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A context-aware Tour Guide: User implications

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Abstract. Although examples of tourist guides abound, the role of context aware feedback in such systems is an issue that has been insufficiently explored. Given the potential importance of such feedback, this paper investigates, from a usability perspective, two tour guide systems developed for Brunel University: one with context-aware user feedback and the other without. An empirical study was undertaken in which each of the applications was assessed through the prism of three usability measurements: efficiency, effectiveness, and satisfaction. Incorporating the participant feedback gathered as a result, the paper compares the use of the two applications in order to determine the impact of real-time feedback with respect to user location. Efficiency, understood as the time taken by a participant to successfully complete a task, was found to be significantly affected by the use of context-aware functionality. Effectiveness, understood as the amount of information a participant assimilated from the application, was shown not to be impacted by the provision of context-aware feedback, even though average experiment duration was found to be significantly shorter in this case. Lastly, participants' subjective satisfaction when using context-aware functionality was shown to be significantly higher than when using the non-context aware application.

Keywords: Context-aware, Tour Guide, user, perception

1. Introduction

The rapid growth of mobile technologies has placed an increased focus on "context-aware" computing, which refers to a program or application feature that changes, depending on the environmental conditions of the user throughout the operation of the application [21]. The growth of context-aware computing has led to the development of location dependent applications, such as mobile tour guide systems. Although providing regular updated information about users' current location, as well as displaying detailed information about specific features linked to their position, relatively limited work has been done investigating the impact of context-aware information on system usability [6,16].

This is precisely the issue addressed by this paper, in which we compare two tour guide systems developed for Brunel University (West London Uxbridge Campus); one with context-aware user feedback and one without. This paper therefore looks at the impact of using real-time context-aware information on system usability. In so doing, we hope to depart from the implicit assumption that, in early stages of proliferation, "technology shapes usability" and highlight the specific usability issues that context-aware systems raise and that designers of such systems must consequently take into consideration. Accordingly, the structure of this paper is as follows: Section 2 discusses research related to ours, highlighting the opportunity of further exploring usability issues in context-aware systems. Section 3 then presents the developed Tour Guide systems, with their comparative evaluation being detailed in Section 4. Lastly, conclusions are drawn and possibilities for future work identified in Section 5.

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2. Background

2.1. Introducing context-aware computing

The term "context aware" software was first introduced by Schilit [20] and is categorised as software that adapts according to the location of use, as well as the proximity of entities (people, hosts, and/or devices). Moreover context-aware systems consider the changes that happen to such entities over time. Stated simply, it is a system that can examine the computing environment and react to changes in the environment based on contextual information, which relates to either [20]:

- *Computing context:* i.e. information relating to network connectivity, printers, scanners, projectors, workstations (objects that would be found in a computing environment), etc.
- *User context:* such as location and orientation, or current social issues, etc.
- *Physical context:* such as lighting, noise levels and temperature, etc.

Subsequently this definition was refined by other researchers. Thus [19] define context as "location, identity, environment and time", while [7] defines context as being any information that can be used to characterise the situation of an entity – an entity being a person, place, or object that is considered relevant to the interaction between the user and an application, including the user and the applications themselves.

Moreover, in support of earlier definitions of context [19,20], it was argued by Kotz [14] that time is also important in this case, and should be defined as the fourth component of context:

- *Time context:* such as month, time of day, season of year and date.

The concept of context is undergoing a continuous transformation and refinement. With a point of view similar to our own, Kakihara and Sørensen [13] argue for including interaction as an essential dimension of context, whilst Dourish [8] espouses that the traditional meaning of context is positivist-technical and ignores the social-phenomenological aspect. He argues that context and activity are therefore inseparable.

Context aware computing can be used in applications requiring one or more of the following four techniques [20]:

1. Proximate Selection: this is where a user interface uses context information to ensure that objects located in close proximity are emphasised to make it easier for the user to choose certain functions.
2. Automatic Contextual Reconfiguration: this is the process of using context information to remove existing components, add new components, or change the connections between the components, in order to aid usability.
3. Contextual information and commands: this represents the case where application outcomes and/or results may differ depending on contextual information.
4. Context Triggered Actions: these are systems where contextual information is combined with IF-THEN rules to specify how context aware systems should adapt.

Reported benefits of context-aware computing include improvement in overall system performance due to reduced and more efficient user interaction [22] as well as more streamlined communication [11]. Now that context aware computing, and its applications, have been defined and described, we shall take a look at existing context-aware Tour Guide applications.

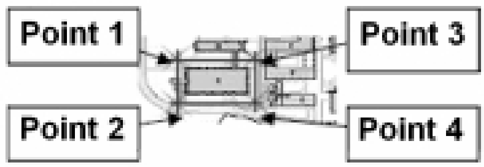

Fig. 1. Hotspot activation Polygons. Adapted from Simcock et al. [21].

2.2. Context aware tour guide applications

Tour guides are one of the earliest and most well known applications of context-aware computing. Such applications include AudioGPS [12], Deepmap [15], LAMP3D [3], LOL@ [18], GUIDE/GECS [5, 6], Hippie Hipps [17], as well as the TellMaris Guide, described by Laakso et al. [16]. This section introduces two previously developed location-based mobile tourist guide systems which are functionally closest to the developed Brunel Tour Guide system: Cyberguide [1] and Tourist Guide [21].

2.2.1. Cyberguide

One of the earliest context-aware tour guides was the Cyberguide (Abowd et al. [1]) which was initially implemented as a building guide by the Future Computing Environments (FCE) group at the Georgia Institute of Technology for the computer science department open days, and was later improved and extended to guide its users through the city of Atlanta. The FCE group was greatly influenced by PARCTab at Xerox PARC [20], the InfoPad project [2], the Active Badge System [23] and the Project Voyager Personal Shopping Assistant [4]. Accordingly, the Cyberguide aimed to build applications that would take advantage of the hardware developed in the PARCTab and InfoPad projects. Two outdoor Cyberguide prototypes were developed; one was centred on the Georgia Institute of Technology campus and the second prototype covered three residential areas surrounding the campus. The core of this system is divided into four components, namely: the map component, the information component, the positioning component, and the commutation component.

2.2.2. Tourist guide

A similar piece of work was undertaken by Simcock et al. [21] who built a location- based tourist guide application, using a PDA and a GPS connection, and explored the associated design and usability issues. The 'Tourist Guide' project investigated the use of context-aware mobile computing using visitors of the Mawson Lakes campus based at the University of South Australia and the North Terrace estate in the Adelaide city centre. The portable device used in the project was the Compaq Aero PDA, which was connected to a Garmin GPS navigation unit that provided the location information needed to run the application.

The user interface has three main modes of interactions: *map view*, where the user can see his/her location and the surrounding buildings on a map; *guide view*, where the user is provided with a path of interesting attractions, and, finally, the *attractions view*, where the user is streamed audio-visual tourist information. As the user walked near to a highlighted attraction, the system would automatically switch to the attraction mode. The location of an attraction was defined using four GPS coordinates that formed a polygon around the attraction (see Fig. 1). The attraction mode accessed 'Hotspot' files, which presented the user with contextually relevant sound, images, and text-based tourist information. All the colour schemes and map annotations were designed in a manner that is clearly visible to the user on the move.

2.3. System comparisons

The Cyberguide project team did not document their systems' requirements. However, both systems incorporated a map component. Both projects recognised that, for the majority of the time, user interests lie close to their physical location. Accordingly, both systems included a positioning module, directly connected to the map module, in order to provide feedback to the user, enabling them to recognise their location and therefore examine immediate attractions displayed on the map. In each system, a repository module was used to stored attraction information.

Both Brunel Tour Guides (context-aware and non-context-aware) will incorporate a combination of application features from both systems, as will be discussed in Section 3. It will provide users with a map of the university campus, capture positioning information from the GPS to show the users' location on the map through an indication icon, and provide information about attractions that surround them. Consequently, the Brunel Tour Guide will include map, positioning and information components to provide a service to the user. A communication component, providing interactive services and messaging capabilities, will not be implemented in either of our systems, as it is not deemed a necessary module in order to implement our study.

Both Cyberguide and Tourist Guide projects used GPS technologies. Similarly, the context-aware Brunel Tour Guide plans to incorporate GPS architectures to determine user location within the university grounds. Both Cyberguide and Tourist Guide prototypes were evaluated by large groups of users, with inexpensive, low-spec, hardware. Consequently – sadly and, perhaps, a bit unfairly – both Cyberguide and Tourist Guide prototypes were perceived as non-robust systems. The portable devices used in previous systems were limited in resources, especially when considering multimedia design features (such as sound and streaming video). To help overcome difficulties encountered with previous Tourist Guide projects, it was decided that a mobile laptop should be used for the purposes of the study.

Both guide systems aimed to develop a computer-based system that informs the user of their location in a physical setting, providing information about objects within the surrounding environment. Both aimed to prototype their systems on commercially available hardware. However, neither of these projects aimed to evaluate the usability of their systems and compare them to conventional (non context-aware) tour guide systems.

Indeed, while evaluations of context-aware tourist guides are presented as standard, with some work even focusing on field trials (Goodman et al. [10]), the exploration of usability considerations in their development has been surprisingly limited. Of the efforts in this sense, we mention Laakso et al. [16] who investigated the usefulness of 3D maps in such applications and that of Davies et al. [6] who investigated user reaction to the use of digital image capture and recognition in a modified version of GUIDE. From a very different perspective, Elting et al. [9] implemented a static tourist information system and looked at the effect that different output modality-combinations have on the devices' effectiveness to transport information and on the user's acceptance of the system being used. As test data, it uses a web based tourist guide that contains text and images, and results show that the most appealing form of information transfer is combined picture, text and speech. Nonetheless, previous work has not examined, from a usability perspective, the use of interactive maps in context-aware tour guides, which formed the focus of our efforts described in this paper. Specifically, the Brunel Tour Guide addresses this point by comparing software that does and does not incorporate information from a positioning component.

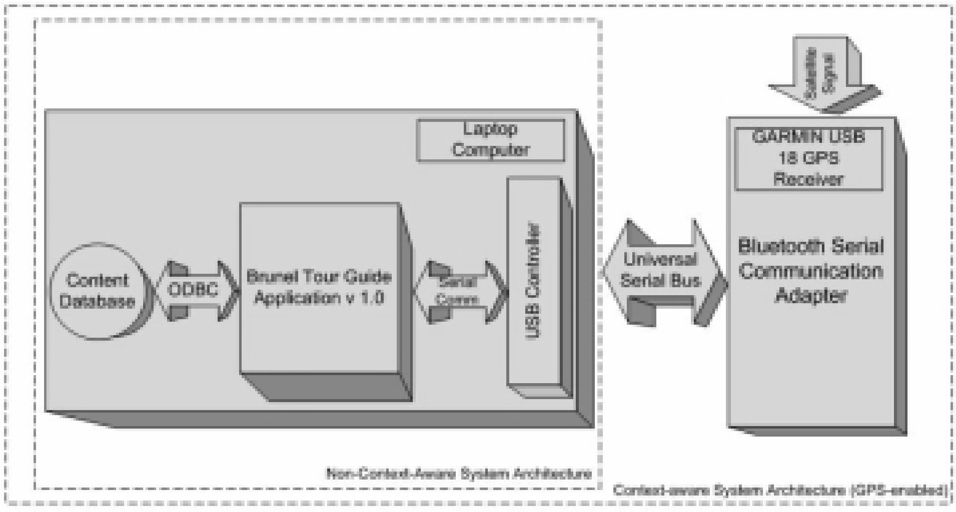

Fig. 2. Context-aware Brunel Guide System architecture.

3. The Brunel Tourist Guide System

3.1. System application design

The non-context aware and context aware applications are similar in terms of appearance and functionality. The system architecture for both consisted of two or three fundamental components (depending on the particular version), which included a map, positioning and information components.

Figure 2 illustrates the relationship between all components. The non-GPS system does not use GPS, and therefore a positioning component was not be included in its system architecture. The primary point of interaction on the user interface was via a map display of the campus. All major attractions / buildings were included in the tour content and users distinguished the location of these by using the map. Accordingly, when using the non-context-aware system, there was a mechanism allowing users to view detailed information about a particular building. Each building was allocated some kind of icon to represent its presence on the map, allowing users to click on the icon to enter a range of information about that particular building. The component information about each specific location was broken down into details about a particular building, including a textual description and images of the indoor contents. Additionally, this information was also broken down, by presenting a list of departments/units associated with each building and, subsequently, access to its relevant details was provided.

Because the context-aware Brunel Tour Guide is an upgrade of the non-GPS application, the only addition to the program was the incorporation of a positioning component (see Fig. 2). This is the variable that differentiates the two systems. This study is primarily concerned with the usability impact of integrating this component. The role of the positioning component determines the real-time location of the user: latitude, longitude and altitude, respectively. These coordinates can be used to calculate the user's pixel position on the map. This pixel position represents the user's current real-time location, which will be visually displayed on the map through a user location icon. The map will include hidden polygons, which each behave as a dynamic proximity location box – when the user walks into one of these boxes, a list of buildings will be displayed, using pop-ups, of information in the user's proximity

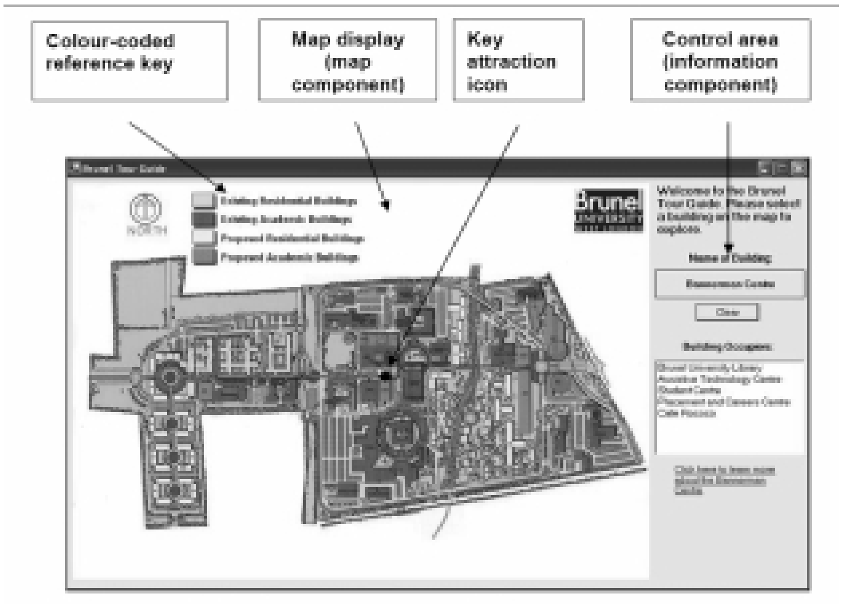

Fig. 3. Non-GPS application: Primary user interface form (information component).

via the information component. Users will be able to select which building they wish to view and, similar to the non-GPS system, the associated information linked to each building.

A Toshiba (1.5 GHz, 448 MB RAM) Personal Laptop, running Microsoft Windows XP Professional, was used in our study, in conjunction with a Garmin USB GPS 18 receiver, structured to function via the Comport 5 input at a baud rate of 4800 KHz.

The non-GPS application was implemented first, using Microsoft Visual Basic.NET (VB.NET). The GPS application incorporated the Franson GPS Tools. The Franson GPS toolkit provided a connection to the GPS device within the application. Google Earth, an interactive global map service (earth.google.com), was used to determine the polygon coordinates used to trigger pop-up information windows. In terms of the tour content, the vast majority of attraction information used in both applications, as well as the campus map, was extracted from the Brunel University corporate website and Intranet. The user interface designs for both systems were based on the same basic interface design. Although the map display was defined as the primary point of user interaction on the interface, a designated control area was included as input was required when operating the non-context-aware Brunel systems (see Figs 3 and 4). A total of one hundred and forty four user interface forms were created when implementing the non-GPS application. One hundred and sixty two forms were created for the GPS-based Tour Guide. The association links between the forms in both systems were based on a detailed use case and activity assessment. It was imperative to create a significant amount of forms as both applications were to be visually driven.

Figures 3 and 4 show the user interface for the non-context aware system. When a building is clicked on the interface, the control area expands and a list of departments/services appears in a list box that relate to the chosen building. The expansion of the control area triggers the appearance of the information component, so that users are able to browse through detailed information about all activities based inside a particular building (see Fig. 4).

Figure 5 shows the primary user interface for the context-aware Brunel Tour Guide system. In addition to the functionality of the non-context aware system, the context-aware system incorporates and displays

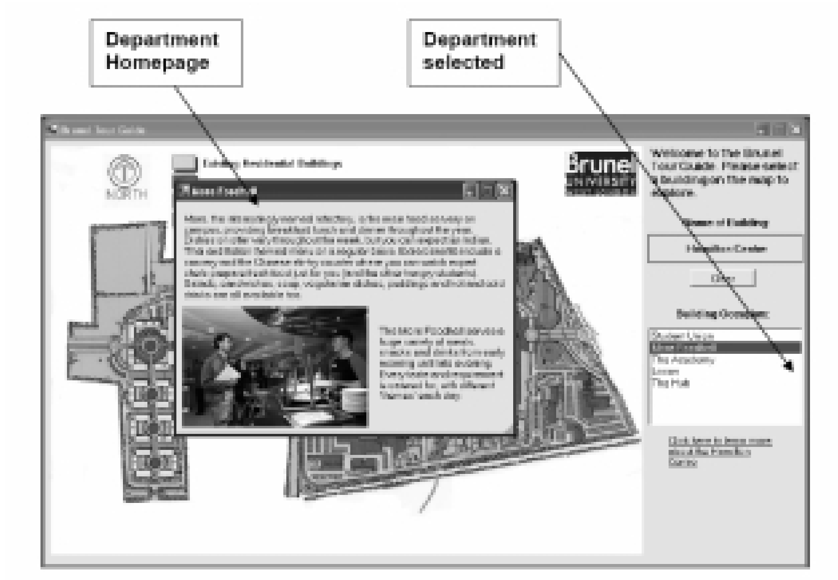

Fig. 4. Non-context-aware system – Information relating to Brunel University FoodHall ('More FoodHall').

GPS feedback to the user. This comprises of latitude, longitude and altitude feedback, as well as an indication of satellite coverage during a position fix. Furthermore, it provides regular updated information on the status of the GPS receiver as it attempts to capture signals from the satellites. Data from the positioning console is used to calculate the position of the user in relation to the map by drawing an appropriately placed icon. Based on the position of this icon, relevant attraction information will appear automatically on the user interface, via the information component of the software.

Figure 5 shows a screenshot of the context-aware Brunel Tour Guide when the user walks near the University's Hamilton Centre, with the name of the attraction being displayed in a label. However, in contrast to the non-context-aware application, a list of departments based inside appears in a pop-up window. This pop-up window emerges if the user is in the physical vicinity of a particular building. The triggering of a pop-up window is dependent on the GPS data shown in the GPS console. Data from the console shows the position of the user in relation to the map by drawing a red icon at the relevant pixel position. The icon is dynamic and flashes, in order to attract the attention of the user. Based on the position of this icon, the appropriate pop-up window appears automatically on the user interface.

4. Evaluation

Each system was assessed against three usability measurements: effectiveness, efficiency and satisfaction. This section starts by discussing the evaluation strategy applied in more detail. This is followed by a comparison of both context-aware and non-context aware applications in order to determine whether the notification of real-time feedback of user location positively or negatively influences three usability measurements (efficiency, effectiveness and satisfaction). Subsequently, research results should help provide information to assess the benefits and aid development of GPS-based mobile tourist guide software.

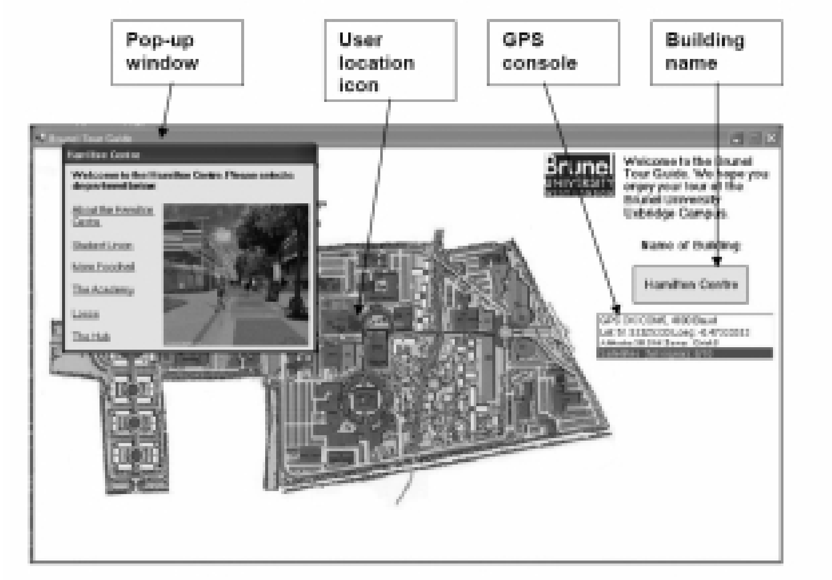

Fig. 5. Context aware Brunel Tour Guide: Hamilton Centre.

4.1. Evaluation strategy

To test context-aware and non-context aware systems, a simple system experiment was used. The experiment involved a consistent tour of the campus using a defined route (see Fig. 6 for the route that was followed). The route visits a total of twelve buildings, starting from the St. Johns (Information, Systems and Computing) building and travelling around the University perimeter road. The route purposefully took the participant in a loop, yet included navigation though the central area of the campus.

The overall aim of the experiment was to compare the usability of both systems, which we examined via a 3-pronged measure comprising *efficiency*, *effectiveness*, and *satisfaction*:

– Efficiency was considered as the measurement of time taken by a user to complete a set of tasks. This parameter was measured by recording how long it took for the participants to answer the questions, using a timer/clock.
– Effectiveness was measured as the type and level of information assimilated by the user. This parameter was measured by getting participants to answer three questions about each of the buildings that they encountered during their tour. Participants each used one of the two versions of the Brunel Tour Guide system, either context-aware or non-context aware, to answer these questions, and their ability to answer correctly was recorded. The questions were designed so that answers were definitely either correct or incorrect.
– Satisfaction relates to the user's attitude and general level of comfort towards the computer-based program. This parameter was measured by asking each participant to indicate their level of enjoyment whilst using the system on a scale from one to ten.

Twelve participants took part in the empirical evaluation. Six participants used the non-context-aware application and six used the context-aware system. All twelve participants carried out the experiment with the same controlled conditions. A brief introduction of the project (see Appendix A), a set of instructions (also see Appendix A) and a short training session concerning use of the system (ether

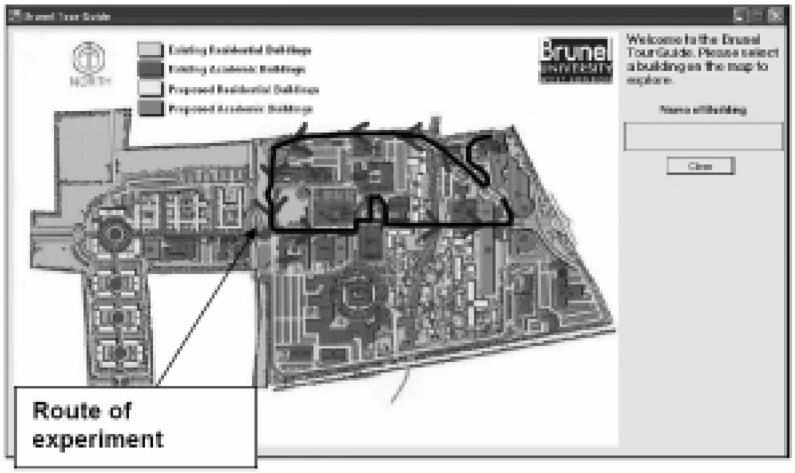

Fig. 6. Evaluation route.

context-aware or non-context-ware) was delivered to each participant. A paper map of the route was given to each participant. Participants had no previous knowledge of the topology or the route to be followed, nor the questions that were asked. Using the onscreen and paper maps, participants navigated between certain target buildings. Participants were asked to stop once they arrived at a target building marked on the paper map. Once a participant arrived at a particular building, a timer was started and they were asked to answer three relevant questions about the current building (see Appendix B). When participants had answered all questions, the timer was stopped and the participant moved on to the next location.

4.2. Results and analysis

After all experiments were conducted, the participants' data was analysed. Score, time and satisfaction were classed as dependent variables, with time representing efficiency (the combined average time taken for participants to answer the questions), score representing effectiveness (the participants combined average number of questions answered correctly) and satisfaction represented by the participants' combined average level of comfort towards the use of the systems. In order to analyse these usability measurements, the following analysis questions will be addressed in Sections 4.2.1, 4.2.2 and 4.2.3 respectively for each usability variable:

- Is this variable dependent on the building, which is being visited?
- Is this variable dependent on the question number?
- Is this variable dependent on the participant conducting the experiment?
- Is this variable dependent on the incorporation of context-aware functionality?

4.2.1. Efficiency

Is the time dependent on the building, which is being visited?

An ANOVA test was done, with time as the dependent variable and the building as the independent variable – $F(1, 11) = 17.399$, $p < 0.001$. Results show (see Fig. 7) that the time taken to assimilate information at the first three buildings in the experiment was high compared to buildings 4–11. This

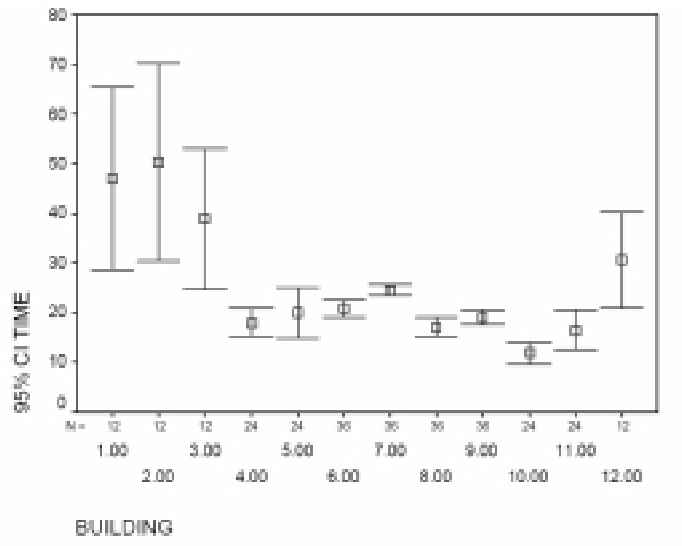

Fig. 7. Error Bar: Time (in seconds) against Buildings (1–12).

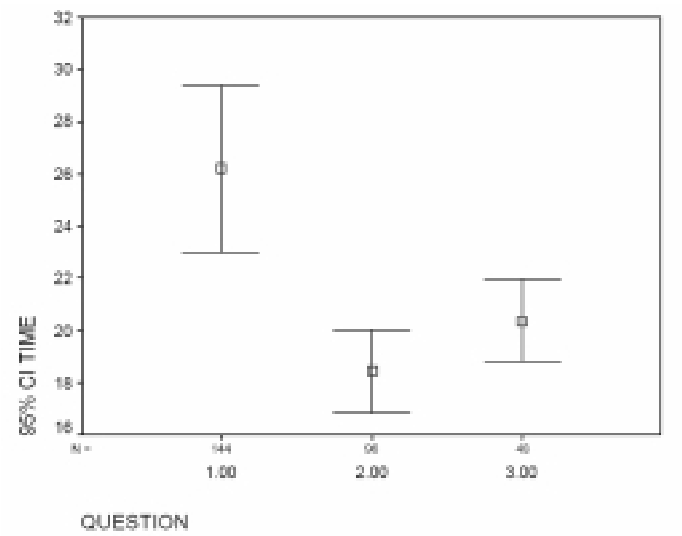

Fig. 8. Error Bar: Time (in seconds) against Question (ordered 1–3).

decreases for the fourth and subsequent buildings due to participants learning how to use the system. The time required to find information concerning the last few buildings is also significantly varied.

Is the time dependent on the question number?

An ANOVA test was done, with time as the dependent variable and the question number as the independent variable – $F(1,2) = 8.771$, $p < 0.001$. Accordingly, we found a significant impact on the time required to answer certain questions (independent of the particular building).

Figure 8 shows that the time taken to assimilate information, when answering the first question, was significantly higher to the time of subsequent questions. This is probably due to participants initially needing more time to become familiar with the menu options and information relating to a particular

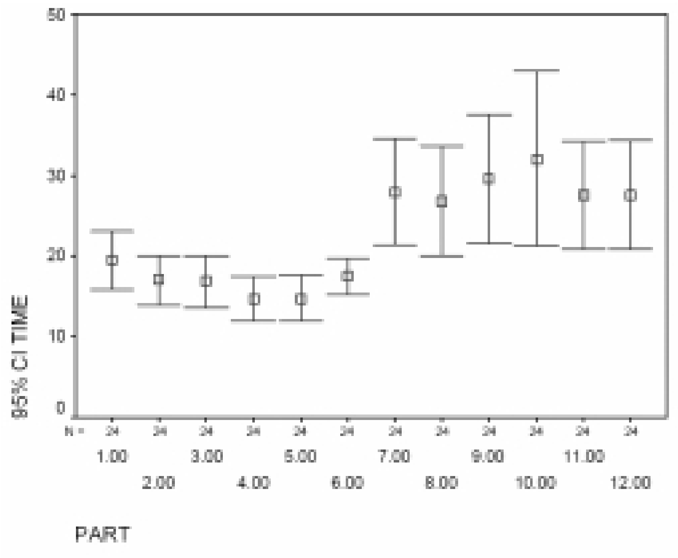

Fig. 9. Error Bar: Time (in seconds) against Participant number (1–12).

building or department.

Is the time dependent on the participant conducting the experiment?

An ANOVA test was done, with time as the dependent variable and the participant as the independent variable – $F(1,11) = 5.101$, $p < 0.001$. Interestingly, results were consistent for the first and the last six participants – this represented respectively the context-aware and non-context aware systems.

The six participants using the non-context-aware system took significantly longer to absorb information (see Fig. 9). However, a within measures comparison presented no significant difference between participants using the same tour guide application. This suggests that use of context aware information can significantly help a participant to absorb relevant information more quickly.

Is the time dependent on the incorporation of context-aware functionality?

To support of the previous finding, an ANOVA test was done, with time as the dependent variable and the use of GPS as the independent variable – $F(1,1) = 52.807$, $p < 0.001$. This result showed a surprising variation in time, with context-aware participants answering questions approximately 80% faster than non-context-aware participants.

Figure 10 shows that participants using the context aware version of the tour guide took significantly less time to assimilate information and complete the experiment when compared to those participants using the non-context-aware system. This is an exceptionally interesting result. From a business perspective, this result implies that the use of context-aware applications could allow an increased number of people/visitors conducting tours, in a set period of time. Alternatively, a context-aware system would allow more attractions (information) to be incorporated in a tour. From a perception/educational context, it is interesting as it implies that being context aware is critical to the amount of information that can be assimilated in a definite duration of time.

4.2.2. Effectiveness

Is the score dependent on the building, which is being visited?

An ANOVA (ANalysis Of VAriance) test was done, with score as the dependent variable and building number as the independent variable – $F(1,11) = 1.443$, $p = 0.153$. Although not significant, the

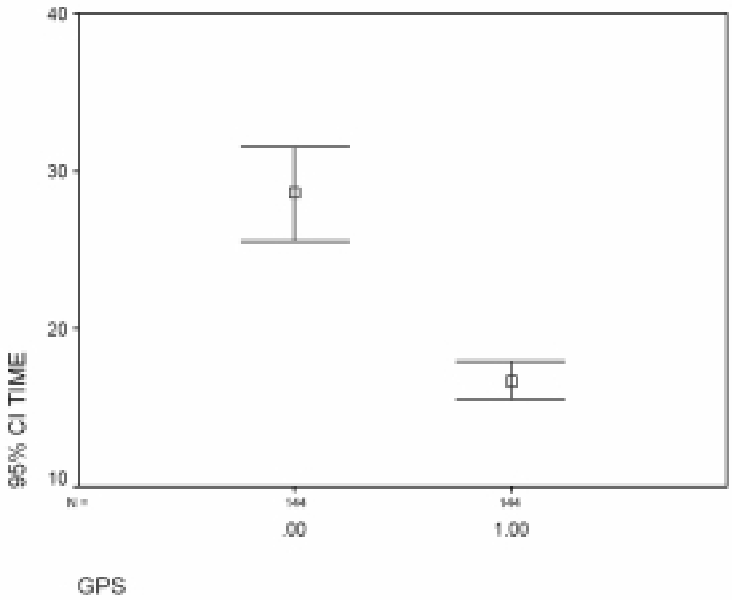

Fig. 10. Error Bar: Time against GPS (.00 denotes non-GPS system, 1.00 denotes GPS Tour Guide).

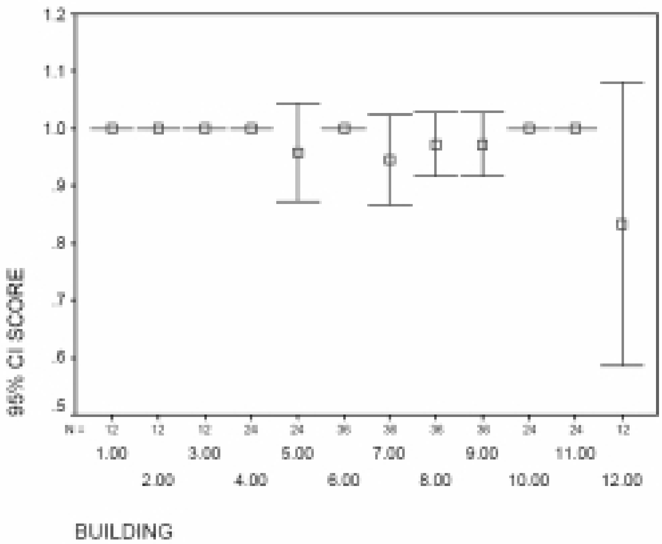

Fig. 11. Error Bar: Score against Building. Score is defined as proportion of questions answered correctly (0 = all wrong, 1 = all correct).

variance in participants' ability to answer questions correctly is shown in Fig. 11. The most extreme variance can be found for building twelve (the last building on the tour – when participants were more focused on completing the task, than correctly answering the questions). When visiting this building, there was a significant variation in the range of scores. Because we had a high standard deviation in scores for the last question, the result was not considered as significant. However this represents a considerable spread, and a large drop in average. This result may be because of limited participant

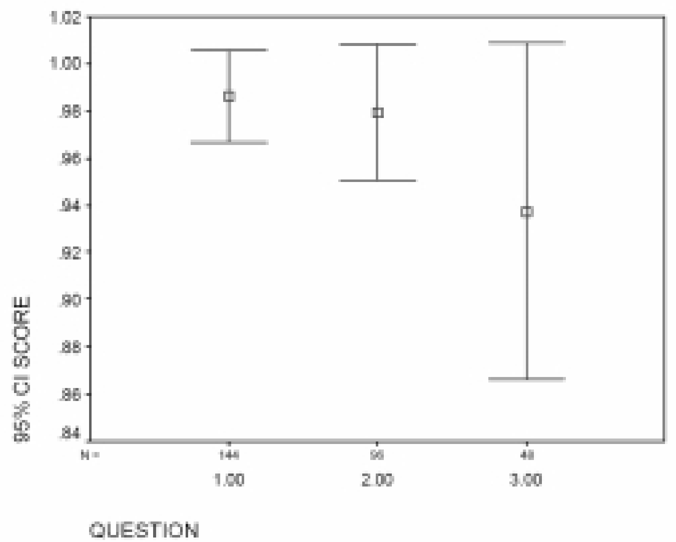

Fig. 12. Error Bar: Score against Question. Score is defined as proportion of questions answered correctly (0 = all wrong, 1 = all correct).

interest in the specific building, but is more likely due to order effects.

Is the score dependent on the question number?

An ANOVA test was done, with score as the dependent variable and the question number (independent of building) as the independent variable – $F(1,2) = 1.834$, $p = 0.162$. Again the statistical result is not significant. Interestingly, however, Fig. 12 shows that, as the participants answers more questions the overall average score falls. The majority of participants answered the first two questions correctly. But increased variation occurred in participants' ability to correctly answer the last question. This is likely because participants assumed that they knew the answer to a third question based on the information that they had absorbed when answering the first two questions.

Is the score dependent on the participant conducting the experiment?

An ANOVA test was done, with score as the dependent variable and the participant as the independent variable – $F(1,11) = 1.105$, $p = 0.357$. Greater consistency in results was found for the first six participants, who used the context-aware system. Nonetheless, this finding was not statistically significant.

Is the score dependent on the incorporation of context-aware functionality?

An ANOVA test was done, with score as the dependent variable and the use of GPS as the independent variable – $F(1,1) = 0.145$, $p = 0.703$. A slight increase was found in the combined average score of the participants using the context-aware system, yet this finding was not statistically significant. Accordingly, in our study, individuals using the context-aware system, despite being able to navigate between and engage with locations with increased efficiency, were still able to assimilate similar amounts of information.

4.2.3. Satisfaction

Is satisfaction dependent on the building, which is being visited?

An ANOVA test was done, with satisfaction as the dependent variable and the building number as the independent variable – $F(1,11) = 0.000$, $p = 1.000$. Due to the single assessment point, this

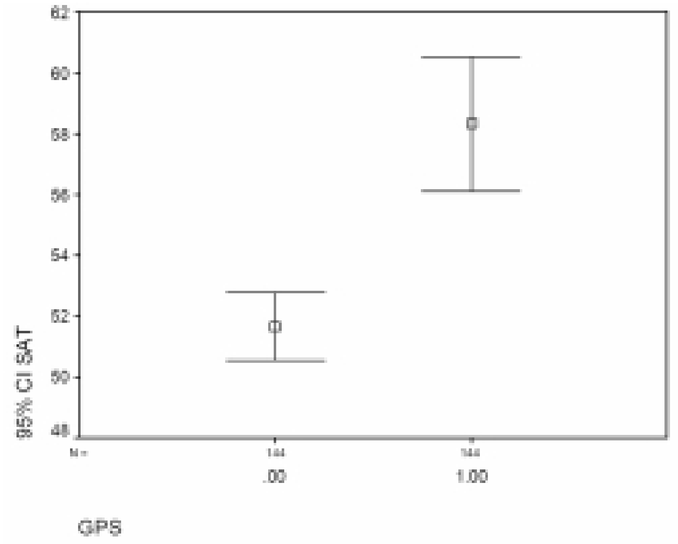

Fig. 13. Error Bar: Satisfaction (%) against GPS (0.00 denotes non-context aware, 1.00 denotes context-aware).

test showed no variation in satisfaction feedback, implying no preference was made to any particular building.

Is satisfaction dependent on the question number?

An ANOVA test was done, with satisfaction as the dependent variable and the question number as the independent variable – $F(1, 2) = 0.000$, $p = 1.000$. Due to the single assessment point, this test showed no variation in satisfaction feedback, implying no preference with respect to question number.

Is satisfaction dependent on the participant conducting the experiment?

An ANOVA test was done, with satisfaction as the dependent variable and the participant number as the independent variable – $F(1, 11) = 5.888$, $p < 0.001$. Not surprisingly, this result showed a significant variation. People always like different things, so it is rarely a surprise to find significant variation as a result of individual user preference.

Is satisfaction dependent on the incorporation of context-aware functionality?

To check whether use of a context-aware system impacted a users' general satisfaction, an ANOVA test was done, with satisfaction as the dependent variable and the use of GPS as the independent variable (independent of a specific participant) – $F(1, 1) = 27.902$, $p < 0.001$. This finding was also found to be significant, with users of the context aware system being, on average, more satisfied when using the system (see Fig. 13).

This may have been because it was quicker to navigate around the campus; maybe it was due to the context-aware system requiring less input contribution in order to operate the system. Perhaps users were simply fascinated by the appearance of the pop-up windows and the red flashing icon that represented their current real-time location. Further work is required to analyse and assess such factors.

5. Conclusion

This paper explored the role of context-aware feedback in tour guides. Accordingly, we have presented the results of an experiment in which the usability of two different versions of a tour guide (one with context aware feedback and the other without) were assessed through the prism of three metrics, namely effectiveness, efficiency and satisfaction.

Efficiency of any participant, when assimilating information about a building on a tour guide, was affected by factors including: the building number (the number of a building on a defined route), the question number (whether it was the first, second or third question relating to a specific building), and the use of context-aware functionality. Content-aware functionality, via use of positioning feedback, led to participants answering questions approximately 80% faster than non-context aware participants.

Interestingly, although participants assimilated information in a shorter period of time, the effectiveness (the overall score) of participants was not affected by the factors described above. This implies that participants are able to assimilate the same level of information in almost half the time! Moreover, the level of satisfaction experienced by participants using the GPS tour guide (context-aware system) was also significantly greater, with a mean increase of 6.5%.

Our results imply that inclusion of context-aware information in tour guide systems, whilst maintaining information assimilation levels, can increase participant efficiency and overall user satisfaction. The potential implications to current commercial users of non context-aware tour-guide systems are a faster-turn around of customers and a higher level of customer satisfaction. Potential implications of this study to non tour-guide non context-aware systems is the implied benefits of using content to increase user's task efficiency, yet maintain information transfer. Use of context in military, transport and navigational systems are largely commonplace, yet we believe that inclusion of context in pervasive, engineering, architectural, and/or health-care applications has much potential to offer. In addition, our results suggest that effective use of context in education-based systems could result in significant increases in user learning. Further work is obviously required to increase our knowledge concerning the impact of context-aware systems on usability. This paper, however, has provided evidence that suggests considerable future potential to the use of context-aware systems.

Appendices: Evaluation material

A. Participant Instructions

Brief introduction of the project

The aim of the project is to develop a GPS-based interactive mobile tourist guide system of the Brunel University Uxbridge campus. One of the objectives is to compare the usability of the GPS-based system against a non-GPS equivalent application. One of the systems incorporates the use of the GPS and the other does not. The objective is to investigate whether the incorporation of GPS has a positive or negative impact on 3 usability measurements of:

- Effectiveness: The type and level of information assimilation/absorption for the user.
- Efficiency: The time taken to complete tasks and the resources exploited in achieving them.
- Satisfaction: The level of users comfort, enjoyment and attitudes towards the use of a mobile tourist guide system.

Instructions

For this experiment, we are going to go on a tour of the campus. We are going to take a particular route. In that route, we are going to visit some buildings. We are going to stop at each building and I am going to ask you some questions based on that building. You will use the system to answer these questions. There is no time limit, but a timer will be used for my reference. So, take as long as you want to answer the questions.

The 3 usability measurements stated will be measured in the following way:

– Effectiveness: The total number of questions you correctly answer.
– Efficiency: The total time to answer all the questions at a particular building.
– Satisfaction: Your subjective opinions on the system via a talk-aloud protocol, during your tour.

The timer will start on arrival at the target building and it will stop on departure. The questions will be given to you on arrival at the destination building, once you believe you have found it, using the software.

B. Participant questions

1. Go to St Johns:
   (a) In DISC, read out the course description for 'Information Technology MRes' under 'Postgraduate Courses'. *Answer: The course aims to provide a detailed insight into IT research and will prepare students either for PhD study or for a career in this profession.*
2. Go to New Student Residential Accommodation (Phase V):
   (a) Read out how many more en suite rooms will be constructed at Uxbridge over the next two years, and read how many rooms this will complement which are already on campus. *Answer: More than 1200 en suite rooms will be constructed at Uxbridge over the next two years to complement the 2663 already on campus.*
3. Go to Experimental Techniques Centre:
   (a) Read out the full names of the people to contact for further information. *Answer: Dr Robert Bulpett and Dr Alan Reynolds.*
4. Go to Science Building:
   (a) Read out the names of the departments based inside the Science Building. *Answer: Biosciences, Sport Sciences, BIB and BEC.*
   (b) For the Institute for Bioengineering (BIB), read out the telephone number to contact for further information. *Answer:* (*44*) *01895 271 206.*
5. Go to Wilfred Brown Building:
   (a) Read out the names of the departments based inside the Wilfred Brown Building. *Answer: Registry, Estates, Beldam Gallery and Marketing.*
   (b) Read out the name of the department that administers the Beldam Gallery. *Answer: Arts Centre*
6. Go to Bannerman Centre:
   (a) Read out the names of the departments based inside the Bannerman Centre. *Answer: Brunel University Library, Assistive Technology Centre, Student Centre, Placement and Careers Centre, Café Rococo.*
   (b) Read out the opening hours of the library on a Saturday during term time. *Answer: 09:30–16:00* (*no enquiry service available*)

(c) Read out the opening times of Café Rococo and the products that the outlet provides. *Answer: Mon-Fri 8:00am–6:00pm, Coffee, Sandwiches, Paninis, Pastries, Cakes, Flapjacks, Muffins.*

7. Go to Hamilton Centre:

(a) Read out the names of the departments based inside the Hamilton Centre. *Answer: Student Union, More Foodhall, The Academy, Locos, The Hub.*
(b) Read out the name of the President of the Student Union. *Answer: Jo Baines*
(c) Read out what time alcohol is served from, in Locos. *Answer: 11am*

8. Go to Lecture Centre:

(a) Read out the names of the departments based inside the Lecture Centre. *Answer: Learning and Teaching Development Unit, Media Services, Disability and Dyslexia Service.*
(b) In the Disability and Dyslexia Service department, read out the e-mail address to contact for further information. *Answer: disability@brunel.ac.uk*
(c) Read out how much money is being invested in updating the buildings teaching infrastructure. *Answer: £160m*

9. Go to Halsbury Building:

(a) Read out the names of the departments based inside the Halsbury Building. *Answer: Institute for the Environment, Brunel Graduate School, Wolfson Centre.*
(b) Read out the names of all the MSc Degrees on offer in the Institute for the Environment. *Answer: Ecosystem and Human Health, Environmental Pollution Science, Environmental Science with Legislation and Management.*
(c) Read out the fax number to contact for further information in the Wolfson Centre. *Answer: 0044* (*1*)*895 203376*

10. Go to Maths Building:

(a) Read out the names of the departments based inside the Maths Building. *Answer: Computer Centre, Mathematical Sciences.*
(b) Read out the facilities that the Mathematical Sciences department provide. *Answer: Laboratories, Video Conferencing, MSDN.*

11. Go to Sports Centre:

(a) Read out the names of the departments based inside the Sports Centre. *Answer: Sports Centre, Bar Zest*
(b) Read out the opening hours of Bar Zest during weekends. *Answer: 10.00am–3.00pm*

12. Go to Indoor Athletics Centre:

(a) Read out the first three facilities the Indoor Athletics Centre offers.
Answer: 132 m of indoor sprints & hurdles straight, Movable High Jump bed, Pole Vault

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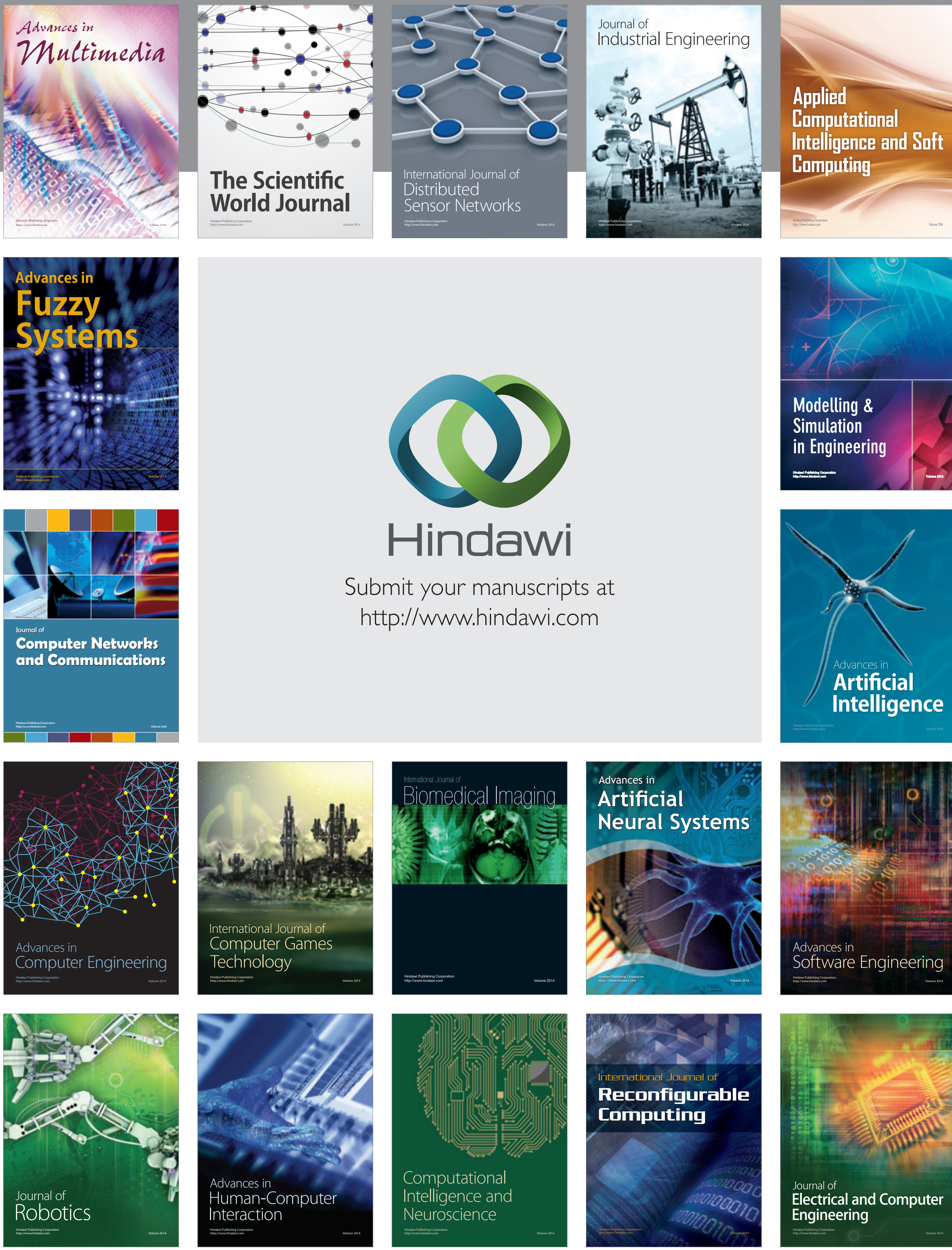
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