Virtual Reality for Repair Engineering Mechanics

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This thesis aims to examine if Virtual Reality (VR) technology can be used by Repair Engineering Mechanics (REMs) to do their work. These professionals create repair methods for components in trucks. Today the work is in many projects done on physical prototypes and the goal is to replace those with virtual prototypes, using VR systems for the work. Five different methods have been used to examine both the field of VR and the work done by the REMs. The final of these is a mapping that compares the requirements of the work being done to the technologies available by matching them to properties common to both. The most important conclusion is that the new system has to support the users' ability to transfer their skills to the new VR system in order for this project to succeed.

Methods used

1. Literature study

A study of research and development in the field of VR and related fields was carried out. The purpose was to gather information both about the technologies themselves and about the research that has been done in relation to VR. The results are the theoretical knowledge base of most other work done in this thesis.

2. Observations

Visits to the REMs' workshop, conversations with them and other related staff in the same department and visits to several installations of VR technologies were performed. The results of these contribute to the understanding of all aspects of how the repair methods are created.

3. Interviews

Seven interviews of REMs were done, each around 1,5-2 hours in length. The interviews were semi-structured to ease the flow of conversation. The main focus was on gathering as much information as possible about how the work on Repair Methods is done and on getting to know the people who do it. The results gave much deeper knowledge of repair methods and REMs and some indications on what their views of working with computer technology was.

4. Follow-up questionnaire

A questionnaire with 18 questions was sent to REMs in Volvo Parts at four locations around the world. The results helped gather more statistical data on many issues.

5. Mapping users' requirements to technology

A final comparison of users and technologies in the shape of a table. It compares them by creating a list of requirements that the work and people set, listing the technologies available in VR today, and creating a list of properties that are common to some parrts of both categories. Results showed the way to several conclusions.

Conclusions

Transfer Skills and Realism is critical for the success of VR for repair methods

The REMs' expertise in their field should be carried over to the new VR system. The mapping shows that Transfer Skills is one of the most important requirements. It also shows that Realism is a very important property. Both of these issues will be important for the success of this project.

VR Gloves create realism by natural interaction, haptic arms mostly by haptic feedback

Both controls are likely candidates for a VR system at the company since they both contribute to realism, which contributes to skill transfer. VR gloves have a higher total score in grades but haptic arms are close. I have not found conclusive data to indicate that one is better than the other by significant amounts, only indications that VR gloves could be slightly better due to the naturalness of their interaction.

Usability and user-centered development can be demanded from suppliers, especially for the software

User-centered development is good because it adapts the tools to the users, making them more efficient. That makes it extra important for the procurer not to lose sight of the fact that they are the experts on what the technology will be used for and that is what matters the most. Usability is especially important in the software. The software of today's computer market is littered with products that simply haven't been created with the users in mind. One way of countering that is to increase the awareness of these issues in the consumers and recommend them to demand usability from those who sell computer products.

A user-centered attitude is already established

Interviews and informal talks have shown that the REMs already have a very user-centered attitude. They constantly think about how it will be to use the methods they create out in the workshops and what will be good or bad for the mechanics that use them. This means that embracing the concepts of user-centered design and usability should be easy since they are already in that frame of mind.

Haptics are not required, but very good for increasing realism

I have found out that haptics definitely are good for enhancing the reality of the system; several of the papers in my literature study claim this. However, while I believe haptics to be very good, I have not found anything that says these technologies are an absolute requirement for repair method work. The ideal system would indeed have haptics with both small and large forces, but the technologies available today –the ones I have evaluated- have downsides in other important areas where non-haptic equipment is good.

Software saves time and money by automating many tasks

Many of the tasks that require finer accuracy of input and haptic feedback can be automated by software, for example the tightening or loosening of bolts. The literature study showed examples of software automation, even some projects where they had gone further than the company intends to do. These projects can serve as examples of what the software can do and smaller parts of these ideas could aid the REMs in their work without removing the application of their skills in it, merely removing the smaller tedious tasks to make more time for other more engaging areas.

Augmented Reality is not a likely solution

The goal is to remove physical objects completely and move over to virtual. AR mixes physical with virtual and is therefore by definition less relevant to the project's goal. Generic physical objects could be used to simulate tools but a major problem with this for repair method work is that there are so many different special tools and they have too varied shapes and sizes to all have to have matching physical objects.

Mapping data summarized

Property	Realism	Attitude	Ergonomics	Interaction volume	Sense Touch
Requirement					
High User Acceptance	2	3	3	2	3
Transfer skills	3	2	1	3	2
Fit components	2	X	2	3	2
Judge Working Position	3	X	2	1	X
Take Standard Times	3	2	X	2	X
Technology					
VR glove	3	3	2	3	X
Haptic arm	2	2	2	2	3
Wand	2	2	2	3	X
CAVE	3	1	2	X	X
Powerwall	2	2	2	X	X
VR helmet	2	-1	-1	X	X

Grading scale: X = Not mappable, -1 = Negative, 1 = Acceptable, 2 = Positive, 3 = Extremely positive

Requirements

High User Acceptance: The users' acceptance of the technology should be high, or it will be harder to make it viable for use in the company.

Transfer skills: The REMs' expertise in their field should be carried over to the new VR system. Lose that and the users won't be able to do their job, and the company will get a lowered productivity. Informal discussions have shown that the company are aware of this and agree.

Fit Components: Examining how components are fitted in place requires careful positioning and evaluation of the working position and freedom of movement. It is also important to be able to see what other components lie in the way when finding a path to add or remove a component.

Judge Working Position: The working-position when doing a method must be evaluated. The ability to reach a component and forces you can apply to equipment in different positions are important.

Properties

Realism: How realistic the system and its parts make the virtual world appear to be to the user.

Attitude: The user's attitude towards the technological tools he uses.

Ergonomics: "Design factors […] intended to maximize productivity by minimizing operator fatigue and discomfort." -American Heritage Dictionary. The ergonomics of the VR hardware itself.

Interaction Volume: The freedom of movement offered by controlling hardware, including Degrees Of Freedom and workspace volume.

Sense Touch: The ability to sense touch, as provided by the VR hardware.

Six common VR technologies

Output

VR Helmet

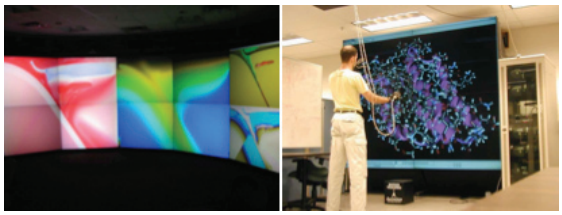
This is a portable display system that mounts two miniature displays, one for each eye, on a helmet or similar equipment that can be worn on the head. The displays fit over a portion of the user's field of view and the helmet usually cover the rest so the user can't see the real world, only the virtual.

CAVE

The virtual environment is projected on the walls in front of the users, on the floor and sometimes even on the ceiling and wall behind them. The users stand inside a box with rear-projected screens with stereoscopic projections on them forming the surfaces.

Powerwall

This display system contains images projected onto a wall in front of the users. They come in various shapes and sizes but common features include that they have a high resolution and when used for VR they are usually combined with motion tracked controls.



Input

Haptic arm

This control has a handle mounted on an arm with motorized joints. The actuators in the joints can generate forces of various strength and frequency and thereby create haptic feedback. The user both controls the system directly by moving the arm around and simultaneously gets haptic feedback from it.

VR Glove

This is a glove that is tracked in real time to give a natural movement. Not many product types exist, but they come in two general flavors. Pinchgloves are motion tracked but only register the contact between fingers and map software commands to that, so you "pinch" your fingers and something happens. Datagloves are also tracked but contain flexibility sensors that sense how much your fingers and hand bends, and update the software accordingly.

Wand

A simpler control type which can take many shapes. It is at heart just basically a remote control. It is motion tracked, which allows freedom of movement. It also has a number of buttons which differ a lot between different designs. The simplest is simply a stick with markers added for optical tracking and two buttons for different functions, like the buttons on a mouse.