convenient prototyping tool for creating master models and finished products made of plastics, wax, wood, etc. If there is no rotary axis, the user can still engrave stamps, prints, small casting molds and die sets using non-ferrous metals such as brass, magnesium, aluminum, copper, etc. Given a USB interface, an automatic Z-axis zero point determination feature and easy-to-use software, the machine is user-friendly even for completely new users.

The proposed equipment allows the prototyping of a variety of component parts, cases, covers, gears, shafts and many others. Apart of accessing the outer looks of a would-be item, the prototyping with high dimensional accuracy allows to access its assemblability and serviceability, too, which cannot be done when using 3D-printers based on the contrary – the additive method of products construction.

Milling machines allow the processing of various materials used in prototyping, including wood, modeling and industrial plastics and non-ferrous metals (Egorov, 2014a, 2014c).

When mounted on the machine, the rotation axis enables the latter to perform processing operations using the axis both as an index head setting the work piece at a predetermined angle and as a constant rotation axis. Items up to 270 mm long and 120 mm in diameter can be processed using a rotary axis.

The scanning head installed on the machine extends the equipment functions, allowing to use the machine as a fully-featured contact 3D-scanner and a digitization device for three-dimensional objects. Even without experience in 3D modeling, the user can scan clay fashioned figures or ready-made models and, subsequently, process them on the machine. The scanning head is equipped with a state-of-the-art active piezo sensor model. The mentioned head can scan and distinguish objects as thick as a human hair, duplicating the slightest changes of shape. Given the USB connection and special software, the scanning head is easy to work with as a regular contact scanner, while the installation of the head itself on the machine takes less than a minute.

The basic software features such functions as setting the point-to-be-scanned monitoring and the scanned area size, while it is possible to assign one or several areas for scanning.

A digitized model can both be stored in the original format and exported to universally accessible formats, such as STL, DXF, WRL, 3DMF, 3DS, JGS.

The software allows data processing required to engrave the PCBs. The software also allows data importing, part programming required for engraving track contours and areas sampling both across the board and in a separate area, centering, holes drilling and circular milling, engraving markings and cutting the boards along the contour. After the part-program creation, processing visualization shall be performed to make sure that the CNC data are compliant with the requirements.

Laser 3D-Scanner

Figure 3. Laser 3D-Scanner

If there is a need to get an accurate model of an item, not reducible to geometric forms by available methods (to that end, it would suffice to use a scanning head combined with a milling machine), then a 3D-scanner should be used.

A 3D-scanner is as user-friendly as any conventional flatbed scanner. The target object needs to be placed into a 3D-scanner to measure the former and evaluate the scanning time. Set the scanning resolution and perform the process.

Two scanning methods

Planar and rotary scanning techniques are universally used to digitize a set of objects.

When rotary scanning is used, a 3D-scanner quickly scans the entire object mounted on a rotating table. When planar scanning is used, the model can be scanned in twenty different planes, allowing digitizing depressions and other irregularities.

Non-contact scanning method

With the non-contact scanning technology used in 3D-scanners, the scanned objects remain intact and undistorted. The scanning process is only confined to the proper use of the technology. Thus, glossy, shiny and dark objects shall resist effective digitizing, but scanning optimization can be achieved if the model is painted dull red, white or yellow.

Usability

One only needs to connect the scanner to a USB port and press a single button. Run a scan, and a specialized program will start an automatic construction of the surface.

Purpose-designed Photo Impact Printer

The device allows the development of skills in a range of occupations involving computer modeling, as well as gaining the skills of operating program-controlled professional equipment to manufacture jewelry, souvenirs, decorations, gift items, etc.

Figure 4. Purpose-designed Photo Impact Printer

A purpose-designed photo impact printer allows the application of engraving and pictures on a wide range of materials and, if used in combination with the supplied software, makes it possible to create a unique product design, combining photographs, illustrations and text.

Customizable software supplied with the set allows importing raster data in .bmp and .jpg formats from a variety of sources including digital cameras, mobile phones, scanners, etc., as well as vector data in .ai and .eps formats. The supplied software supports all font types, thus allowing an along-the-curve and circle arrangement of fonts or the creation of the user's own single-pass fonts. The set comprises 100 - 200 work pieces supplied with the device.

In the Purpose-designed Photo Impact Printer technology, along with the specialized high-precision engraving machine technology application, one can use an ordinary digital camera photo, first to make a design diamond engraving on a medallion and then, after receiving a 3D model of that photo, to fabricate a low relief three-dimensional medal.

Discussions

Interactive multimedia center

– Developing and conducting interactive lessons. An interactive multimedia center includes software to be used when preparing and conducting lessons. The software, specifically designed for application in the educational domain, contains a large collection of templates and objects, including interactive animated effects, a gallery of off-the-shelf lessons in different subject areas.

– Presentation of instruction materials in all formats. State-of-art software allows the presentation of any electronic educational resources: on-line encyclopedias, electronic training programs, video and audio materials.

– Online learning. A comprehensive array of interactive materials is accompanied by software that allows a multipoint HD web video-conferencing with a 720p resolution.

– Students can log into a video-conference from any PC or mobile device using the link provided in the invitation generated by the organizer.

– Harnessing the Power of the Internet. This system enables the user to explore every avenue in the use of modern networking services features: communication, exchange of experience in social and professional networks; server-based files and objects cloud storage; access to network resources of the educational institutions (web portal, e-library, etc.).

It consists of the following components:

– An interactive dual touch LCD monitor with three frame-mounted USB-ports.

– A powerful integrated Core i5 PC (4GBRAM / 320GBHDD / Wi-Fi)

– An HD webcam with an inbuilt array of microphones (720p, 1280x720, up to 30 frames per second);

– Inbuilt speakers;

– A wall mount or a mobile stand;

– OS Windows 7 Pro

– Microsoft Office 2010 Standard software

– Software to develop interactive lessons.

Mobile interactive computer lab

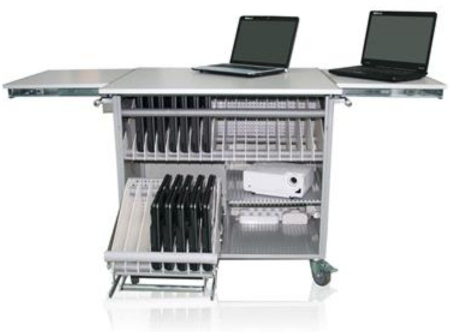

Figure 5. Mobile interactive computer lab

Intel ® Core ™ teacher laptop.

10 Intel ® Dual Core student laptop.

Wireless LAN access.

Uninterruptible power supply.

MS Windows Operating System.

Group collaboration software.

Benefits for students

The ICLab is wireless, so there is no chance for anybody to incidentally catch his or her foot, be injured or damage the equipment - a particularly important point for younger students.

Increased interest in the taught subject matter.

An opportunity to develop an out-of-the-box approach to solving problems.

Benefits for teachers

An ICLab is easy to deploy and use.

A wireless network enables easy teacher control from his/her laptop over the information transmitted to students' mobile PCs.

A variety of forms to present the instruction material.

A projector, an interactive whiteboard, graphic tablets and other accessories help make the lesson more vivid, interesting and up-to-date.

Benefits for educational institutions

A mobile lab does not require a specially prepared room. An ICLab can be easily and quickly moved to any school laboratory - lessons will no longer be tied to the computer class schedule.

Feasibility to extend information support to any school discipline.

Information support for traditional extracurricular activities, academic competitions and contests.

Conduction of general meetings, teachers' council meetings and tutorial teaching sessions.

Great tool for tracking public events: conferences, seminars, training sessions.

Opportunities for teamwork

Teacher's screen sharing with certain or all students' computers.

Video clips transmission from the teacher's computer to the students' computers.

Feasibility of connecting to any student's computer in a screen view mode or in full control mode (mouse, keyboard).

Recording audio and video clips from the teacher's and the students' computer screens for further use in the educational process.

Creation of a text negotiating zone between the students and the teacher.

Transferring files from the teacher's computer to the students' computers with subsequent collection from specified directories.

Development and conduction of interactive tests on any subject using computer multimedia abilities and receiving test reports from each student and the entire class.

Feasibility of teacher's offline work with the product to develop instruction materials (plans, records, tests), including the use of home computers.

Conclusion

The article brings up the problem of an extreme necessity of the modern digital manufacturing technical support centers development at industrial enterprises.

Based on the positive development experience of such centers at technological universities, the project offers the structure of such centers, prototypes of technological equipment, key technologies to be used in the training process of qualified personnel, software and methodological support. The novelty of the offered project lies in the considerable expansion of the technologies range and used equipment as compared to famous projects such as FabLab, as well as the proposal to use technological universities' qualified personnel in the development of such centers.

The future intention is to expand the model range of the equipment, which will allow to cover more industry fields using digital technologies and to offer engineering services of technological universities as a base for educational training and professional development of the industrial enterprises staff.

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No potential conflict of interest was reported by the authors.

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