NETIVAR: NETwork Information Visualization based on Augmented Reality

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***Abstract*—Connecting network cables to network switches is a time-consuming and inefficient task, and requires extensive documentation and preparation beforehand to ensure no service faults are encountered by the users. In this paper, a new AR smartphone application that overlays network switch information over the user's vision is designed and developed for real working environment to increase user's efficiency in working with a network switch. Specifically, the prototype of the AR App is developed on the Android platform using both the Unity game engine and Vuforia AR library and connecting to the network switch to retrieve network information through telnet. By using the camera on the smartphone for capturing the visual information from the working environment, i.e. the network switch in this App, the network switch information such as speed, types, etc. will be overlaid on each port on the smartphone screen. A user study was conducted to evaluate the effectiveness of the AR App to assist users in performing network tasks. In particular, participants were tasked with connecting switchports to a patch panel to match up corresponding configurations. After three tests, it was found that the times for completion and mistakes made were reduced in the final test when compared to the first. This highlights the positive effects of the application in improving the user's efficiency.**

***Index Terms*—Network tasks, Network switch, Augmented reality, Smartphone app**

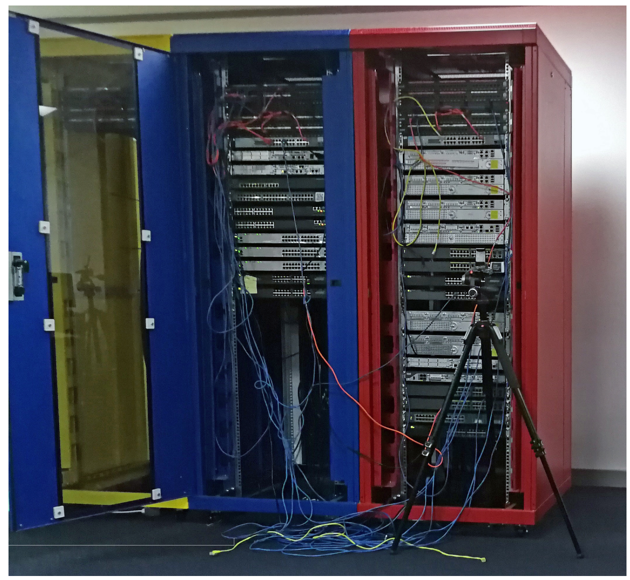

Fig. 1. A network cabinet with a lot of network switches and cables.

I. Introduction

The daily work routines for network engineers could include any and all tasks of removing and replacing switches, cleaning out switches that had accrued dirt from the surrounding environment, removing and tidying the cabling in place, or replacing the cabinet altogether. After these tasks have been performed, all the ports on the switches would need to be matched up to their patch panel counterparts, with different switch configurations dependent on the team, location and function. The complexity of these tasks can be time-consuming, inefficient, and would require extensive documentation and preparation beforehand to ensure no service faults are encountered by the users. Issues arise when cross-referencing information between documentation, or laptops connected to the switch, where the operator's view is drawn between the two locations, making it hard to concentrate and retain large amounts of information, especially in a manufacturing environment, which is often loud, cramped and in some cases potentially dangerous. Also, most network cabinets contain many network switches and cables (Figure 1), which makes network tasks become more challenging.

Augmented Reality (AR) is a concept compatible with many devices, from specialized Head-mounted-displays (HMDs) to common smartphones. The core idea of Augmented Reality is the overlaying of digital information over the top of the user's real-world view. AR technologies have been adapted and utilized in a broad range of industries, from medical and engineering to teaching and Military. In one system, various sensors will collect various types of information from soldiers in combat, cameras, UV and infrared sensors will be utilized to "paint" their view, highlighting friendly combatants, danger areas, locations for air support and more [1]. Closer to home, AR is being implemented into everyday cars to improve various aspects of the driving experience. At CES, Mercedes Benz illustrated their concept of AR assisted driving, where icons for various landmarks, such as shops, restaurants and more, would display on the users view, controllable by gesture

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if they want to know more [2]. Both examples demonstrate how drastically different situations can be improved with the use of AR. Such serious applications of AR motivated us to conduct this research to 1) develop an AR prototype to assist network engineers in performing networking tasks, and 2) evaluate the effectiveness of using such an AR App in term of accuracy and efficiency in those tasks. In particular, an Android smartphone AR App is developed in the Unity game engine that would overlay the switchport information of a network switch over the view of the user. The application will open an SSH or Telnet connection, based on the services available, and display the retrieved information to the user. The user is then able to use the app to select the information that they require, for example, port speed or flow control.

A user study was set up to gauge the applications effectiveness at improving the efficiency of network engineers. Subjects were tasked with connecting the correct patch panel ports to switchports with varying configurations. The difference between the mean time of completion would provide an effective benchmark of the efficiency of the application, improved or otherwise.

The main contributions of this work can be summarized as follows:

- To the best of our knowledge, we propose and develop the first AR App that connects to the network switch and overlays the switchport information over the view of the user.
- A comprehensive user study is conducted to evaluate the effectiveness of the AR app in assisting users to perform network tasks.
- We make the source code available to the public as an open source project (https://github.com/edmondslho/NETIVAR) to stimulate the research in this area.

II. Related Work

In this section, we will first review existing examples of AR in various industries. While Virtual Reality (VR) and interactive computer graphics have been used for teaching and learning, such as partner dancing [3], visualizing wrestling [4], [5] and boxing [6], [7] skills, in the last two decades, more attention has been paid on vision-based frameworks which make use of cameras and sensors. By capturing the information from the surrounding using cameras and sensors, useful feedback can be provided to the user, such as posture monitoring [8] and interacting with virtual objects using body movement [9], [10]. AR combines the advantages from VR and vision-based frameworks - interactivity and environment understanding - which can further improve the user experience. The following paragraphs will give foresight into the potential of AR, as well as any drawbacks and issues that others have encountered.

AR has been used in numerous ways to achieve a wide range of objectives and tasks. Google Translate, formerly Word Lens [11] uses a smartphone camera to translate written text from and into any required language for the user. Users simply need to point their device camera at some written text, and the app will overlay the translation over the top of it. This product shows how AR can be used to enhance users lives when travelling, allowing for seamless translation without the need for paid translators or referring to books. Implementing the translation in real time is more efficient, convenient, and time effective. Google translate uses Neural Machine Translation, a type of Neural Network, to provide the completed translation once the words have been identified [12].

In education, AR has been embraced to further increase students understanding of different concepts. One example uses AR to visualize chemical reactions [13]. In this example, real world markers represent molecules when viewed using the application installed on a smartphone. When the students combine the different markers in the real world, the application will display the chemical bond between the molecules. This project illustrates the positive implications that AR can have for the education sector, providing new methods of teaching concepts that can be difficult to visualize using only a two-dimensional plane. Volkswagen utilized AR to great effect to provide an alternative method of crash testing their cars. These crash tests can be virtualized using the AR application, ARVIKA [14].

III. Methodology

A. User Interface (UI) Design

Designing the UI for an AR app is a challenging task. Given a large amount of information to be overlaid onto the video stream, the following design aspects are considered in the design:

1) Cognitive Overload: Cognitive overload is described as a phenomenon within areas such as programming, maths and science which poses the challenge of teaching these subjects to individuals with limited experience in these areas. Their ability to learn these subjects is restricted by ”the limited cognitive processing of human memory”. This is due to a multitude of factors, notably, the misdirection of the users attention. This is in addition to an excessive cognitive load for the user, meaning that users should not be subjected to large amounts of excessive information in a small time-frame [15].

For AR applications, while the effort to provide the user with an additional amount of information will appear to improve the efficiency of whatever task they are aiming to achieve, other sources believe that too much information in this case will impair the user by distracting them and causing impairment to their vision and reaction. When considering the design principles of AR, the issue of cognitive overload arises, the issue of having too much information presented to the individual at once. Dunleavy [16] suggests a tactic to mitigate this issue, ”create a simplified experience structure initially and increase complexity as the experience progresses”, while this is presented in the context of an AR video game, the principles can still be applied to the project, have the user only access limited features to start, and let them choose to enable more as they grow comfortable with the product. Schwarz and Fastenmeier used AR to measure its effects on drivers of vehicles [17]. While not completely relevant to the projects aims, an automotive setting is an ideal sector to test the effects of sensory disruption as it provides an easily measurable context for the effects of AR on reaction times. Schwarz and Fastenmeier theorize that AR will provide an increased reaction time since ”drivers attention is directly guided towards the hazard without looking at a separate display”. Using a driving simulator provided with significant hazards, and testing with both visual and auditory alerting mechanisms, they found that ”The participants rated the visual concepts better than the auditory ones within both categories”.

Another study that confirmed the presence of cognitive overload in AR applications is the Alien Contact! App that was created to teach math and literacy to secondary school pupils [18]. The subjects in the test found trouble when attempting to synthesize multiple tasks, which OShea et al. describe as each being complex. This led to the researchers reducing the difficulty for their next application, Gray Anatomy. Gray Anatomy tasked the users with solving the mystery of a beached whale using science and maths skills on the AR app. To make the interface more simplistic to combat the cognitive overload several changes were made. The number of characters and objects that the user was to interact with was reduced. An additional element of cognitive overload that was identified by this study was that of misunderstanding the tasks that were required of the participants. For the Gray Anatomy application OShea et al. created a method of delivering the objectives through the medium of multimedia rather than written [18].

These studies demonstrate the risks of cognitive overload in AR applications leading to decreased effectiveness. Some of the findings of these studies can be incorporated into the development of the application. Namely the reduction of elements to interact with and the method of teaching the use of the application to the user, however the nature of the application should mitigate some of these elements in that the UI concept is relatively simple.

2) Enhanced Understanding: A company that is using AR in a similar fashion to the aims of this research is FieldBit [19]. FieldBit uses smart eyewear and phones to allow remote assistance for engineers by having remote engineers draw instructions as an overlay on their view. Despite the similarities in this project, FieldBit mitigates some AR issues by not requiring an anchoring point for the image, as the remote support is manually drawing over the users view. FieldBit shows that the industry applications of AR are quantifiable and justified, on their website they advertise a 50% increase in Remote resolution rates when using their system [19]. However, this is an advertisement and not a scientific study, so these results may not be entirely reliable, as they may have been gathered in a way to ensure the positive representation of their application.

AR has also proven to be useful in the education sector, providing a new experience for students to enhance their learning. Matt Dunleavy attempts to categorize AR in his journal. Here, he separates AR into two distinct categories. Location-based, which is primarily based on the GPS technology, presenting media to the user as they physically move around an environment. The other classification is vision based, which utilizes the camera functionality of the device to overlay information over the user's view. Although this project only deals with the latter, Dunleavy theorizes that both types are useful for increasing students understanding of a subject matter [16].

Providing more evidence that AR increases childrens understanding of learning materials, Rabia Yilmaz set out to gauge the reception of AR learning materials from both students and teachers [20]. Using a sample size of 33 students and 30 teachers (All teachers sampled were female, an oversight in the representation for the sample), subjects were issued an Educational magic toy, a card or puzzle containing a QR code that, when scanned with a smart device, would animate a story, 3d object or flash animation relating to the toy. When collecting feedback from participants, Yilmaz finds that both students and their teachers responded positively. However, they found no higher cognitive attainment while using these toys, providing a counter-argument of whether AR increases students understanding. This research may differ from industry applications of the technology, since half the sample size are considerably younger than industry professionals, therefore their levels of understanding and engagement would be significantly reduced.

Chen, Lee and Lin [21] used augmented reality to enhance skills of autistic adolescents. In this test augmented reality was used to display 3D character models displaying various emotions to three participants with autism. The subjects were delivered a story relating to a particular emotion and were asked to choose the relevant 3d mask that fit the situation. The researchers found that at the beginning of the test, the participants ”could not identify the facial expressions that corresponded to the emotions” [21]. By staging an intervention with the participants and matching the correct adjectives to the correct facial expressions, they were able to improve the subjects recognition of the emotions from an average of 20% to 80% during their follow up sessions. This test obviously loses some element of credibility through its extremely small sample size; however, it does unanimously prove that AR can be used to increase subject understanding, and even here, teaching them skills that they would not have otherwise been able to gain.

A large amount of evidence provided seems to demonstrate that in various cases, the use of AR can increase individuals understanding of different information values, whether that be learning emotional responses or engineering methods. The blending of virtual elements with the real world allows users to more easily visualize and retain the information that is being presented to them.

B. Our design

An important element of the UI design was the concept of not having the UI display too much information at one time. The concept of cognitive overload was discussed in the analysis, and this is an important issue that was considered in the design of the application UI. To this end, the UI needed to be as non-obtrusive as possible, providing a lightweight and tidy method of displaying the information.

As there was a large amount of information gathered from the ”show interface status” command (five options for each of the eight ports on the test switch would mean forty pieces of text, seven options for each of the forty-eight ports means three hundred and thirty-six pieces of text for the larger switch), it would not be possible to implement all this information at the same time. For this reason, the concept of a scrollable menu was implemented. This would allow the user to pick from a list the exact port detail that would be needed. Two buttons were placed in the top right of the view, allowing the user to scroll through the port options as they needed them. The original design had separate UI elements for each of the port options, clicking the scroll options would simply deactivate the last in the sequence and activate the next one. This method was abandoned for several reasons. First, the extra UI elements would increase both the size and latency of the application, more objects to render would equal more processing power and less battery power used while the application was running. Removing so many UI elements would enable the application to become more lightweight and usable.

The method that was instead implemented was a more lightweight, practical solution that was more dynamic in nature. Rather than several UI elements that would have to be created, a single text field was created, that could be dynamically altered based on the port option that the user would need to view. After the switch information code had been run, the results would be saved to a multi-dimensional array. From here, the contents of the text boxes could be dynamically altered to fill in the appropriate port option. This means that a new type of switch with any number of port options could be added into the application and the port options for all of them would be able to be displayed.

IV. Implementation Details

The AR App is developed in Unity. Vuforia is used for detecting and tracking visual features of the network switch captured in the input video stream. The application was running at 60HZ. Before the network switch is being recognized, the application will check the status returned by Vuforia at every frame (i.e. every second in a 60HZ setting). Once the network switch is tracked, the application will connect to the switch using Telnet as explained below.

A. Retrieving Network Switch Information

One of the most essential aspects of designing the code was ensuring that it was multi-platform and adaptable to change. Having the device unable to work with systems would hinder the users entrustment of the system and devalue it. The switch retrieval code was written to maximize compatibility with other systems. The application will first probe the server to determine whether SSH is open. While SSH is significantly more secure than Telnet, some organizations still use Telnet and some legacy systems will not have SSH enabled by default. Therefore, the option was implemented to communicate over Telnet when no SSH exists. During development the SSH library was found not to be compatible with Unity, therefore, the product was created with just Telnet functionality as a proof of concept.

Having connected to the network switch, the network information will be overlaid to the input video stream captured by the camera on the smartphone (Figure 2, Figure 3 and 4). A demo video is submitted with the paper and it can be watched online on https://youtu.be/tn7IK1dfA_g

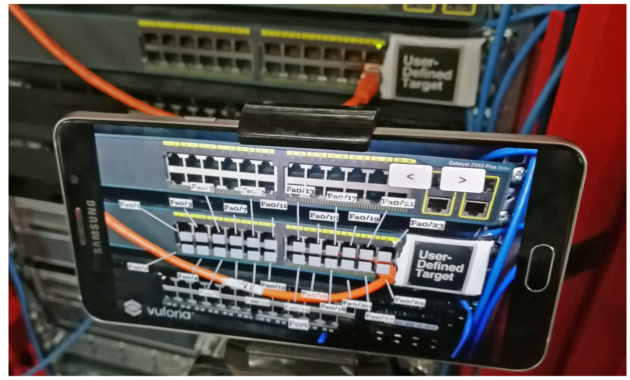
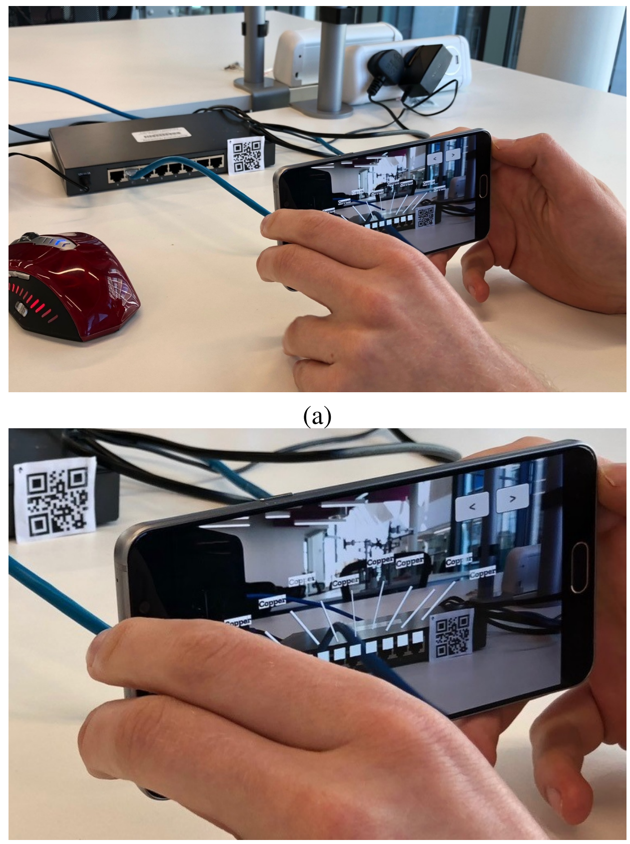


Fig. 2. An example of the output of the AR App working with a 24-port network switch.



(a)

(b)

Fig. 3. An example of the (a) output of the AR App and (b) the close-up view of the App working with a 8-port network switch.

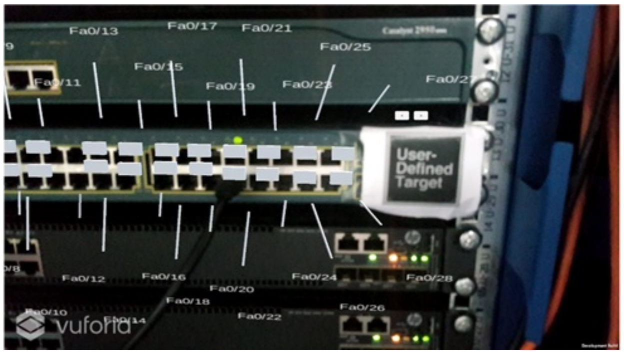


Fig. 4. An example of the overlaid network switch information.

V. Evaluation

To quantify the improvement of the AR applications effectiveness, a user study is conducted using participants with the required networking skills. Creating this test should create a scenario that is indicative of a real-world networking environment and be challenging enough that the time difference with and without the AR HUD software is easily measurable. Nicholas Walliman states that a good hypothesis ”is tested in order to support, or reject the existence of the stated relationships between the variables” [22]. The hypothesis that this test addresses is ”The application improves the effectiveness of the users when performing network maintenance”.

A. Design of the User Study

In the user study, we designed 3 tests based on the rationale below:

- First Test
  - Establish a baseline of measurable data to gauge the improvement made by the application
  - To aid in the discovery of the requirements
- Second Test
  - Measure the effectiveness of the application compared to the baseline data gathered in the first test
  - Gauge users feedback on the application to ensure high standard of quality
- Third Test
  - Measure any increased effectiveness from any anomalies that may have occurred in the second test
  - Gauge the applications learning curve

The users will be timed in their completion of the provided network test, to give a numerical representation of the efficiency achieved. A quicker completion time will represent enhanced efficiency, although aspects such as previous skill levels, external factors and the learning curve of the product will need to be considered

B. Experimental settings

10 participants were found through various methods, including the Computer Network Technology course at Northumbria University, this would ensure that some participants would have an increased knowledge of networking practices and equipment, while the others would not. This would give a diverse sample that would allow testing the effects of the application on individuals from different experience levels. The test was designed to be as simple as possible when referring to network theory, the act of matching cables up to correct ports is the main aim of this test, where introducing complex networking concepts would require the user to operate the switch via putty, negating the eventual use of the application. This level of simplicity will ideally mitigate any disparity between aptitude in the subjects (male vs female, old vs young etc.). Ensuring the test was as simple as possible evens out the challenge disparity, leading to a fairer research test overall.

To facilitate a quick and efficient test process that would allow the features of the application to prove representative of a finished product, the second test process was replicated to a smaller capacity 24 port switch. This would allow for the measure of the user’s efficiency in this environment while keeping the testing process succinct and allowing the application to work to its full potential. For this test, a cisco catalyst 2960 was configured with the various port settings.

Users were given a brief introduction to the activities of the test, introducing to the concept of the switchports and the application. They were encouraged to use whatever process they felt most comfortable, and informed that there were many correct combinations of connections.

For the first test, a laptop was provided with an open connection to the switch with the output of a show interface status command. 23 network cables were provided on a nearby table. The port requirements of the patch panel ports were provided to the user on a printed sheet and a copy was fixed to the network cabinet in the users eye line for ease of use. A timer was started to initiate the test, then finished when the user made the last connection on the patch panel.

The app is introduced for the users in the second test. They were shown a brief demonstration of the app to demonstrate how it works. Users were given the option of holding the smartphone as they completed the test or utilising the provided tripod to secure the phone in place. All participants chose to use the Tripod as it was a more convenient method of using the phone. These options were purely voluntary; however, their choices are recorded in case of any correlation between their method and performance. While the test was performed, certain aspects could interfere with the tracking of the application, to compensate for this, in the event of the app encountering a tracking glitch or loss of connection, the timer for the test would be stopped while the issue was fixed, then resumed when the app was functional. Any inconvenience and lack of usability introduced by these faults would be covered in the participant feedback sheet conducted at the end of the test.

The third test involved performing the same task again with the application. This would allow the users to perform the test having more experience with the application. Once again, they were given the option to use the phone either handheld or static in the provided tripod. After they had completed the third section of the test, they were provided

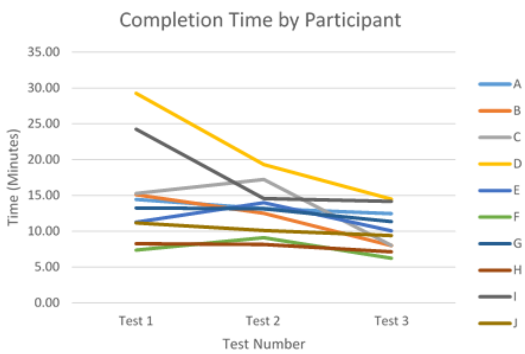


Fig. 5. Completion time by each participant.

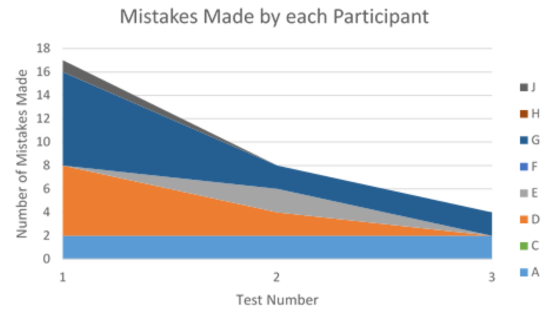


Fig. 6. Mistake made by each participant.

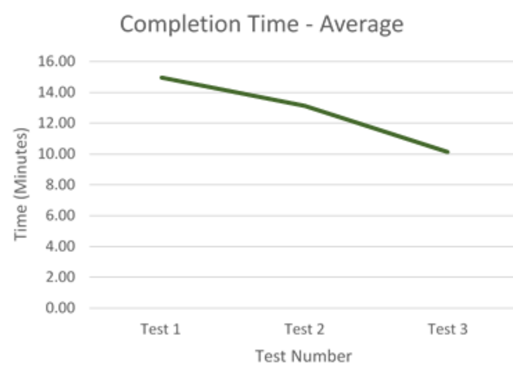


Fig. 7. Average completion time for all 3 tests.

with a feedback questionnaire to fill out with their impressions of the application.

VI. Experimental Results

While in various cases the use of the application seems to correlate with a quicker completion time, in many cases there is also a distinct correlation with errors. One participant seemed to have been confused with the information provided by the app and had connected the ports not up to their similar configured siblings, but with the same number ports on the switch. This was although they had completed the benchmark test within a relatively reasonable time with few errors.

A. Efficiency Improvement

In nearly all tests, participants were able to complete the test quicker on their final attempt than on their first. In some cases, the first test with the application being used would be performed in a longer time than the laptop test. In all cases, this would be resolved as the user became more familiar with the application. The largest difference can be observed in the participants with no networking experience. The results are illustrated in Figure 5.

On average, the time taken by participants in the last test was 67.7% that if the first. Meaning on average, the use of the application (with the prior experience of one test with it) garnered an increased efficiency of 32.2%.

B. Accuracy

After the participants finished each test, their completed setup was compared against the correct switch configuration. The number of errors made was recorded for each test for reference and illustrated in Figure 6. In nearly every test (apart from one anomalous case), the number of errors conducted during the test was either reduced or stayed the same. This can provide an alternative indicator of the performance across the three tests.

C. Learning Curve

In "mechanisms of skill acquisition and the law of practice", Newell and Rosenbloom state that repeated practice of an activity will bring improvement in that activity [23]. This can be represented by plotting a graph of aptitude against experience. This is known as the learning curve. Most demonstrations of the learning curve present a sigmoid function, where the aptitude of the individual rises exponentially up to a point where they cannot gain any more knowledge and the curve flattens out. This is to be expected when repeating the same task in the same way. To compare this theoretical model to the gathered results, the results gathered by this project should demonstrate a sharper rise in efficiency because of the application being introduced. Newell and Rosenbloom demonstrate the Power law [23] where if T decreases by a factor 5 in the first N trials, it will take another N(N-l) trials to decrease by the same factor again [23].

By calculating the average times taken, the results can be compared to the theoretical model established by Newell and Rosenbloom. Figure 7 demonstrates a distinct disparity from the theoretical model. This can be attributed to the relatively few numbers of tests conducted compared to the model. The exponential component can be seen to be interrupted by the introduction of the application in test 2, with further reduction of time in test 3.

While the app that has been developed provides a simple user interface, there are aspects of the application that mean the extended use of the application will improve users familiarity with it. Aspects such as the location of relevant options in the menu, limits of the tracking ability and more can be implemented by the participants in the test. Of all the participants tested, the final test had an improved time over

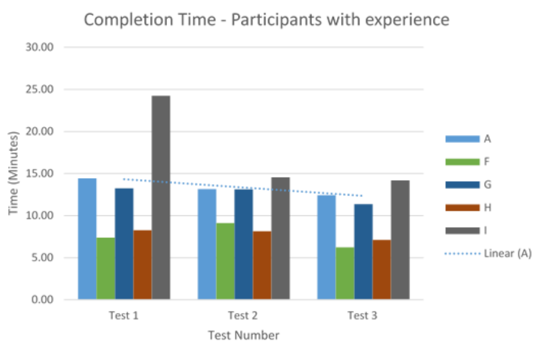


Fig. 8. Completion time of participants with networking experience.

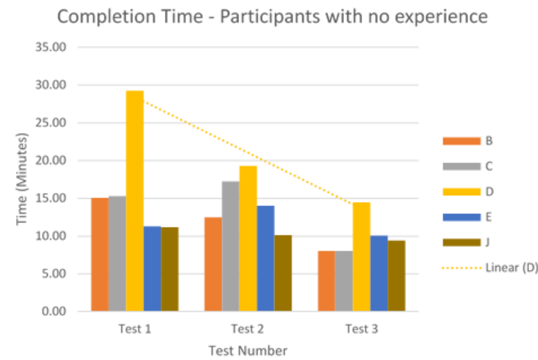


Fig. 9. Completion time of participants with no networking experience.

the first time using the application. Due to the decrease in time, it is reasonable to suggest that the application has a short learning curve. Additional tests using the application would have been advantageous, however it was difficult to get participants for the tests as the test was quite long to perform (over an hour in some cases), the resources were not available to perform the test more times.

D. Prior Experience

Before being asked to participate in the test, participants were questioned if they had any experience interacting with network equipment such as switches, routers etc. While a gauge could have been established to identify what qualifies as experience (had been in a putty config, interacted with industrial equipment etc.), this was not required, as there were no participants involved in this study with a small amount of knowledge of experience. All participants were either taken from the Computer Network Technology course at Northumbria University (i.e. over 3 years of experience in networks) or had never had any interaction with industrial networking equipment. The corresponding answers are marked on the results. A total of five of the participants had experience, while five did not.

An important trend that can be identified from the results gathered is the margin of improvement between experienced and inexperienced participants in networks. By taking averages of the times taken to complete the tests by both parties, participants with no network experience obtained an increase in efficiency on average of 39.1% (Figure 9), compared to the participants with network experience who experienced an increase of effectiveness of 24.0% (Figure 8).

From this improvement, it can be determined that the application provides more of an efficiency benefit to individuals with no previous experience handling networks. Different causes for this could be argued, that because they had no prior experience with this equipment, the results increased due to participants gaining familiarity with the equipment regardless of the application. However, this could be disputed because the test did not require an extensive understanding of the subject matter, rather using networking as a theme for a simple match test, and so their performance should not have been hindered by their lack of experience. The potential explanation for this correlation is that the application helps to visualise the networking concepts better for those not already familiar with the field. As was discussed in the literature review, AR can often aid users understanding by framing the subject matter in new and relatable ways, it could be argued that directly overlaying the port information over the users view was beneficial to the inexperienced participants in helping them understand the workings of the switchport information.

E. Discussion - Factors Affecting Results

While the improved times can be attributed to enhanced understanding while using the application, other factors must be considered when correlating these results. As the participants were completing the same test repeatedly three times, there is a potential that the application may not have increased their understanding and that the improved test times were due to participants retaining the correct combinations from reciting the same test continuously.

Participants were left to devise their own methods to best tackle the challenge. It is possible that some participants may have produced a more successful method leading to better results. It could also be considered that as the tests went on, the experience of the former tests would inform the user of better strategies that would improve their results. However, this could be disputed in that some participants performed with a slower time on their second test than their first.

When considering the retention and understanding of information in learning, many researchers refer to ”rote” learning. This is a method of learning that allows individuals to retain information due to repetition [24]. While it is argued that this kind of learning does not give a deeper understanding of the subject matter [24], it has been stated that this method of learning can give the individual increased retention of the material. This could have affected the test results in a way that reduces the amount of time that the task takes for the individual, as they have already taken the test prior. However, this could be disputed as the tests did not have a single correct answer, the nature of the port configurations meant that there were many correct combinations to correctly finish the test. In addition, in some cases the time taken to complete the test increased between the first and second tests, before reducing after the participant conquered the learning curve of the application. This shows that repeating the test does not guarantee an enhanced completion time.

Another aspect that could have affected the results obtained is the distance between the network switch and the laptop provided. It could be argued that some of the time difference in the tests could be attributed to the participant being required to move between the switch and laptop to gain the information they need. The laptop was placed on the closest surface as could be provided with the resources available. As the equipment needed for the test is only available in a limited number of labs in the University, testing had to be done in rooms with other individuals using the facilities. It can be argued that the distance between the cabinet and laptop is representative of real world networking jobs, where there are not always computers to read configurations nearby.

VII. Conclusion and Future Work

In this paper, we proposed and developed an AR application to overlay the information of a network switch when a camera is positioned towards it. User study is conducted to evaluate the effectiveness of the proposed AR app in assisting users in performing networking tasks. The results indicated that the usability of the application increases the effectiveness of the participants within the simulated network environment. The results found from the testing process also highlighted areas in which the application seemed to excel, particularly in enhancing the efficiency of individuals with no networking experience. This could indicate that with further development and expansion, this application would be beneficial in teaching network concepts to those with no prior experience.

Currently, the objects for the various switches have been manually created within the Unity editor, this includes the placing of the various labels and objects. For the application to be truly dynamic, this application could be adapted so that the sizes, locations and even the UI elements themselves can be dynamically created via the script and visual information captured from the camera. For example, upon recognizing a Cisco 3500XL 48 port switch, instead of assigning the port information to existing UI elements, the application would create the definition for that switch, with correct dimensions of the ports, switch and QR code, and create the objects for this accordingly. This will be an interesting future extension for this work. We are also interested in conducting another user study on a larger scale, such as using the App for teaching undergraduate courses, in near future to further evaluate the proposed AR App.

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