Modular Work Terminal for greater social inclusion and efficient production organization

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Abstract. Aging society, technological progress and the need for greater social inclusion along with the rising need of human resource mobilization has a major impact on the modern society and production organization. To overcome these difficulties and identify one of the possible solutions this paper proposes the idea of a household work terminal. The terminal corresponds to the requirements of the both sides: individuals and enterprises. While the work terminal is highly customizable as per the needs of disabled and elderly people and is capable to assist them in daily working from home environment, at the same time it allows companies to decentralize their production system and incorporate highly skilled individuals, such as retired professionals. The solution is developed through the concept of the home production lab, based on the main frame and modular components, which contribute to adjustable comfortable and individual smart home production station. This research makes an emphasis on the effectiveness of the work terminal and the development of a smart and modular working environment.
Keywords*: Work from home, Smart environment, Ambient Assisted Living, Fatigue monitoring, Home labs*

INTRODUCTION

Worldwide disabled or partly disabled people continue to occupy positions as entrepreneurs, engineers, doctors, teachers, researchers, artists, computer technicians etc. According to a research[1], in U.S.A. almost every 13th person 18 years old and above is unable to walk more than 400 meters, and every 7th has some kind of physical functioning difficulty. Other kind of disabilities (e.g. neurological, orthopedic etc.) or disabilities caused by accidents on permanent or temporary basis also influence these statistics. 44% of workers with disabilities are in some contingent or part-time employment arrangement, compared to 22% of those without disabilities[2]. There might be various reasons behind this phenomenon, including but not restricted to special working conditions, need for therapy treatment and inability to travel. However one should take into consideration the fact that people with disabilities could perform well in majority of job positions if given the right environment. Working from home practice is getting well known nowadays as a productive and convenient method[3]. Despite that fact among all the positions offered there is no possibility to work from home for people who want to get involved in sectors like prototyping, electrical, mechanical or mechatronics engineering. Furthermore there are currently no such job offers available in the hardware field.

On the other side, demographical changes in the developed world lead to increased number of older population as compared to younger one, causing the phenomenon of aging society[4]. Retired professionals, however, constitute an important source of knowledge, which should be absorbed by the business world. The need for this is already recognized by large international corporations, which provide an opportunity for retired people employment. Good example is Your Encore network employed by Procter & Gamble's[5].

The paper is structured as follows. The first section gives a brief review of the research methodology and describes the literature review. The next section discusses the need of the Work Terminal and provides a case scenario to validate the system by showing how the proposed working terminal can respond to one of the most difficult scenarios – production line for individualized products. In further sections a detailed description of the whole concept as well as the proposed integrated systems are discussed and a representation of our mock up models and implementations are shown. Finally the last section presents our conclusion based on the achieved results and suggests future possibilities in furthering the research.

RESEARCH METHODOLOGY

In the initial stages of the current research we followed a qualitative approach, the analysis is based on secondary data (relative papers and articles were reviewed). At later stages we provided content and thematic analysis of the literature. After careful consideration of the above findings we proceeded with further development of the concept, provided necessary calculations and built a mockup model.

LITERATURE REVIEW

Working from home concept constitutes a great part of Ambient Assisted Living (AAL). In order to develop an effective automated and functioning environment in a smart home working space, it is necessary to enable technologies and include interfaces that allow residents to maintain a direct link with their col-

leagues and the required information[6]. Automation and technologies that provide assistance in manufacturing and storage tasks contribute significantly to an effectively functioning environment in case of working terminal; good example can be the publication regarding the Jaco robotic arm, which is controlled using the Graphical User Interface GUI and the Leap Motion controller[7]. The development in the cloud manufacturing technology allows a great opportunity for decentralized working environment remotely, without physical boundaries. With appropriate technology and automation it provides a platform where costs are reduced and collaborative design and project solutions are created[8].

Furthermore the ergonomics also play a crucial role in providing productivity. This includes the layout of the work terminal and ease of access to each section of the layout. The layout follows a series of processes, specifications of the equipment and the ergonomic rules[9]. Increased size of the terminal results in more spacious working environment but creates difficulty in easy access.

THE WORK TERMINAL

The work terminal (Fig. 1) concept is developed based on existing studies on similar topics and takes a deep inspiration from an existing project USA² (Ubiquitares und Selbstst andiges Arbeiten in einer alternden Gesellschaft). The terminal is designed to fulfill the ambitious needs of people working from their abode. It is specifically designed for production or prototype development of small products with complex design and requirements, for example ear phones, gear boxes, shoes etc.

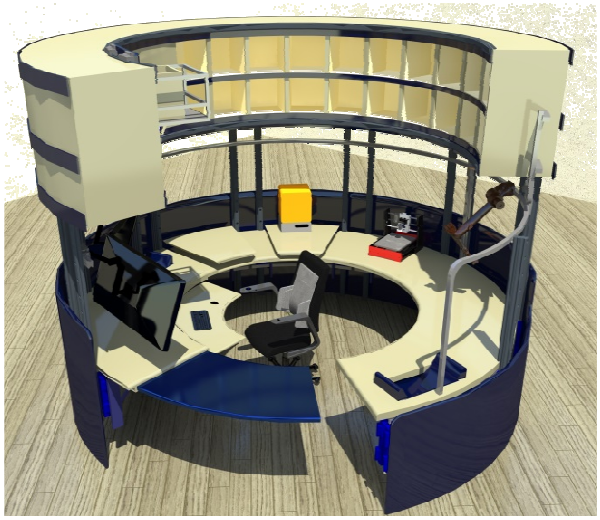


Fig. 1 View of the full version of the prosed working terminal

ADVANTAGES AND NEED OF THE WORK TERMINAL

To respond to the aforementioned needs and trends of the modern society, the work terminal can be proposed as one of the possible solutions. The home working terminal can provide significant ad-vantages to both: enterprises and individuals. From the point of view of an individual, the work terminal can offer an opportunity for greater social inclusion and professional realization to people with limited abilities or to the elderly. On the other hand companies can benefit by accessing skilled work labor and incorporating retired professionals. Working terminal can also lead to a greater decentralization of the production system and satisfaction of the local customer needs.

The working terminal is designed to assist any person who falls under the respective categories, namely people with disabilities and elderly people, aiming to increase productivity and provide comfortable accommodation to the user. However, it is important to mention that the work terminal is suitable for any one due to its customizable nature. The work terminal creates a smart individual and adjustable environment giving birth to new opportunities. The time-waste due to traveling can be reduced to minimum and possibilities of flexible scheduling can increase dramatically. Large scale integration of such concept can lead to other important social advantages as well. In case of a broad implementation of this concept, it can be assumed that it will also have a positive effect on the transportation system and will reduce the pressure during the rush hours, because an increasing number of people would not need to travel to the office.

Secondly, one of the most important aspects of the working terminal concept is greater social and professional inclusion for retired employees, which means that they can continue adding value to the fields in which they acquired significant long-term experiences. This concept is a win-win situation for companies and retired employees. While enterprises could benefit from skilled and knowledgeable working labor, elderly people would continue to be integrated in a professional environment.

PRODUCTION LINE SCENARIO

The work terminal is designed such that it follows an ergonomic flow for production. The purpose of the design is to provide a work flow pattern. This work flow pattern makes it easier for the user to develop a product in the right sequence increasing the productivity of the user. The design also provides easy access all around the working space.

The production sequence follows a step wise procedure. It is like a mini factory and the desk platforms are divided into a sequence of different phases. Let us consider an example for production of customized ear phones. The work process would commence in the following phases (Fig. 2a&b):

1. Data Input: This is phase 1 where the customer first provides the design specifications through special software, then the customer visits the work terminal where his ear is

scanned using a 3D ear[10], making a digital impression of the ear canal.

2. Design Phase: The data collected from the first phase is used to develop a cad model.
3. Production Phase: The cad model is used as an input for 3d printing of the required components and a mini cnc mill is used to print small pcb boards.
4. Assembly Phase: The developed and pre-ordered components are all assembled together.
5. Testing Phase: The assembled product is tested using respective testing equipment.
6. Delivery and Storage: The finally tested product is then stored in the mini warehouse until the customer comes to collect it.

ASPECTS OF THE WORK TERMINAL

The aspects of the work terminal are as follows:

- Ergonomic design and modularity
- Modular components
- Raising desk
- Automated modular shelves (mini warehouse)
- Robotic arm
- Massage embedded chair with a holonomic wheel base
- Fatigue monitoring system
- Intelligent environment
- User following light intensity
- Well-designed wiring placement
- Centralized manual control unit for overall system

ERGONOMIC DESIGN AND MODULARITY

Besides the circular shape of the desk for better ergonomics, flexibility in the nature of the work terminal can be achieved by providing modular desk panels. For this reason, during the design phase of the working terminal, the desk panels are designed in an independent way. Each desk division consists out of two main parts (Fig. 3), one fixed and one removable. The removable part will accommodate the right equipment for a particular task. If the task needs to be changed the equipment can be replaced directly with the desk part to avoid any needed uninstallation process. Each division is fixed to rails of the main frame with a lifting mechanism to provide independent adjustable height (Fig. 4). It is up to the user to decide whether the complete version (Fig. 5) of the working terminal is required or a smaller version with less desk divisions, depending on his/her particular needs. A smaller version, however, is expandable and further desk divisions can be added.

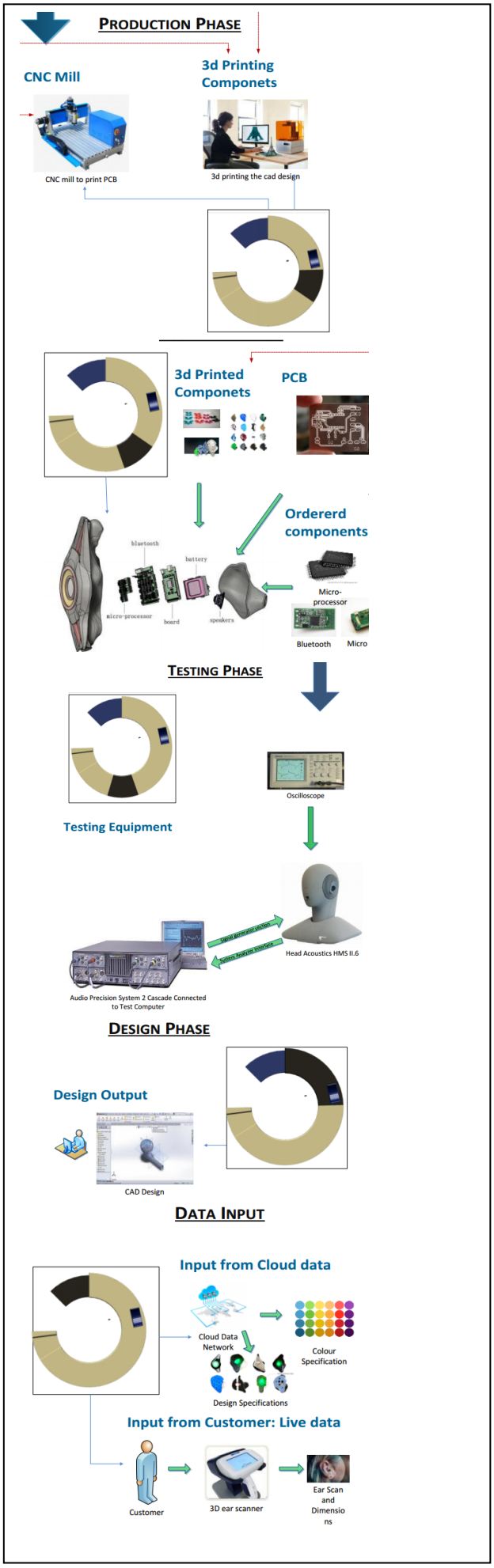


Fig. 2a Production Flow

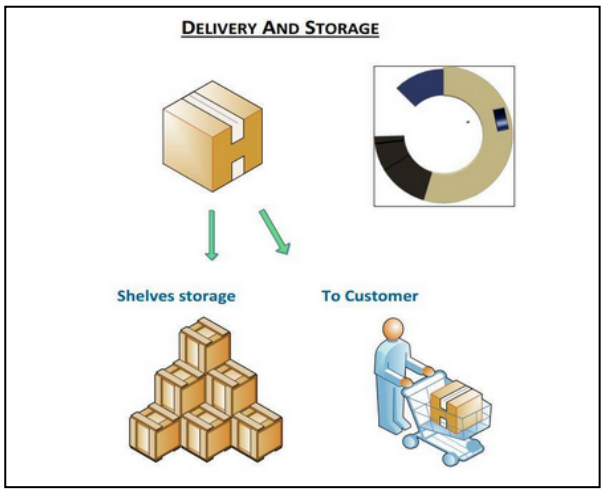


Fig. 12a Production Flow

AUTOMATED MODULAR SHELVES (MINI WAREHOUSE)

Many various storage systems with integrated automation exist, however none of them have been implemented in a home environment. For the proposed concept, a “Mini warehouse” system compliments the design. The designed “Mini Warehouse” consists of four main sections:

- The Shelve Set
- The Load-Unload Mechanism
- The Delivery Mechanism
- The Delivery Platform

With efficient control (voice and gesture control) and by cooperation with other systems (e.g. robotic arm) the user can be provided with a great deal of assistance.

The shelve set is also modular in nature like the desk panels; it may differ in number as per the users requirement. The user can expand the shelves further if he/she requires.

The shelve set consist of the main infill frame, the fixed shelf storage compartments and the light weight shelve boxes which are stored into the fixed shelves.

The shelve load-unload mechanism (Fig. 6) is fixed on the rails and moves across the shelve section to access any existing shelf and its contents (shelf box). Once it accesses the shelf, it moves on to the delivery mechanism and transfers the shelf on to the delivery mechanism (Fig. 7 & Fig. 8).

The shelf delivery mechanism in its place follows another rail line which moves along two different paths. One of path includes a turning point from a vertical to a horizontal axis. Therefore, the delivery mechanism has a circular shape and has another part which is integrated from the inside. When the delivery platforms reaches the turning point, the additional integrated platform will always rotate towards the opposite direction so that when the delivery platform moves from horizontal to vertical the integrated platform will compensate the rotation and always keep the delivered shelf in an upright position.



Fig. 3 Single desk component

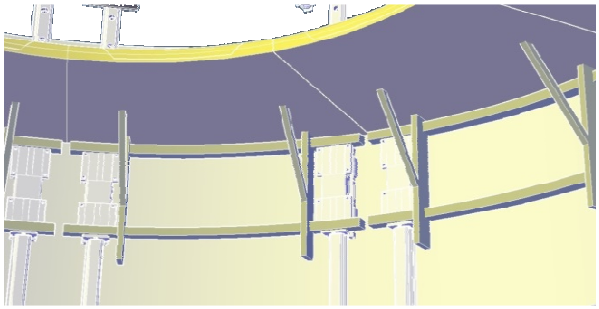


Fig. 4 Supportive structure of desk divisions

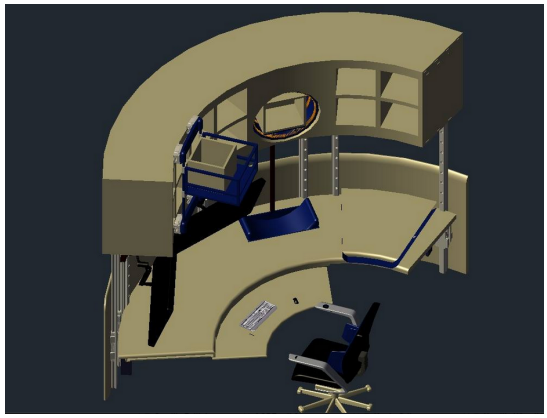


Fig. 5 Smaller version of the desk

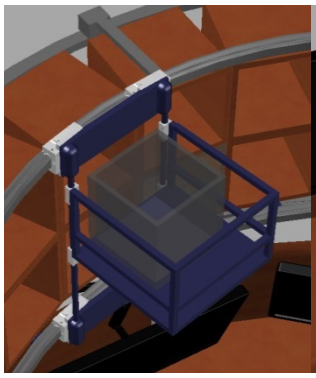


Fig. 6 Shelve Load-Unload mechanism



Fig. 7 Shelve Delivery mechanism

ROBOTIC ARM

The Robotic arm is proposed as an optional feature of the working terminal. Various ways of installation

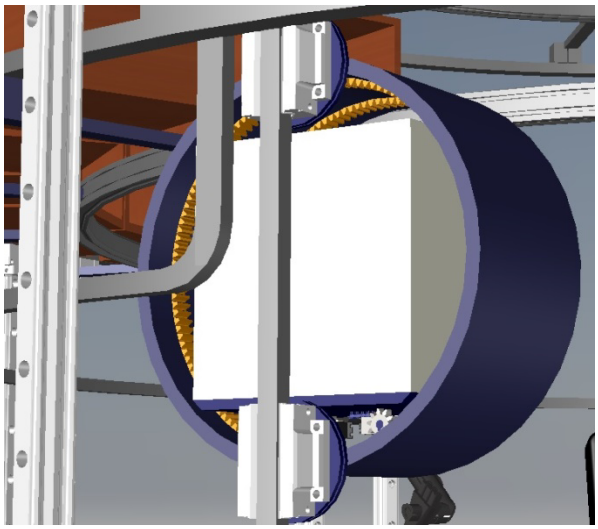


Fig. 8 Shelve delivery mechanism view from behind

have been considered. The most modular way is to install the robotic arm on the rail which is already being used by the delivery mechanism. In this case an additional rail is provided and attached to the main rail, providing the robotic arm a path to free the rail for the delivery platform when required (Fig 9). The mechanism to provide the change of path is based on the train rail principle (Fig. 10a&b).

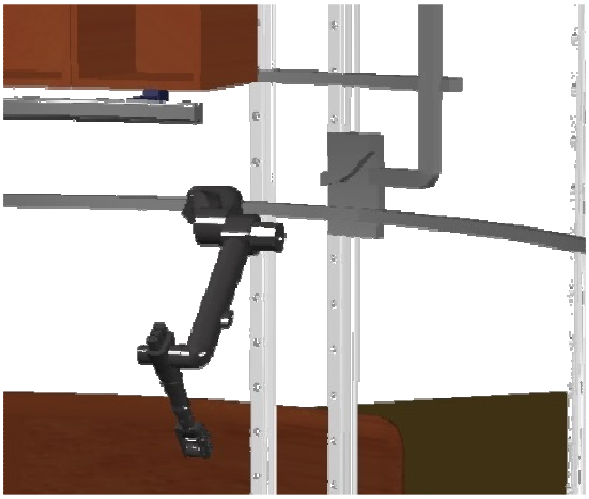


Fig. 9 Robotic arm

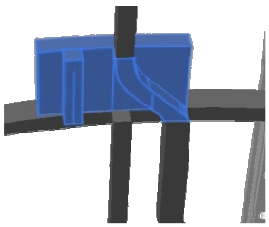


Fig. 10a Path changing mechanism

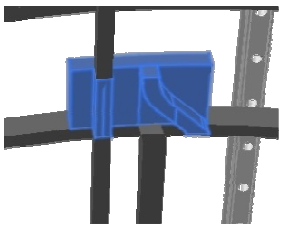


Fig. 10b Path changing mechanism

THE CHAIR AND THE INTEGRATED SYSTEMS

The chair is designed to accommodate to the comfort of the user and increase his/her productivity. Considering the design of a typical office chair (Fig. 11), this research combines modern technologies without changing its shape and dimensions. The employment of the dominant chair design allows to fulfill the requirements of a comparatively compact size and to keep basic chair functions (Fig.ure 12).



Fig. 11 Chair – Conceptional view



Fig. 12 Basic chair functions

The next important fact which is taken into consideration is the needs of the targeted groups, namely elderly people and people with disabilities. To respond to those requirements, the chair is equipped with the smart control method that provides freedom and maximum flexibility in movement. An office chair's base is already flexible and can move to almost any direction without significant restrictions, however if it needs to be controlled electronically to provide assistance to the person, it has a lot of technical issues which cannot be solved without significant modifications. For this reason the proposed concept has a holonomic wheel base controlled with touch pads. The control concept is represented in Fig. 13. On the sides of each arm bracket there is a touch button to enable the electric control of the chair (Fig. 11).

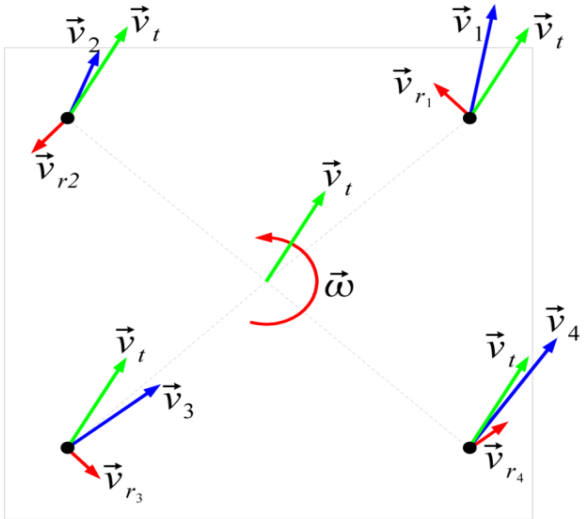


Fig. 13 Holonomic Drive representation

the vector for the speed and the direction of the

chair, while the one on the left represents the rotation direction. For better productivity and relaxing the chair has a massage feature embedded in its backrest. Another feature includes integrated pressure and vibration sensors embedded in the seat for monitoring the heart rate and the posture of the user.

FATIGUE MONITORING SYSTEM

Various researches have been conducted about integration of fatigue monitoring systems in vehicles for automotive industries[11]. The fatigue monitoring system includes a camera, a seat of the chair integrated with pressure and vibration fiber optic sensors[12] and an optional addition of Kinect. Using these elements various physical features including the human posture, heart rate and respiratory rate can be monitored.

The fatigue level can be monitored by using a blinking counter[13]**;** the camera can calculate how often the person blinks and how the shape of the eyes changes while the person's fatigue level increases. The Kinect can cooperate with the camera and also monitor the posture of the user[14].

The data collected from the sensors embedded in the chair as mentioned earlier with the cooperation of the camera and/or Kinect will be processed on the central computing unit being able to detect and minimize fatigue level by giving hints to the person. Using this technology the user can be guided on some stress releasing activities, for example the user will be notified to take a break or/and proceed to elementary physical activities such as moving, stretching etc. The same data can also be used to make historical analysis about the user's health statements and productivity, which can be shared with a physician if required.

INTELLIGENT ENVIRONMENT

The proposed working terminal combines various automation systems, sensors, monitoring activities and human-robot interaction. To combine all these efficiently an intelligent environment is a definite requirement. The data concerning all the systems (condition, current task, position, activity etc.) needs to be transmitted to one central computing unit, which would provide the master control by using various algorithms and an intuitive graphical user interphase. Through combination of the sensors and machine learning algorithms the environment will be able to adjust to the user accordingly to his/her activity (predicting his/her next movement or task, adjust the lighting, remind scheduled medicine taking etc.).

IMPLEMENTATION IN A MOCKUP MODEL

Based on the detailed 3D-Design a semi-functional mockup model of the work terminal was developed. For better details an unusually large scale of 1/5 was chosen. It was decided to use mostly wooden material with combination of mdf sheets. Fig. 14 represents the results of our semi-functional mock up models which includes the chair and the working terminal.

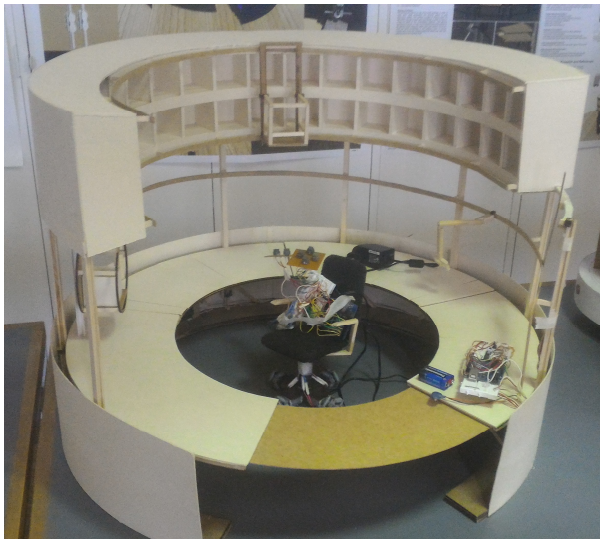


Fig. 14 Mock up model

THE WORKING TERMINAL MOCKUP

During the implementation process several simplifications were made in the mock up models. As shown in fig. 15, instead of two supportive rails only one has been developed and placed in the center of each desk component. The question whether the structure will hold the real load is not being researched on this stage of the project, but existing technologies show that it is indeed possible with a careful and well calculated design. Great examples are firms like Dexion and Schaefer that specialize in storage systems and automated pallet racks. The structures that they make for storage systems are made of stainless steel and other metals, they are compact in space and comparatively light, yet they carry tons of heavy load.



Fig. 15 Supportive rail simplification

All the modular desk components can slide on their supportive rail; a representative mechatronic implementation has been developed for one such component. To achieve successful mechatronic height adjustment a simple servo-motor has been used. Similarly each desk component can be adjusted accord-

ingly, however in the real concept a detailed feedback about the position of each desk component will be provided to a cloud platform, which has been mentioned previously in the section Intelligent Environment.

The rails used in the mockup are made out of wood. An “H” shape column has been used for the rail as shown in (Fig. 16).

The physical model of the robotic arm is hosted on the rail, the robotic arm shares the rail with the shelve delivery platform Fig. 17. Physical coexistence of these two could not be tested because the rail is simplified and the “Path changing mechanism”(Fig.10) has not been implemented in the mock up model.



Fig. 16 Mock up rail shape

User following light intensity has also been implemented using LED stripes; however the sensors have been simulated with buttons. This part of implementation makes clear that such integration is easily possible with any sort of furniture.



Fig. 17 physical model of the robotic arm

THE CHAIR MOCKUP

The most important part of the chair is the movement control and proof of concept of the holonomic base integration. There have been several studies for different variations of holonomic bases used for robotic applications[15] or even for wheelchair applications[16], but no studies have been made integrating such base into an office-chair for better mobility in a home environment. Fig. 13 represents all the necessary required movements in order to achieve or provide full freedom of control. As for our first mockup model (Fig. 18) Omni directional wheels were specially 3D printed to fit the size of the chair, 4 simple 6volt DC motors were used to power these wheels, which were simulated with buttons. However, for precise control step motors with rotary encoders would be required. The mockup was developed to perform and prove basic movements (Front-Back, Right-Left, clockwise-anticlockwise rotation).

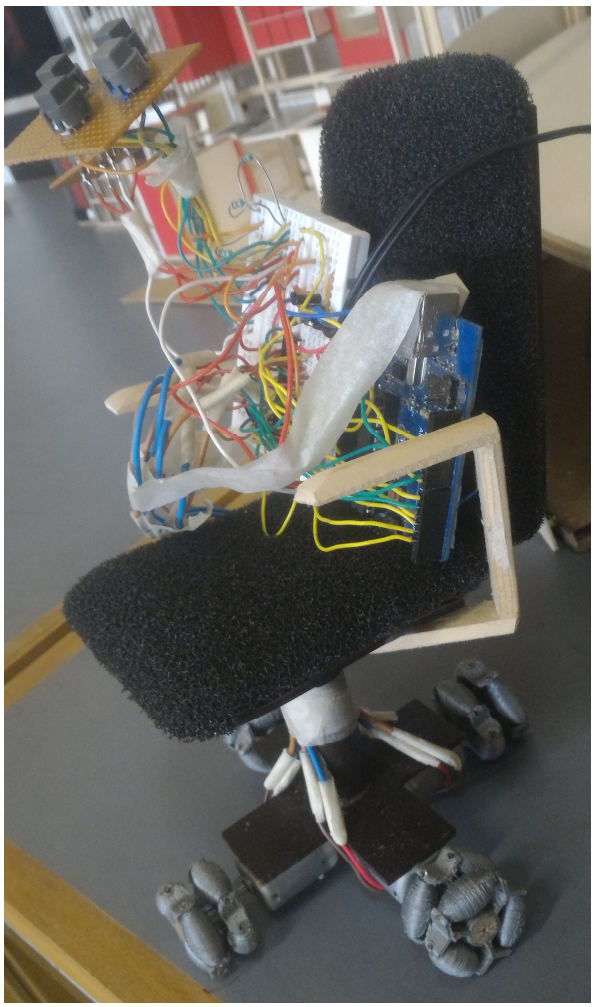


Fig. 18 Mock up model of the chair

RESULT

The research focus was based on the concept of the working terminal and its feasibility. The mock up leads to a conclusion that at this stage the rail should be designed in a way to be able to host a sliding mechanism from two opposite sides, it should be symmetrical, but the exact shape has to be decided based on the sliding mechanisms chosen.

The Load-Unload mechanism of the mockup is just a physical model, which keeps the dimensions that have been used during the design to prove that it can physically coexist within the working terminal with the other system. The same applies for the shelf delivery mechanism (Fig. 19).

Furthermore several wiring issues occurred which lead to serious complications in case of sliding objects, there are examples of electrically powered sliding mechanisms out of which the most common is the elevator, but in the proposed working terminal the path for the mechanisms is much more complicated than just a line. Therefore, the example of pallet racking systems is taken into consideration, specifically the “Pallet Shuttle System” from Dexion[17], which uses a platform to move loaded pallets. The platform is not connected to any power supply with wires; instead it has a battery which is

charged at a docking station every time the system is not in use. This concept is to be implemented to the proposed terminal's mechanisms and to the platform which holds the robotic arm and simultaneously powers it.



Fig. 19 Shelve load-unload and delivery mechanisms

In case of the Chair Mockup, the poor quality and rough surface of the wheels caused a lot of friction. Therefore the wheels were unable to rotate smoothly. It was observed that due to high friction and different floor surfaces the displacement of each wheel varied, even though the same signal was sent to each wheel. These observations lead to the conclusion that implementation of step motors with encoders to provide feedback will not be enough. Another reference point needs to be created, it could be a precise accelerometer in a combination with a gyroscope e.g. the chip MCU6050[18]. Data from this chip can be compared with the feedback from the motors and a more efficient PID controller could be designed if not only the data from the motors is used but also from the gyroscope and the accelerometer. Another considerable factor is that when we add a holonomic base to a chair the weight distribution per wheel changes as per the person's sitting position. Compared to holonomic bases for robotic applications, our case requires more attention for particular issue.

CONCLUSION AND FUTURE WORKS

The current paper proposed a concept of the home work terminal, the terminal which would enable home production, increase decentralization of the production system and assist people with disabilities and elderly people. The main advantages of the module are greater social inclusion, mobilization of the resources in aging society and greater production efficiency. The concept is based on the main frame to which other modular objects are attached, the fact which provides greater flexibility.

It is suggested that the future research would look in detail on the concept of empowering objects using the rails holds, where the plug and play system allows avoiding complication of the necessity to provide a docking station for every object. Therefore, research could be made on a way which would provide the possibility to simply attach an object i.e. the sliding mechanism on the rail. The area of wireless power transfer[19] has unlimited potential and can solve this issue by embedding this technology among the length of all the rails and realizing with that continuous energy transfer between each rail and the modules attached to it.

Another research possibility is with the fork lift robot which would assist in the modularity. The concept is that the robot can change the platforms along with the machines and replace it with another platform that changes the nature of the production line.

On the other side, one of the possible limitations of the working terminal could be accounted for design. The mock up model implementation showed that there are some important drawbacks in the design and aesthetics; the design outcome of a structure is restricted when it comes to providing modularity. It is assumed that design-research could contribute to more aesthetic, furniture-like, appearance of the terminal and thus add on to the value proposition of the module.

ACKNOWLEDGEMENTS

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REFERENCES

1. U.S. Department of Health and Human Services CDC, *Summary Health Statistics for U.S.Adults: National Health Interview Survey*, CDC, 2012.
2. Schur, L., "Barriers or opportunities? The causes of contingent and part-time work among people with disabilities", *Industrial Relations*, Vol 42, pp. 589-622, 2003.
3. Bloom, N., Liang, J., Roberts, J. and Ying, Z. J., "Does Working From Home Work? Evidence From A Chinese Experiment", *The Quarterly Journal of Economics,* Vol 130(1), pp.165–218, 2015.
4. Borsch-Supan, A., Mariuzzo, F., "Our Sample: 50+ in Europe," *Ageing and Retirement in Europe*, Vol.2, Survey of Health, 2005.
5. Huston, L. and Sakkab, N., "Connect and Develop: Inside Procter & Gamble's New Model for Innovation", *Harvard Business Review*, Vol. 84 (3), 2006.
6. International Conference on Smart homes and health Telematics, "Toward Useful Services for Elderly and People with Disabilities", *9th International Conference*, Vol. 9, pp. 319-323, 2011.
7. Bassily, B., "A Novel Manipulation Scheme of a 6-DOF Robotic Arm for Modular Workplaces", *Proceedings of the CIB*IAARC W119 CIC 2014 Workshop*, pp. 39-43, 2014.

8. Dmitrieva, D., “Fabrication of prosthetic sockets and covering layers via 3D printing and Cloud Technologies in Home Labs”, *Proceedings of the CIB*IAARC W119 CIC 2014 Workshop*, pp. 59-70, 2014.
9. Elzamlout, A., “Implementation of Customized Automotive Parts using Cloud Manufacturing Technologies”, *Proceedings of the CIB*IAARC W119 CIC 2014 Workshop*, pp. 52-58, 2014.
10. Lantos Technologies, *“Making a Digital Impression Using 3D Ear Canal Scanning”,* 2012, http://www.hearingreview.com/2012/05/making-a-digital-impression-using-3d-ear-canal-scanning/.[Accessed 22 June 2014].
11. Zhang, Z., Zhang, J., “Driver Fatigue Detection Based Intelligent Vehicle Control”, *Proceedings of The 18th International Conference on Pattern Recognition* (ICPR'06), IEEE, 2006
12. Mizuno, N., Washino, K., “A model based filtering technique for driver's heart rate monitoring using seat-embedded vibration sensors.” *Proceedings of IEEE Communications, Control and Signal Processing (ISCCSP) 2014 6th International Symposium*, pp 137 – 140, 2014.
13. Chau M., Betke M. "Real Time Eye Tracking and Blink Detection with USB Cameras" *Department of Computer Science Technical Report BUCS-2005-012, Boston University*, 2005.
14. Gauthier, S., Cretu, A. M., “Human movement quantification using Kinect for in-home physical exercise monitoring*”, Proceedings of IEEE International Conference, Computational Intelligence and Virtual Environments for Measurement Systems and Applications (CIVEMSA), 2014*, pp. 6- 11, 2014.
15. Mourioux, G., Novales, C., Poisson, G., Vieyres, P., “Omni-directional robot with spherical orthogonal wheels: concepts and analyses”, *Proceedings of the 2006 IEEE International Conference on Robotics and Automation*, 2006.
16. Mazumder, O., Kundu A.S., Chattaraj, R., Bhaumik, S., “Holonomic Wheelchair Control using EMG signal and Joystick Interface”, *Proceedings of 2014 RAECS UIET Panjab University Chandigarh*, 2014.
17. Dexion, “Pallet Shuttle System”, *Pallet Racking,* Available: http://www.dexion.com/Product-Categories/Pallet-Racking/Pallet-Shuttle-System/. [Accessed 22 Apr. 2014].
18. InvenSense Inc., MPU-6000 and MPU-6050 Product Specification Revision 3.4”, *MPU-6050 datasheet*, 2013 [Revised Jun. 2015].
19. Kesler, M., “Highly Resonant Wireless Power Transfer: Safe, Efficient, and over Distance”, *WiTricity Corporation*, 2013.