9th Balkan Region Conference on Engineering and Business Education
and
12th International Conference on Engineering and Business Education

Sibiu, Romania, October, 2019

DOI: 10.2478/cplbu-2020-0043

Conceptual Overview of an Anthropocentric Training Station for Manual Operations in Production

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ABSTRACT

The paper presents a conceptual overview of a human-centred training station for manual operations (ATASMO). It identifies the main users of the system but also the long-tern targeted features of ATASMO. Moreover, the current implementation, its limitations and future work on ATASMO is synthetically presented.

Keywords: *training system, adaptive instructions, manual operations, human-centred.*

INTRODUCTION

To successfully embrace the Industry 4.0 paradigm in a socially sustainable way, manufacturing enterprises need to accompany their technological developments with new tools and technologies by which the human operators are affected. A special focus is to support humans with assistive technologies to easily train and fulfil correctly their work in current and future factories. This becomes even more critical in the context of an aging workforce in manufacturing (Niessen, Swarowsky, Christine, & Leiz, 2010). Thus, anthropocentric approaches applied throughout the design and exploitation of any tools, technologies and systems for manufacturing is required.

Due to global competition and a diminishing number of available workforce (e.g. migration, aging workforce etc.), approaches for training unskilled people, unfamiliar with the production processes and technologies are critical for manufacturing companies to remain profitable. Various training systems to support learning of the correct manual manufacturing process before effectively working in production exist (Gorecky, Schmitt, Loskyll, & Zühlke, 2014) (Aehnelt & Wegner, 2015). Progress in IT, promises to offer solutions for custom job experiences, keeping into account a 4-dimensional space (i.e. worker, machine/ workstation, HMI interface and context – operations, tasks etc.). Although approaches for designing human-centred manufacturing systems exist e.g. (Peruzzini & Pellicciari, 2017), (Pirvu, Zamfirescu, & Gorecky, 2016), one of the main difficulties is to adjust ad-hoc the assistance keeping into account a specific worker (e.g. impaired, normal, young and old) and its current state (Kosch, Abdelrahman, Funk, & Schmidt, 2017), (ElKomy, et al., 2017). Assistive systems are at best only rely on predefined profile (age, skills etc.) and are not keeping into account one's state (e.g. tired, distracted, neutral, angry etc.) despite advancements in human behaviour research and psychophysiology (Park, 2009), (López-Gil, Virgili-Gomá, Gil, & García, 2016).

In this paper a conceptual overview of an anthropocentric training system for manual operations (ATASMO) is presented, targeting to support an interactive adapted training experience relying on ad-hoc adaptive instructions.

In the first section the user profile as well as the hardware and software requirements are presented. In the second section, the current implementation is presented. In the third section the outlook and the concluding remarks are synthesized.

SYSTEM CONCEPT AND MAIN REQUIREMENTS

The main goal of ATASMO is to enable a large spectrum of adaptive training scenarios for various operator profiles, from the simplest ones (i.e. predefined instructions) to complex ones (i.e. adaptive instructions based on context-awareness and real-time data from biosensors). Thus, both hardware and software modularity are essential.

Hardware modularity is essential to ensure that ATASMO can: a) enable appropriate set-up of training environment (e.g. sensors, position of parts, sub-assemblies and instruments etc.), b) read all the relevant artefacts/actions through sensors (i.e. parts, instruments, semi-finished product and trainee actions) on the training station in order to c) output the training instructions for the user to correctly assemble a broad spectrum of products. A modular software architecture is essential because besides the robustness to unexpected malfunctions of an individual service, it enables fast customizability regarding the training scenario by simply enabling and disabling services from a main application. Thus, the best training station usability for various target groups and industry use-cases can be achieved (e.g. younger trainees might be satisfied by having new features, while the elderly ones would prefer rather more established ones).

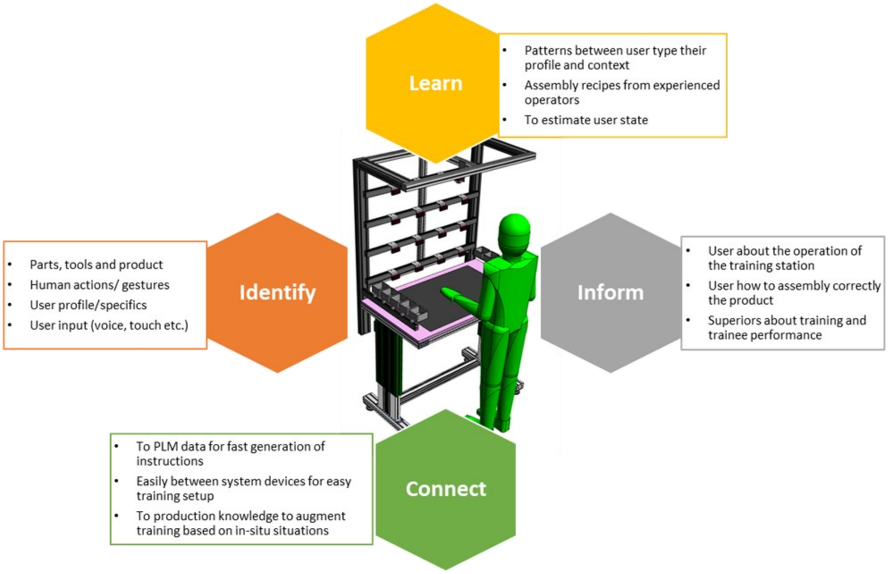


Figure 1: Overall features of ATASMO

ATASMO's overall hardware and software should allow a broad spectrum of system functionalities to (see Figure 1):

- Identify or recognize components and tools relevant for the assembly as well as human actions, interactions and profile;
- Learn during operation or calibration phase of the system about patters or correlations related to the human operator and context, human state (e.g. neutral, angry, joy etc.) and regarding the assembly recipe;
- Inform users how to use the training system and to correctly assemble a product. The training manager should also receive information about trainee and training performance (e.g. how many errors were executed in production after the training scenario X);
- Connect to relevant data systems for easy generation of instructions and support plug & play of devices for easy training set-up.

The system's users are manufacturing operators in industries which execute manual work to create final or semi-finished products. Data gathered from manufacturing companies located in the Centre Region of Romania, from automotive to industrial equipment suppliers, employing more than 3000 operators, revealed that the most common users of such a training system would be women, aging between 26-35 years old, with professional school or high-school education having 2-5 years of experience in the field of manual work. The general profile of operators is summarized in Table 1.

Table 1: Operator's profile overview

Gender	Education	Age	Work experience
Male: 44% Female: 56%	Primary: 24% Middle: 74% Higher education: 2%	< 25: 26,5% 25-35: 40% >35: 33,5%	< 1 year: 18% 1-2 years: 21% 2-5 years: 25 % > 5 years: 36%

CURRENT ATASMO DEPLOYMENT

The current implemented training in ATASMO focuses on the assistance of unexperienced users to correctly assemble of a customizable modular tablet (CMT, see Figure 2). The tablet's components can be chromatically (e.g. black, blue, red, yellow) and functionally customized (i.e. power bank, flashlight and speaker modules in various numbers can be selected). Each individual module (i.e. 3.1, 3.2 and 3.3 types from Figure 2) is mountable in any mainboard location. More details about the modular tablet design can be found at (Stanciu, Petruse, & Pîrvu, 2018).

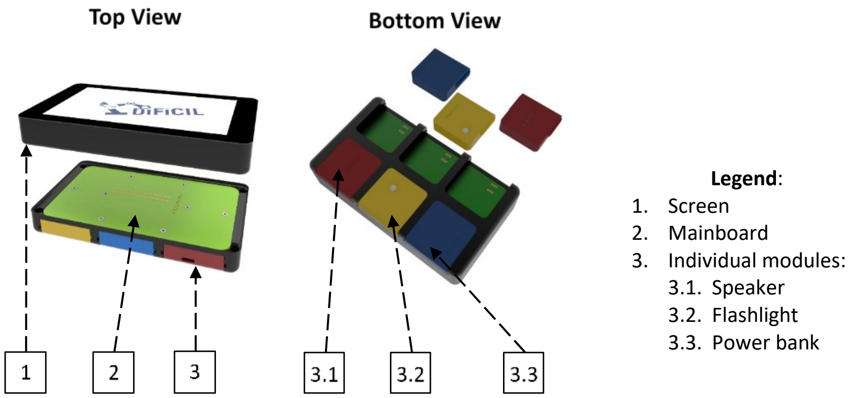


Figure 2: Customizable modular tablet (CMT)

The tablet design enables four main recipes for the correct manual assembly without using any tools or support instruments:

- R1: 1) Screen + 2) Mainboard + 3) Six individual modules;
- R2: 1) Mainboard + 2) Six individual modules + 3) Screen;
- R3: 1) Mainboard + 2) Screen + 3) Six individual modules.
- R4: 1) Individual module + 2) Mainboard + 3) The other five individual modules + 4) Screen.

The training is executed on ATASMO (see Figure 3), a physical training station, where human users are aided in order to learn the correct assembly process of a product (i.e. the CMT). The table surface is approximately 0,84 [m²], with 0,7 meters wide and 1,2 meters long, having an overall

height of 2 meters. Thus, the system can be used for a large spectrum of trainings for small to medium sized products.
Sensors to detect objects and recognize human features (e.g. 3D depth camera and Kinect respectively) can be easily placed and adjusted thanks to standard aluminium profiles. Moreover, wearable and non-invasive biosensors with wireless functions are used (e.g. galvanic skin response, eye tracking etc.) to optimise the training experience. Finally, to assure ergonomic working conditions, the table enables 400 [mm] height adjustment through electrical motors actuation.

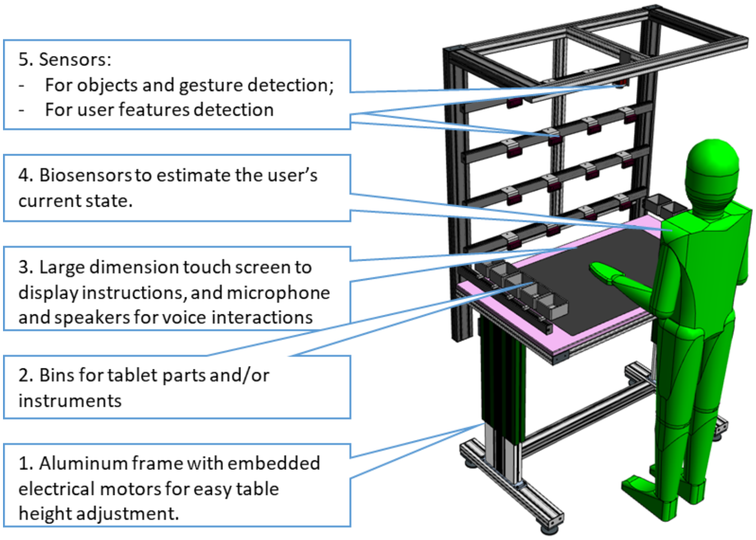
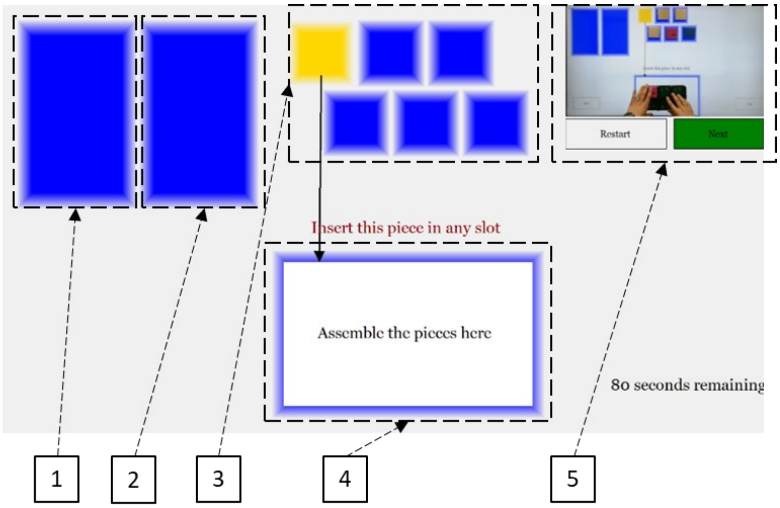


Figure 3: ATASMO system current design

The current training implementation has the following main steps:

1. Training start. A voice command "Start Training" from the user triggers the execution of the training application.
2. Height adaptation and user identification. Once the training application has started, based on the Kinect data, the table is adjusted to allow an ergonomic position for assembly of parts. For this, the user initially sits in a predefined position to correctly determine its height. Moreover, user features such as gender, age are also extracted from Kinect to link user profiles with their training performance.
3. Introduction to the system and manual assembly guidance. To familiarise with ATASMO, a video with sound explaining the system and the product is played before the actual training starts.
4. Step-by-step assistance. The subcomponents of the CMT are placed on predefined areas on the training table, before training begins (see Figure 4, table areas 1-3). The user must follow instructions displayed on the upper right area to complete the assembly recipe. After completion of each step, the user must press next to trigger the following instruction; if not pressed in a predefined time, the next instruction is automatically triggered. If the user executed each step faster than the predefined maximum time, it is considered a successful step. Finally, in the background, the system measures how much time the user spends for each assembly step as well as the overall training time per user.
5. Training end. After the product is assembled, a voice command "Stop Training" closes the training application. If the user executed all steps faster than the predefined maximum time, it is considered a successful training. After the training, the user is informed about its

performance, i.e.: a) successfully passed the overall training or, b) failed, with recommendation to follow a new training focusing on the unsuccessful assembly steps.



Main table areas:

1- Screen storage.

2- Mainboards storage.

3- Modules storage (battery, flashlight, speaker).

4- Product assembly area.

5- Training instruction area (video) and touch area to trigger the next instruction.

Figure 4 Current user-interface of ATASMO

Five microservices orchestrated by a main application enables the training execution. These are:

- A voice service to start and end the training. The commands are received in the tablet's microphone (embedded in the table) and detected from a local data base;
- A human features extraction service, which uses Kinect input data to extract human user features among which is also the user's height;
- A height adjustment service, which based on the user's height actuates the electric motors to raise or lower the training table;
- Object recognition service, which based on the information from a 3D camera, the position and types of CMT sub-components is determined.
- Training application service, which displays the introduction and step-by-step assembly instructions. It enables also touch interaction to select the next instruction.

CONCLUSION AND OUTLOOK

The long-term features of an anthropocentric adaptive training station concept as well as a first implementation version of ATASMO were presented. Among ATASMO's key features are real-time adaptation of training content keeping into account the user's actual state, its general profile and the product assembly recipe.

The first demo has limited adaptivity features implemented, having only user height adaptation to enable an ergonomic assembly position. In the next iteration the following upgrades are targeted:

- Adapt the training instructions considering which part was selected by the user based on 3D stereo camera data. Thus, the instructions will depend on the touched subcomponent of CMT. Moreover, finalized assembly sequences (e.g. screen assembled with mainboard) will be detected to automatically trigger the next instruction without pressing the "Next" button;
- Identify the most relevant training characteristics in order to adapt user-interface and instruction content. Moreover, analysis to identify if a clustering of user-groups based on them is possible. This information will result after discussions with industrial training experts and laboratory experiments;

- Adapt the training instructions and user-interface based on image processing for automatic approximation of gender, age and experience.

On the mid-term, real-time assessment and integration of real-time data from biosensors into training adaption is targeted. Next, algorithms will be "trained" to recognize assembly patterns of various products executed by different user groups in order to generate automatically adaptive training instructions. Finally, ensuring easy adaption of training content based on PLM data or real-life knowledge back into the training are long-term goals of ATASMO. Only after coupling PLM data to ATASMO, with less time-consuming training content creation, industrial organizations could be easily convinced about the training productivity of the system.

From an educational perspective, ATASMO offers an excellent use-case for involved students to experiment and use advanced biometric hardware (e.g. Shimmer GSR/EMG, Tobii glasses, etc.) and software (iMotions) to analyse and improve their skills in human-machine interfaces designs and interactions for adequately engineer the human factors in manufacturing system. Moreover, ATASMO derived applications will be embedded in courses dealing with the design of systems requiring multi-disciplinarily (e.g. design thinking, human factors engineering etc.).

Moreover, for regional companies ATASMO offers a flexible training system concept that can be used from a specific products training towards a one-stop training system, where e.g. frequent production problems and appropriate solutions can be explained, and their comprehension verified through simple tests. ATASMO developments can be showcased to outside organizations as part of Sibiu Smart Systems digital innovation hub (Connected Intelligence Research Center, 2019).

ACKNOWLEDGEMENT

This work is supported through the DiFiCIL project (contract no. 69/08.09.2016, ID P_37_771, web: http://dificil.grants.ulbsibiu.ro), co-funded by ERDF through the Competitiveness Operational Programme 2014-2020.

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