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Augmented Reality System for Virtual Training of Parts Assembly

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Abstract

The term 'augmented reality' is not as widespread as the term virtual reality. Augmented reality has become very popular with cheap "smart devices". There are many more applications for manufacturing companies such as logistics, evaluation of workshop layout, prototyping and virtual training. Cheap and easy to implement virtual training support is the goal of this work.
The proposed system uses a conventional webcamera to shoot a referential workplace with a worker. There is a characteristic marker on the assembly table. The software environment can define a plane and transpose data according to the position of this marker in the real world space. The proposed software solution processes the webcamera image data and adds virtual 3D model instructions to the real image. The final image is presented on a monitor placed in front of the worker. We were able to measure a time improvement in assembly tasks using proposed system in comparison with classic methods.

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Keywords: Augmented Reality; Training; Virtual Training; Ergonomics; Assembly

1. Introduction

Augmented Reality represents new challenges and new common usage in everyday life[4]. With a smart device and the proper tools a car, for instance, can be fixed directly at the place of breakdown without the need for an expensive tow. If the problem can be diagnosed, a normal, non-mechanic could wear see-through glasses and follow the dynamic and interactive instruction process projected directly into the glasses. A virtual 3D object accompanied by 2D instructions can be projected and the user simply follows the steps in the "virtual repair manual". In practice there is no need for expensive glasses, as a common tablet or smart phone can be used with similar efficiency. These

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kinds of applications, not yet available to the general public, are used by automotive companies [5] such as BMW[9] and VW[10]. There are also more general virtual assembly systems [15][16].

Augmented reality is anything which combines digitally processed reality with digitally added objects. One view considers that these artificial objects could also be 2D "flat" objects (like the information about soccer game results). On the other hand, most definitions allow only 3D objects immersed into the scene [3].

This concept was first used for military purposes. A jet pilot can see a beautiful sunrise from his cockpit which is in terms of navigation not so helpful. If there is poor visibility the landscape relief is projected directly into a special helmet, or other navigation intel. Soldiers also use special monocles which are able to display tactical data.

The biggest advantage of augmented reality is the minimal or zero purchase expense because it uses conventional hardware used in many cases (only the see-through glasses can be more expensive). Let us describe how it is possible to add brand new digital elements into a scene:

1. Capturing the scene – Scene is captured in real-time (but it is possible to utilize a pre-captured record for the next phases). In fact a conventional webcamera is sufficient (auto-focus function recommended).
2. Scene recognition –characteristic markers are set in the scene (see Fig. 1), pictures or scene can be 3D scanned ('3D markerless tracking'). A marker is recognized and upon its transformation the position of a 3D model is established (e.g. a sink in our case)
3. Scene procession – On the basis of the previous step 3D objects, 2D pictures, video, etc. are transformed and displayed.
4. Scene display - The complete scene, supplemented by the new object, is displayed on a monitor, projector, tablet, see-through glasses, etc.

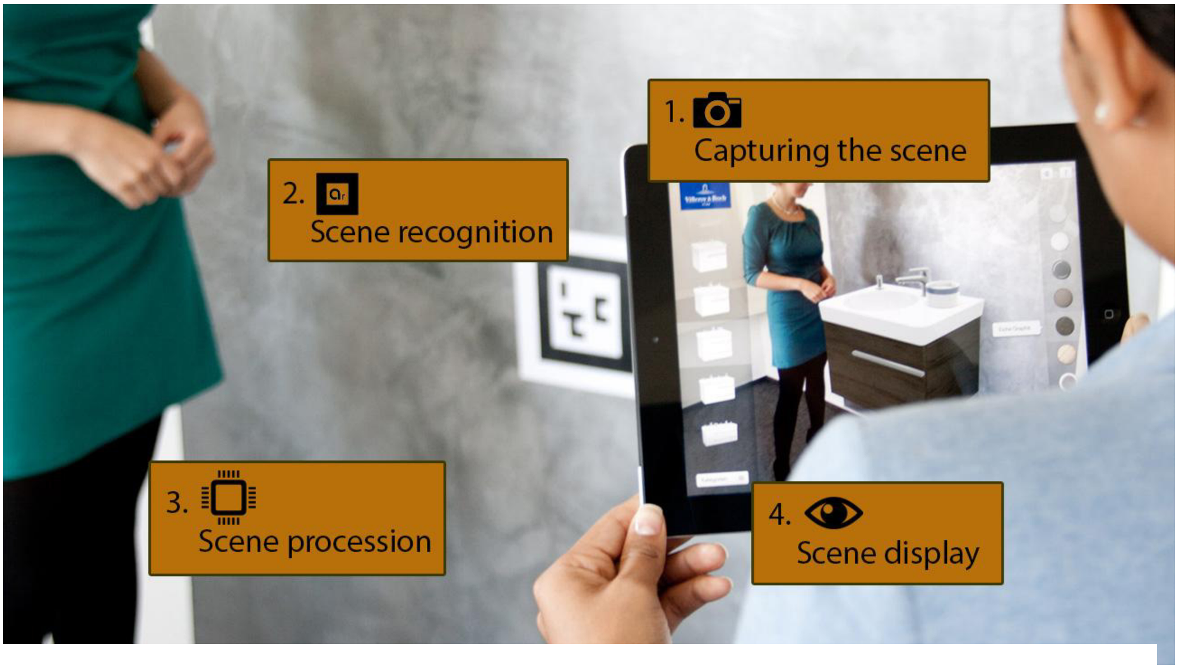

Fig. 1. Augmented reality display principle - V&B Augmented Reality App [11].

The application presented in this paper is mainly focused on virtual training using augmented reality. Commonly in manufacturing there are more areas where this new approach can be applied[6]:

- **Logistics** - The study of the company DHL from 2014 [13] discovers 11 possible applications of augmented reality on logistics

- **Layout planning and prototyping** [14]
- **Virtual/Augmented training** [7]

One of the current time-solving opportunities lies in a new concept for placing and delivering to/from the warehouse (so called Pick-By-Vision solution) [12]. Currently (October 2014) companies like SAP, Knapp and Ubimax are in test phases for a full commercial implementation. Here is the concept (see Fig. 2): Stock keeper wears special glasses which displays the current warehousing task. Tasks are assigned according to stock keepers utilization or proximity to a task. The stock keeper is navigated by addition of 2D and 3D objects displayed in the glasses. Just by looking at the barcode of an article the state “in stock” is changed to “in delivery” in the ERP database.

Another proposed application from DHL [13] relies on a system which helps the driver of end-customer-delivery-car with tagging the delivery items together in a vehicle according to the projected delivery route[8] or driven by other optimization methods[2]. In practice augmented reality has also been used for placement of 3D digital robotic arms on the shop floor.

Fig. 2. Testbed for Pick-By-Vision for SAP company [12].

2. Virtual assembly

There is a referential workplace at the Department of Industrial Engineering and Management at the University of West Bohemia, Pilsen, Czech Republic which serves for the assembly of a gully trap from the company Alca plast s.r.o. [1] This workplace primarily serves as a reference for ergonomic analyses which should help improve the work environment and worker performance. We describe the unconventional way we used it for development of interactive assembly instructions with the concept of augmented reality. The workplace (see Fig. 3a) consists of an assembly table with antifriction feet, back plate, work chair, racks, lamp and electronic screwdriver. Each part of the gully trap is placed in a box with a unique code label.

We carried out an experiment with 20 volunteers who tried to assemble the gully trap according to the instructions (see Fig. 3b). It was proved by experiments that it takes approximately from 5 to 7 minutes on average until a worker actually learns how to assemble the gully trap (see Fig. 4). The volunteers needed 12 attempts on average until they could actually assemble the gully trap without instructions. Volunteers spent the most time looking for the proper part in the box.

The augmented reality seemed like a good solution in this phase for learning curve improvement. The basic idea is to stick one marker on the table, point a webcamera at the table (the marker has to be in the webcamera view finder). The images from the webcamera complete with 3D instructions will be projected in front of a worker on a monitor. Then we can measure the improvement in learning.

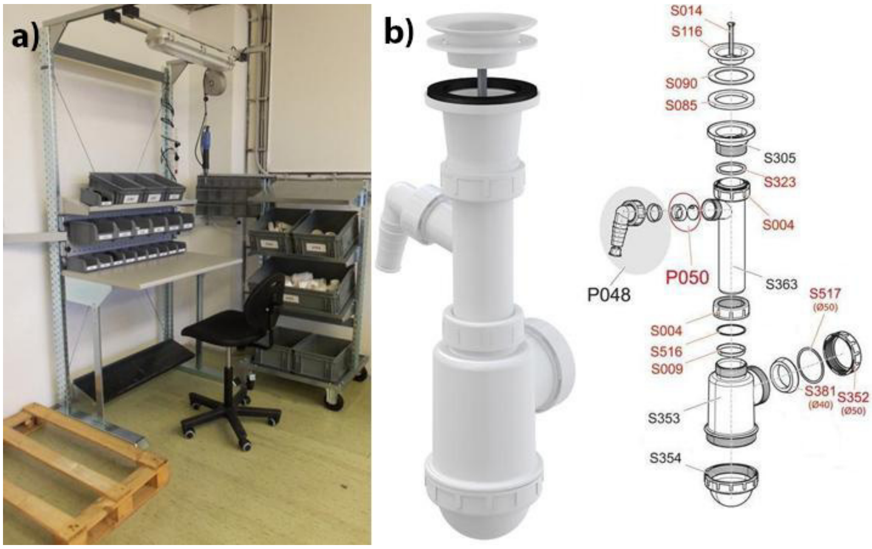

Fig. 3. (a) Model workplace, (b) Gully trap assembly instructions.

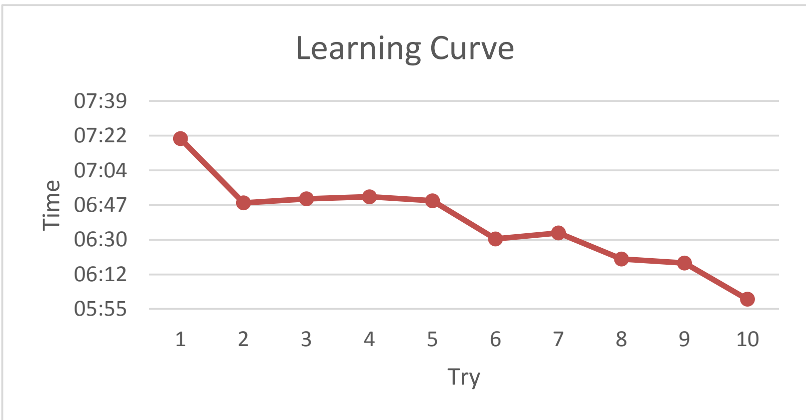

Fig. 4. Learning Curve - assembly of the gully trap with "paper" instructions.

3. Technical solution

First conventional working instructions were prepared which consist of 4 sheets of paper. There are more operational steps on each sheet (see Fig. 5). In the next phase we prepared the 3D model of the gully trap assembly. A new 3D model was generated on this CAD model for each step. There will be the possibility to interactively move through these steps in the final augmented reality instructions.

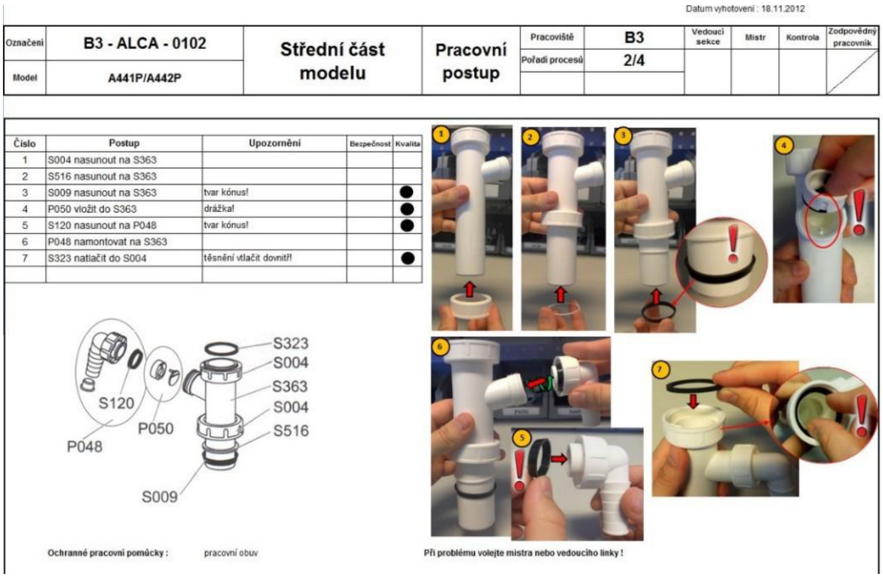

Fig. 5. Prepared "conventional" instruction sheet.

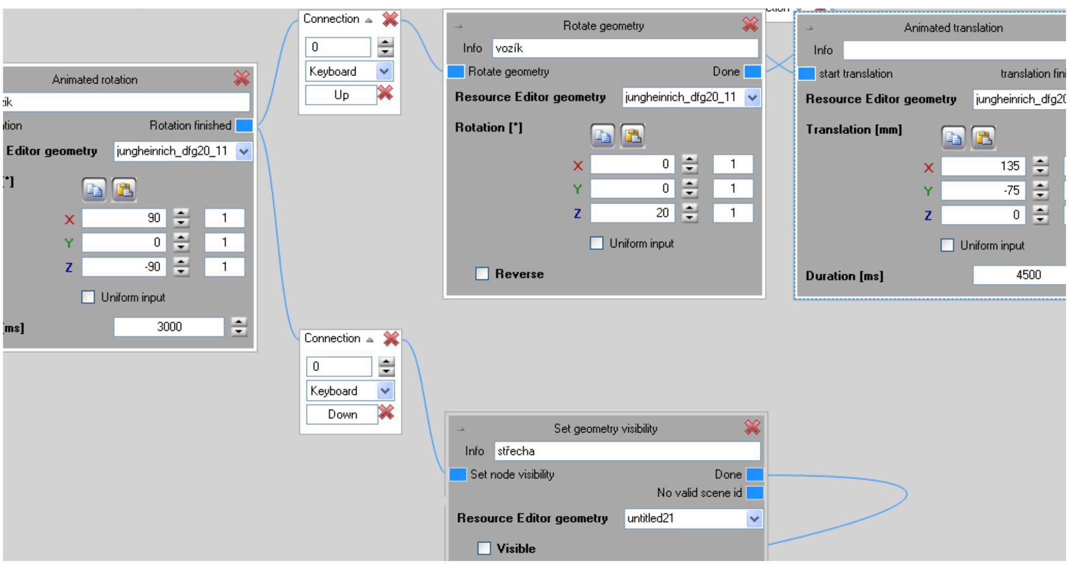

Fig. 6. Example of block structure building.

In terms of technical realization we were looking for a more simple solution which could be replicated by another subject, and this was the main reason we did not want to make the whole environment from scratch in programming development tools, instead we wanted to use some commercial, off-the-shelf program with augmented reality direct support. We researched more software tools which could provide building of augmented reality worlds like BuildAR Pro, D'Fusion Studio or PTAMM[1]. In the end we chose Unifeye Design software provided by the Metaio company. Using it, it is possible to not only make a simple connection marker to a 3D model but also to implement interactivity with the aid of Workflow editor. The whole programming logic lies in the block-programming (see Fig. 6).

All the 3D designs were imported to the resources. Because we need to keep the system as simple as possible to use, only one marker which needs to be connected to all 3D models was considered. Then a logic was given where the user will move through assembly instructions by pressing Up and Down arrows (it can be virtually any arbitrary button on an arbitrary controller). Mainly the block Set geometry visibility (Hide/Show object) was interconnected with keyboard interactions. This block could be accompanied by 3D objects Transformation blocks.

4. Testing, Conclusion and Future Work

A new environment of augmented reality instruction set for one specific case was developed (see Fig. 7). Right now we needed to test the developed environment. Another 20 volunteers were asked who had never worked with the assembly table before. The time for the first attempt was 4 minutes 8 seconds which means a **more than 2 minute improvement** in comparison with the original paper instruction based assembly. Volunteers were able to assemble the gully trap after 10 attempts on average. They were able to assemble the gully trap in 2 minutes 55 seconds on average after 10 attempts. So we have proved that learning is quicker when using the proposed environment.

Fig. 7. Working with interactive instruction set.

The main core of Unifeye Design proved a high resistance to low light conditions. The only issue is the webcamera which has a tendency to "lose" the marker if the resolution is too low. The resolution for normal work has to be set to at least 800x600. After using the webcamera for a longer time, there could be a problem with web camera latency – but this issue is dependent on the webcamera type. Although the camera is in a fixed position during this application, it is better to have a camera with the auto-focus function because the worker is in different positions in relation to the camera during the assembly process.

The methodology of building similar solutions promises quick development of such environments. The hardest work is to prepare the CAD data. The proposed Workflow in Unifeye Design can be easily modified. The architecture promises a significant contraction of the learning time and it is suitable especially for companies with a high worker fluctuation rate.

We assume that for more complex assemblies the learning could be shortened accordingly. And now we are facing the biggest problem of this solution. The software we used has an uncomment limit of the number of blocks which can be used in the workflow (150-200) because of a program error. We discovered this mistake after completing our environment. So the proposed technical solution (Unifeye Design) is suitable only for smaller projects (maximum size is the gully trap).

The environment was then modified. The new instruction set now points the user to particular boxes with the aid of navigation arrows (see Fig. 8).

Fig. 8. Augmented Reality Instruction Set With Navigation Arrows.

There were more difficulties while testing this modification because of the mentioned software limitation. Metaio was also aware of these mistakes so they released brand new versions working on significantly different cross— platform logic. So the next step is to recreate the proposed architecture in new software packages – metaio Creator and metaio SDK and probably also Unity3D metaio Asset.

The next phase is to make the whole environment more generic and common. The goal is to develop an application where a common user can create a database with text instructions accompanied by CAD data and then the instruction sets program for augmented reality will be generated automatically.

Acknowledgements

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