Problem solving through remote guidance supported by augmented reality

Hjalmar Eriksson, Ove Jansson, Johan Lewing, Niklas Lindvall, Peter Nordmark, Jessica Sunderling, Andreas Walfridsson. Linköping university 2012.

Abstract

One possible application of augmented reality is remote guidance. An experiment set out to test the differences between solving a problem with the aid of a present instructor and by being guided remotely by either virtual hands or a digital marker. The three conditions allowed voice communication. The problem to be solved consisted of a box containing switches to be manipulated and counting the lamps lighting up when some of these manipulations were performed. From the experiment it was concluded that the feeling of loneliness and human presence didn't differ significantly between the group guided by a present instructor and the group guided by virtual hands while there was no major loss of performance. This supported the viability of using remote guidance to reduce time costs of sending experts to remote locations.

Introduction

Baillot et. al. (2001) suggested that an augmented reality system is defined to have the following properties:

- Combines real and virtual objects in a real environment;
- Runs interactively, and in real time; and
- Registers (aligns) real and virtual objects with each other.

Augmented reality has the ability to alter the way the world is perceived. This is done by merging reality with virtual information. If executed properly, the extra information becomes a natural part of what you for example see or hear.

There are many emerging possibilities for applying this technology, especially within a diversity of workplaces. Augmented reality can be a useful tool in easing the burden of everyday work.

Discoveries have been made that guidance from a remote expert could be useful in areas where the need for assistance emerges in another location then where the expert is located. Augmented reality could be applied in for example surgery and maintenance work.

One of these solutions was VIPAR, a system that has been tested to assist neurosurgeons. With the help of cameras, a local surgeon and a remote expert surgeon shared the same visual workspace. When the remote expert's hands moved in front of the expert's camera, they were presented visually in front of the local surgeon. The hand interaction combined with headset communication created an enhanced work situation where the expert could use its virtual hands to point out and demonstrate how the local surgeon should act. The result was more thorough instruction and localization of problem areas (Shenai et. al., 2011).

According to Huang, Alem, & Albasri (2011), visually shared workspaces where its participants observed and manipulated artifacts contributed to a common knowledge base. This created a feeling of co-presence and has been shown to improve performance in cooperative tasks.

The concept of the experiment presented in this report was based on an observation study of field technicians connected to Teracom, a media operator and service company. It was found that augmented reality could possibly play a part in speeding up the work process of the company's field technicians. This was of interest since traveling far to Teracom's work stations in need of repairs consumed precious time.

By placing novice technicians closer to the stations and remotely guiding them with the help of an expert at a central in another location, travel time would be conserved for the expert. Augmented reality technology could play a major part of this remotely guided solution.

In order to examine whether remote guidance was a viable option in replacing experts with guided novices, an experiment was established with the following set of hypotheses:

A. The group with a guiding instructor present in the same room as the test subject will be the most time efficient one in solving a given problem.
B. There will be no difference in the number of errors made between the groups guided with either virtual hands, a digital marker or a present guiding instructor.
C. The group guided by a digital marker will feel the least secure.
D. No difference in the feeling of control will be encountered between the groups guided with virtual hands, a digital marker or a present guiding instructor.
E. The group guided by a digital marker will feel the least human presence.

Since the system simulates the guidance of a present instructor, an assumption would be that hypothesis A would be confirmed. If the differences between using the system and not using it were to be found low enough, it would be in the systems favor.

Since the groups received the same instructions the expected number of errors was assumed to be evenly distributed among the test groups. Confirmation of hypothesis B was of interest because an even distribution would be in favor of the system.

Earlier theory states that guidance by virtual hands was a natural form of communication. Since the only test group without this type of guidance was the marker group, it is assumed that hypothesis C and E would be confirmed. It was believed that ordinary people trusts that a problem was correctly solved when solved by an expert. It was also believed that ordinary people trusts that a problem was correctly solved if it was solved by a novice with an expert by its side if the expert instructed the novice. If a novice experienced the same level of human presence (or expert presence) when being guided by an expert through remote guidance, it was believable the ordinary man would trust that the problem would also be solved in this case. From this it was assumed that systems of remote control would be of interest for companies and other parties. Through the results, conclusions could be made what type of guidance would be the most suited for a design proposal.

A feeling of loss of control through the use of remote guidance systems would be negative for its applicability. No earlier studies supported that there would be a loss of control but there still was a relevance to investigate this further. This was investigated with hypothesis D.

Method

In order to confirm the hypothesizes, an experiment was constructed measuring time taken to solve a given problem, number of errors made by the test subject, feeling of safety, control and human presence during the experiment. This by the usage of a timer and form.

There were 45 test subjects all together and they were sequentially split into three test groups with different conditions.

The overall average age of the test groups were approximately 26 years. Two test subjects did not state their age, the average is based on the rest of the participants. The majority of the test subjects consisted of university students and the rest were full time employees. Five of the test subjects were female.

The first condition was guidance by virtual hands. With the remote guidance augmented reality system called XMExpert developed by XMReality, the test subjects from this group were guided by having their views enhanced by the hands of the test leader sitting in another room. Paired with voice communication through a headset, the virtual hands were used to complement and clarify the instructions given.

Figure 1: XMExpert guidance station with virtual hands

The second condition was guidance by virtual marker. Similar to the first condition, XMExpert, was part of guiding the test subjects by having their views enhanced. This time it was done by a virtual marker with the shape of a circle controlled by the instructor by a computer in another room. Paired with voice communication through the headset, the marker was used to complement and clarify the instructions given.

The third condition was guidance by present expert. This group did not use the remote guidance system. Instead, an instructor was present at the side of the test subject and instructed the test subject throughout the experiment.

Two of the test groups used the XMExpert system. The system consisted of a display and a camera mounted on a helmet, sending visual information to a computer in another room. A person stationed at this computer could present stimuli on the display viewed by the test subject by moving different objects in front of another camera mounted on the computer. By looking through the display, test subjects view would be augmented with whatever the person at the computer chose to move in front of the camera of the computer. Other parts of the helmet were a light source and a headset for voice communication.

The task solved by the test subject consisted of manipulating a metal box formerly being part of a fighter jet. It contained switches and buttons and there were also lamps that lit up when some parts of the box were manipulated. Imperfect conditions were part of the work situation for the field technicians that had been studied and this was simulated in the test by having the test subjects perform the experiment in a dim lit room. A way to induce stress and uncertainty was to tell the test subject that the box could become electrifying if too much time was consumed or if too many errors were made. In reality, this was not the case. No electric shocks were administered during these experiments.

Figure 2: Metal box manipulated during the experiment

Procedure

All of the test subjects received the information that they were to follow the instructions of the experiment leader, that their performance were to be measured in time and number of errors, and that the metal box used in the experiment might become electrifying if too much time passed of too many errors were made. Once again, the box did not actually have the feature of becoming electrifying.

In the conditions using XMExpert, the test subject were equipped with the helmet and left alone in the dim lit room where the box was located. Instructions were given from the experiment leader through the headset and by receiving the same visual information (displayed on a computer screen) as the test subject, the experiment leader was able to use its hands or marker to guide the test subject depending on guidance condition. This was a complement to the voice communication.

Figure 3: The equipped XMExpert

In the condition not using XMExpert, the experiment leader stood next to the test subject, instructed by voice and pointed on the parts that were to be manipulated in the box.

The task to be solved by test subject was to first open the box followed by a series of 13 manipulations that involved flipping switches, turning a knob, pressing buttons and checking lamps being lit up. All according to the instructions of the test leader. The experiment was finished by closing the box.

After the experiment, the test subject was requested to in solitude fill out a form. The forms were analyzed with the help of the program IBM SPSS statistics 19. Since three conditions were analyzed and the resulting data was non-parametric, Kruskal-Wallis was the method of choice. When Kruskal-Wallis indicated a significant difference between the groups, this data was analyzed with a Mann-Whitney test between the relevant groups and "Bonferroni correction" was applied to reduce the risk for type 1 error. The Mann-Whitney test was used to calculate the effect size and to check if the difference between these groups were significant. All relevant average values were reported.

The qualitative data were put together and the opinions analyzed.

Design

The experiment was constructed as a between-group design. This design was necessary to test the above hypotheses because a comparison between the groups was of interest to prevent learning effects from participating in more than one group and the fact that a between-group design allowed results that showed how the different conditions compared to each other, which would not have been possible with an within-subjects design.

Result

The group with a guiding instructor present in the same room as the test subject will be the most time efficient one in solving a given problem.

The time consumed by the three groups differed significantly, H (2) = 26,322, p < .05. Between virtual hands and present instructor groups there was a significant difference, (U = 6.0, r = -.81) and there was as well a significant difference between the virtual marker and present instructor groups, (U = 10.50, r = -.77). No significant difference was found between the virtual hands and digital marker groups, (U = 77.50, r = -.27).

There will be no difference in the number of errors made between the groups guided with either virtual hands, a digital marker or a present guiding instructor.

A significant difference was found between the groups regarding how many errors that were made, H(2) = 8.876, p < .05. A large effect was found between the virtual hands and present instructor groups, (U = 60.0, r = -.54). A medium effect size was found between the virtual marker and present instructor groups (U = 75.00, r = -.44). A test between the virtual hands and digital marker groups showed no significant result, (U = 92.50, r = -.18).

The group guided by a digital marker will feel the least secure.

There was no significant difference between the different groups regarding the statement "I felt secure when I went through the experiment", H(2) = 2.76, p > .05.

No difference in the feeling of control will be encountered between the groups guided with virtual hands, a digital marker or a present guiding instructor.

No differences between the groups regarding control was found, H(2) = 2.926, p > .05.

The group guided by a digital marker will feel the least human presence.

There was a statistically significant value between the groups in the two variables testing if the test subject felt a human presence, statement 1: "The guidance gave me an feeling of human presence", H(2) = 8.406, p < .05. There was no significant difference between the virtual hands and present instructor groups (U = 83.50, r = -.26) neither was there a significant difference between the groups virtual hands and digital marker groups (U = 76.00, r = -.29). There was a significant difference between the digital marker and present instructor groups (U = 49.00, r = -.52).

This hypothesis was also confirmed with statement 2: "I felt lonely throughout the experiment" which showed a significant difference between the groups, H(2) = 8.318, p < .05. There was a small non-significant difference between the virtual hands and the present instructor groups (U = 86.50, r = -.29). No significant difference was found between the virtual hands and digital marker groups (U = 64.50, r = -.37), although a significant difference was found between the digital marker and the present instructor groups (U = 50.50, r = -.48).

These results confirmed the hypothesis that the feeling of human presence would be the least in the digital marker group.

Discussion

There were a number of possible explanations on why the digital marker and virtual hands groups performed worse than the present instructor group. The test subjects did not get a chance to become acquainted with the equipment prior to the experiment. This could have affected their performance. Some of the test subjects stated that the display limited the field of vision and that the virtual hands got in the way.

It is notable that even though the differences in time and number of errors were significant, they were also surprisingly small. This together with the benefits of remote guidance supports the concept of using this kind of technology in solving the logistics problem of maintenance work of remotely located work stations.

Since no difference between the present instructor and virtual hands groups was found regarding the feeling of human presence and being lonely, it was supported that the usage of virtual hands as guidance possibly could replace a present instructor and still retain some of the benefits of human presence.

Conclusions

This report has shown that by using an augmented reality system a present instructor could be replaced without the user feeling lonely or losing the feeling of human presence. This without a major loss of performance.

With the results of this study, it was supported that remote guidance with the aid of an augmented reality system was viable as a way of solving the time consuming logistic problem of sending experts to remote locations.

References

Baillot, Y., Azuma, R., Behringer, R., Feiner, S., Julier, S., & MacIntyre, B. (2001, November). Recent Advances in Augmented Reality. *Computers & Graphics*, pp. 1-15.

Huang, W., Alem, L., & Albasri, J. (2011, December 8). *HandsInAir: A Wearable System for Remote Collaboration.* Retrieved Maj 10, 2012, from Computing Research Repository: http://arxiv.org/abs/1112.1742v1

Shenai, M. B., Dillavou, M., Shum, C., Ross, D., Tubbs, R. S., Shih, A., et al. (2011, Mars). Virtual Interactive Presence and Augmented Reality (VIPAR) for Remote Surgical Assistance. *Operative Neurosurgery 1, 68*, 200-207.