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DEVELOPMENT OF A UBIQUITOUS LEARNING PROTOTYPE TO ADDRESS VEHICLE TELEMATICS

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ABSTRACT

In education and vocational training, e-Learning systems are often considered to play a key role in disseminating knowledge. However, including the disclosure of complex products for engineering and design is difficult in distance learning setups. Such content calls for solutions beyond standard rich text formats, whilst learners might easily get lost in 3D virtual representations. This paper presents the development and results of an interactive prototype. The central notion is the employment of a three-dimensional model as navigation and messaging means. As a part of the EADIS project on teaching automotive telematics, an application is tailored to provide a research case study learning unit. The content features work of mechanical engineering students on tele-sensing of a hybrid car and the spatial structure of the vehicle is used to navigate through the information. It has been evaluated informally by automotive experts, which appraised the novel user experience. Although similar user interfaces have been presented elsewhere, the contribution of this work is the information design and didactic approach, which facilitates the future development of similar e-learning experiences.

KEYWORDS

E-learning, interface design, ubiquitous learning, multi touch, telematics.

1. INTRODUCTION

At present and in the near future, e-Learning systems play a key role in education and vocational training. With the advent of rich Internet applications and wireless communication facilities, modern distance learning applications can be accessed by anyone, anytime. Online computing features support social networks and peer-to-peer learning, leading to potential communities of practice in a wide range of interests.

However, the disclosure of complex products for engineering and design is difficult in distance learning setups. For example, a car harbours a multitude of elements and functions. To compile such topics to educational content calls for solutions beyond standard rich text formats. 3D representations might solve some of these issues, but learners are highly likely to get lost in virtual space.

This article covers the development and results of an interactive mobile learning prototype that provides a spatial navigation paradigm. It is part of an European Union-funded project entitled “The European Automotive Design Innovation Studio” (EADIS). After explaining the background on the overall project and didactic aspects of mobile learning, the article provides details on the prototype and its software architecture. Then, initial evaluation is discussed, followed by conclusions and future developments.

2. BACKGROUNDS

2.1. EADIS objectives and structure

As part of the European Commission's Lifelong Learning Programme, Leonardo Da Vinci an internationally funded collaborative initiative was formed in Late 2008, called European Automotive Digital Innovation Studio (EADIS)[1]. It aims to support national training strategies by funding a range of transnational partnership projects aimed at improving quality, fostering innovation and promoting the European dimension in vocational training. EADIS was awarded 400,000 Euros to bring together five automotive and design-related educational institutions from across Europe to develop a knowledge map for vehicle telematics and an internationally accessible virtual learning environment (VLE) in the form of an online training programme. It aims to promote a multi-disciplinary awareness of telematics technologies, systems and their appropriate and innovative integration and application. This VLE is known as the Digital Innovation Studio (DIS) and will be used to train and develop professional designers in the automotive industry [Peck and Verlinden, 2009].

The five partners include: Coventry University (UK); Oulu University of Applied Sciences (Finland); Munster University of Applied Sciences (Germany); Turin Polytechnic (Italy); and, Technical University of Delft (Netherlands). The team have diverse and complementary specialisations, ranging from: e-learning and the technological development of online learning environments and content; programming; automotive design and industry liaison; industry connections and project management. All have a common interest in promoting vehicle telematics awareness. Importantly, the project is also supported by an advisory panel made up of industry representatives including Tom-Tom, FIAT, BMW, MIRA, The Where Business & TNO. This panel helps to evaluate and advise on the development of the VLE content.

We investigated presentation and didactic issues of nomadic learning to explore the potential of mobile learning as presented by several researchers, like Tella (2003) regarding access and richness of information. In achieving this, EADIS aims at emerging learning methods and technologies, such as Mobile and Ubiquitous Learning (Horvath et al., 2009). A number of web-based tools were selected to establish this, including Moodle and Typo3 (Bull et al., 2009). The telematics curriculum was structured in a basic module and three optional modules to specific interests, namely design, engineering and innovation management. The basic module, called the EADIS Knowledge Core is depicted in Figure 1 below. Each of the rectangles represents a learning unit that the learner can access, each representing material that can be studied in 20-45 minutes. Furthermore, each learning unit can refer to other internal or exernal sources of information, while a

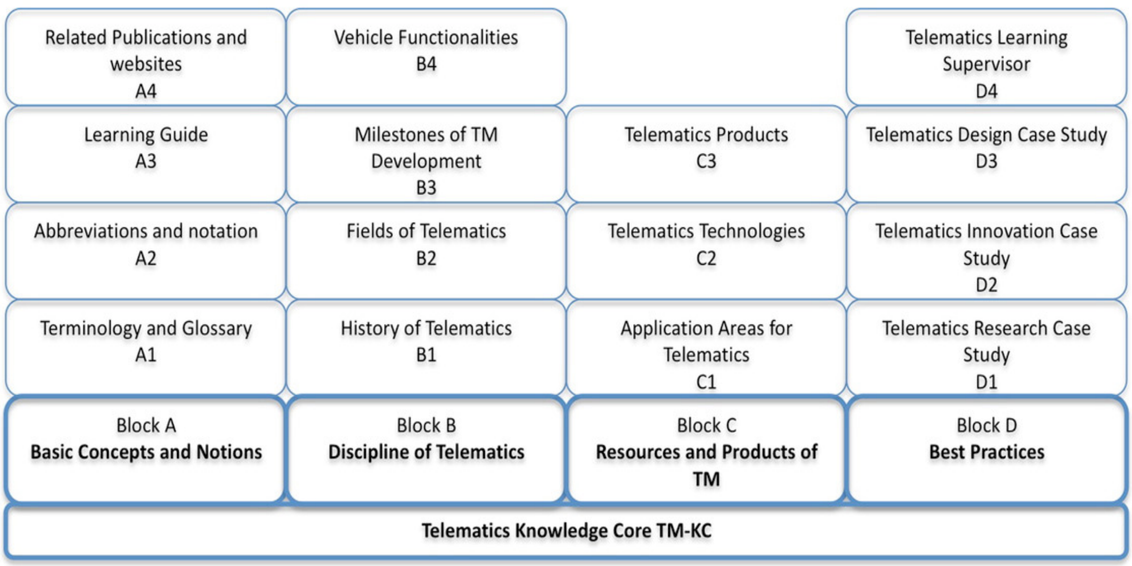

Figure 1 EADIS Telematics Knowledge Core (Bull et al., 2009).

[1] www.eadis.eu

telematics learning supervisor tracks the progress of the learner.

The Case Study covered in this article would be hosted as one of the EADIS Learning Units labelled Unit D1 *Telematics research case study*. The specific objective of this task is to develop and evaluate a pilot implementation of this learning unit. If successful, the same framework can be applied to similar telematics case studies throughout the curriculum.

2.2. Case Studies and E-learning

Although many topics in the curriculum of the vehicle telematics course can be taught from their theoretical basis, examples and best practices allow the learner to be aware of the challenges of integrating various types of ICT technologies in automotive applications. Such demonstrations of theoretical concepts in an applied setting are well known as Case Studies. As Davis and Wilcock (2009) propose, these cover a variety of different learning structures, ranging from individual case studies to longer group-based activities. Essential characteristics of case studies are outlined in Yin (1988). Firstly,: the case is a 'bounded system'- it has boundaries, Secondly, there is an explicit attempt to preserve the wholeness, unity and integrity of the case. Finally, multiple sources of data and multiple data collection methods are likely to be used, which are collected in a case study database. Gross and Davis (1993, p. 162) claim that a good case study tells a story, raises a thought-provoking issue, has elements of conflict, promotes empathy with the central characters, lacks an obvious and clear-cut right answer, encourages students to think and take a position, demands a decision and is relatively concise.

As Kreber (2001) argues, case studies have the potential to create genuine experiential learning experiences, to balance theory based education that is paramount at universities. Raju and Sanker (1999) demonstrate the importance of case studies in engineering education to expose students to real-world issues with which they may be faced. Case studies have also been linked with increased student motivation and interest in a subject (Mustoe and Croft, 1999), which is relevant in the field of vehicle telematics, as its body of knowledge easily converts to a technical encyclopaedia. Grant (1997) outlines the benefits of case studies as an interactive learning

Figure 2 The testing car at Oulu University of Applied Sciences.

strategy, shifting the emphasis from teacher-centred to more student-centred activities.

To develop a case study database that can be repurposed to various didactical means, the Learning Objects paradigm plays an important role in this endeavour. Learning Objects (LOs) are knowledge constructs, which capture the content of the learning. They can be represented in various forms including text, graphics, audio/video and other media, and can be organized into learner and topic oriented education modules (Churchill, D., 2007). The main advantage of such an object-oriented approach is its versatility in structuring, extending and formatting e-learning projects.

3. PROTOTYPE AND ARCHITECTURE

To devise the learning unit, a standard e-learning workflow was adhered, in which i) we explored and demarcated the case study content, ii) developed a case study database and subsequently refined the learning objectives and iii) developed a content structure and iv) a suitable information disclosure method. Upfront we knew that the case study included many design and engineering solutions. To compile these topics calls for solutions beyond standard rich text formats. These topics are discussed in detail in the following sections.

3.1. Case Study Content: the OAMK Prius

At Oulu University of Applied Sciences (OAMK), the Department of Mechanical Engineering trains their students in optimizing the performance of car engines. To facilitate both staff and student research on telematics, a vehicle tele-sensing test bed was developed based on a Toyota Prius (Figure 2). Several commercial and in-house devices are interconnected to enable remote monitoring. As the car hosts complex electronics to control the hybrid engine and is already equipped with an extensive array of sensors to monitor the driver behaviour, it serves as a springboard for students and staff of

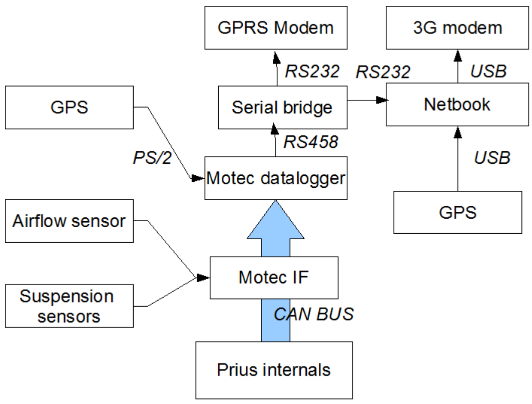

Figure 3 Embedded components and electric connections.

OAMK to develop additional in-car and external sensing capabilities. A collection of extensions and tests were successfully done.

In order to host student home-made components and services, the approach was chosen to select an open architecture, available for extension by students with some programming skills. As figure 3 indicates, the architecture includes an interface to connect to the onboard diagnostics infrastructure (the CAN bus). The internal diagnostics reported on over 100 different sensors and engine states, including speed and acceleration of each wheel, torque on the steering wheel, state of the battery and so on. At OAMK, an array of additional sensors were integrated by students, including an airflow sensor to measure wind speed, several GPS units to add accuracy in positioning and time information, and a small laptop to convert, accumulate and interpret system data to meaningful events.

The communication facilities included GPRS and 3G bands, sensor data is forwarded to a web server and client structure to enable global monitoring, e.g. a real-time position indicator on Google Maps (figure 4). The students performed several tests with the vehicle, including several winter tyres in moist conditions at a local test track. The remote diagnostics data was analysed to assess vehicle performance and wear. Some of these results have been published by the local newspaper Kaleva.

This project was selected as a research case study, as it showcases some advanced telematics technology that can be implemented by others with modest resources. Furthermore, as a hybrid vehicle the OAMK Prius features appealing engineering and onboard telematics solutions that can be accessed with ample training.

3.2. Didactic approach

The challenge of devising a didactic approach for this growing body of knowledge is to provide the learner means to grasp the complexity of design and engineering solutions. The content will familiarize the learner with terminology as well as commonly available solution strategies to build his or her own tele-sensing system. In essence, the learning content comprises a collection of 'best practices'. The case study database content was collected from interviews, student reports and local newspaper articles. Draft versions were validated by telematics experts.

The initial structure of the case study contents is depicted in Figure 5. It features a table of contents and several recurring LOs that cover subprojects executed by OAMK students and staff. The *Overview* distinguishes the project's objectives and its context. Central notion is the *Solution Architecture*, which covers blueprints of the current setup in diagrammatic and spatial formats. The *3D Model of Hardware* offers interactive 3D viewing of the Prius model and links to other LOs through hyperlinks.

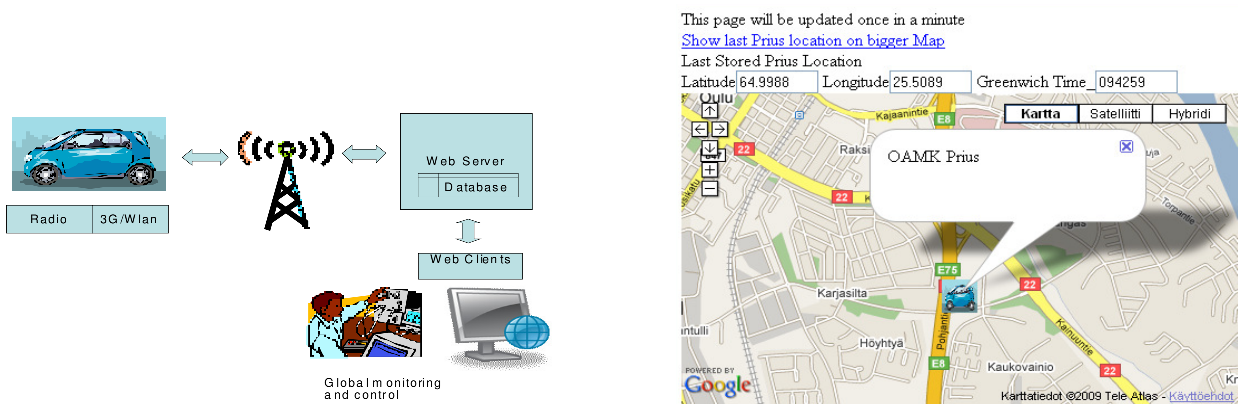

Figure 4 . The OAMK Prius communications infrastructure (left) and sample page (right).

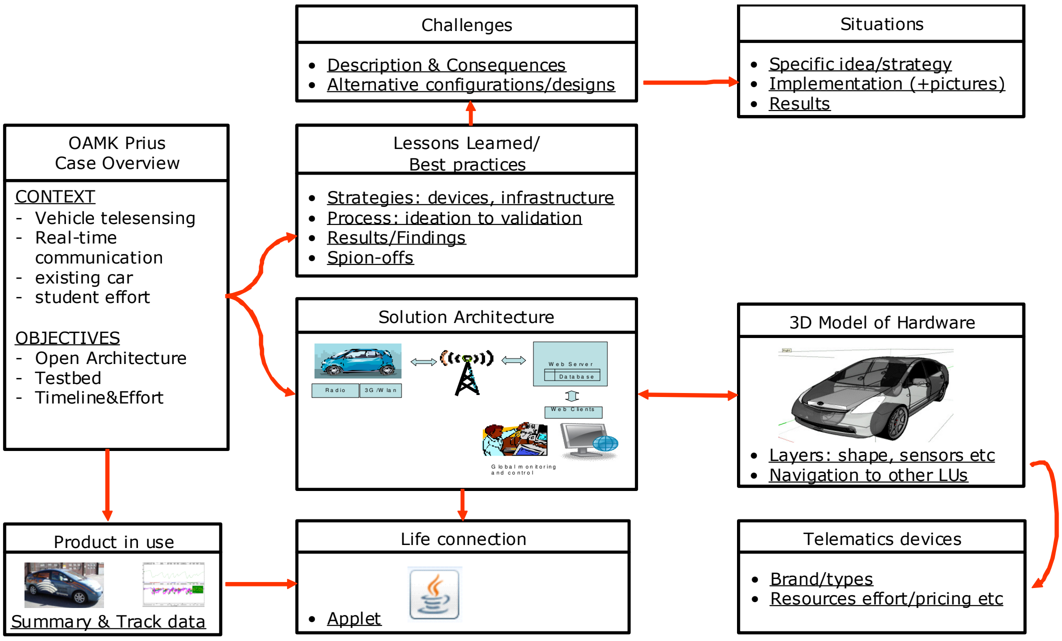

Figure 6 . Initial content structure of the case study on OAMK Prius.

Furthermore, it links to life and captured data to get a realistic impression of the fidelity of the sensed data. The *Lessons learned/Best practices* LO encompass knowledge on solving specific engineering challenges. This learning object might refer to a structured definition of *Challenges* and associated *Situations* (i.e. specific ideas and possible conditions of evaluating a solution).

3.3. User interface Design

In developing a mobile and comprehensive environment for teaching vehicle telematics, our initial idea was to develop a spatial virtual environment to convey knowledge on automotive hardware and software technology of the OAMK Prius. However, standard e-learning facilities fail to deliver such complicated content by restricting the course builder to formatted text, pictures and videos. Although CAD packages do allow annotations and external references, the employment of such an application was considered overwhelming and overcomplicated for the specific use of apprehending engineering challenges.

Consequently, the didactic model is based on 3D model navigation. The learner is teased by a short introduction and questions before entering the learning unit, while a more formal assessment will be offered to test the knowledge gained. A source of inspiration to such presentation means was Microsoft's address given at the Consumer Electronics Show (CES) 2009 [Microsoft 2009]. This demonstration encompassed a vision on cloud computing and education in the medical field: blending rich text, animations and social interfaces by a 3D interface of the human body. The basic mode of operation was a touch screen, which established a natural mode of navigating through the data. Figure 6 shows three snapshots of this Tablet interface: on the left: 1) human skeleton with annotations, a part-whole map shown in the top-right

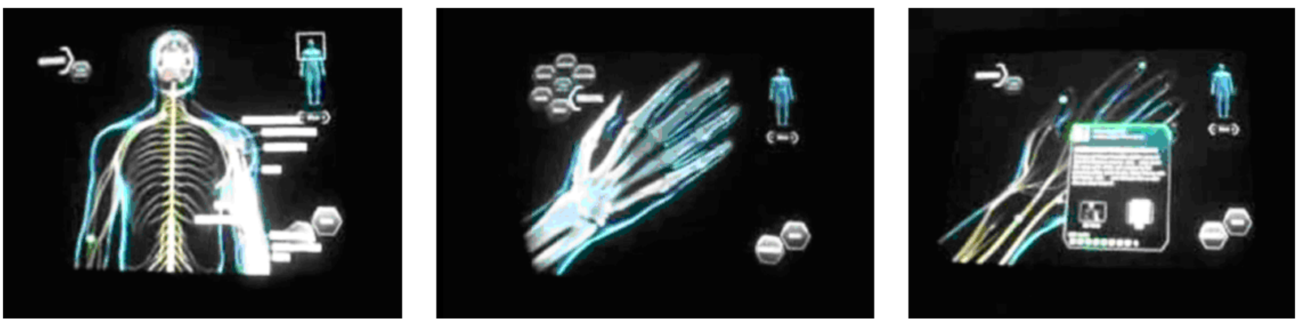

Figure 5 . Three snapshots of Microsoft Computing of the Future address [Microsoft 2009].

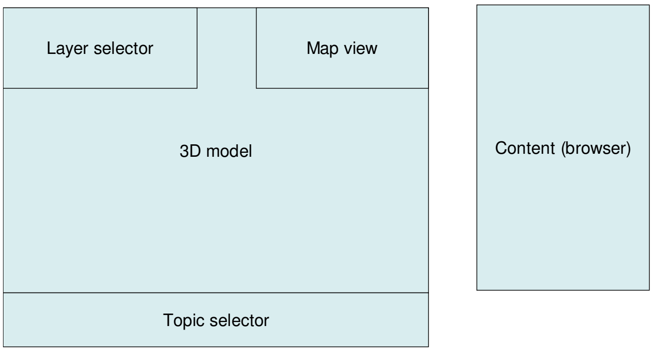

Figure 7 Functional layout of the application.

corner, 2) bones of the hand with different layers accessible on the left-top corner, 3) content shown in a browser window on top of the 3D display.

The notions of this example were generalized. The resulting constituents of the user interface are depicted in Figure 7. A 3D model is rendered in the centre of the screen that provides a real-time interface to browse through and activate annotations. When annotations are clicked, its corresponding content is presented in a separate browser. 3D components and annotations are hidden or shown by activating different layers in the Layer selector. This is basically a menu, only one item can be active. The model's view can be changed by interacting with the Map View, located at the top right. This map shows a 2D section view of the model; the 3D view (camera) will be constantly updated when the user taps or moves his/her finger on this control. Finally, the Topic selector allows switching between different sets of content (and corresponding maps). Its concept resembles a tab selector, by activating the complete content of the 3D viewer and its respective annotations can change.

3.4. Application semantics

Before an implementation of this user interface can be made, first the information structure needs to be devised to ensure storage and retrieval, as well as navigation between different modes. In translating the interface functionality and usage scenarios to digital concepts, 4 groups were identified: 3D model, learning content, access, and 3D navigation, as depicted in Figure 8. The layered, spatial model is at the centrepiece of this learning unit. The access to this 3D model is done by activating of layers. After exploring the case data base of the OAMK Prius project, the following categories were determined: *Sensors, Interfaces, Engine, Body, Power, Network,* and *Software*. Furthermore, the layers are grouped in Topics and Categories. After discussion with teachers, the case study topics were set to: *Basics* (*Prius Basics, Tele-sensing*, and *Open Infrastructure) Applications (Test drives), Future Applications (CAN hacking).*

Annotations convey the actual learning content, comprising engineering details, discussions or results. Basically, they act as point of interest that the learner discovers while browsing through the 3D model and activating various topics and layers This approach is scalable, as the database of annotations is separate from the components and the access objects – they can be stored in a central database or a remote (real-time) facility. The appearance and style of the annotation can be determined by its type or browsing

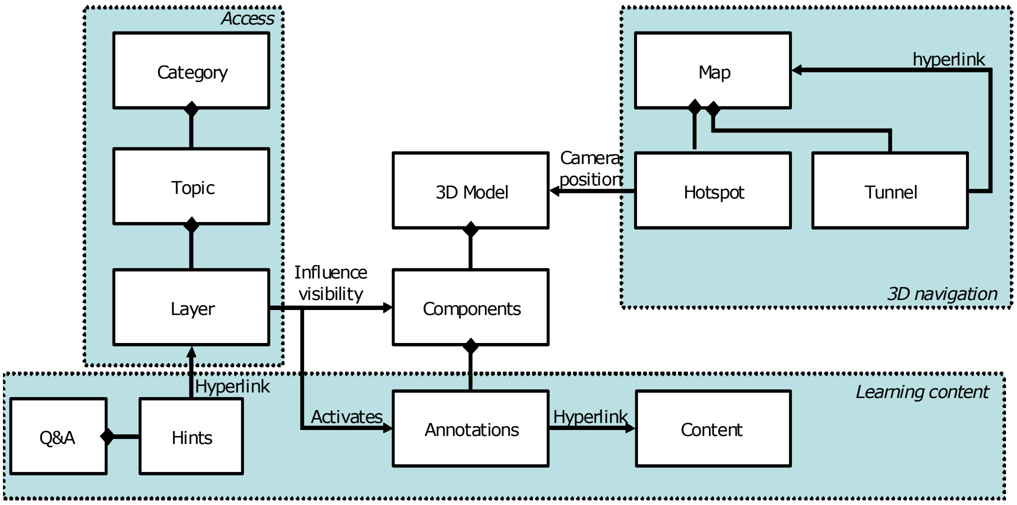

Figure 8 . Semantic network of the application.

behaviour of the user.

Navigation is primarily done by interacting with 2D maps. By tapping across this map, the user can alter the viewpoint in the spatial scene (determined by hotspots, cf. section 3.5). By tapping on so-called tunnels the learner can activate another 2D map, i.e. a top-view.

For each layer, the learner can be challenged by hints and questions and answers to create a active pattern of discovery.

3.5. Implementation

A Dell Latitude XT Tablet PC was selected to develop and evaluate the Learning Object (1280 by 800 pixels screen, 1.3 GHz Intel Core Duo U770, weight. 2 kg.). To enable full multi-touch support, a beta release version of Windows 7 was installed (release candidate).

As software platform, we selected Director (version MX) after testing several other 3D environments such as X3D and java3D viewers. The advantage of using Director in this development stage is the freedom in scripting user interaction (e.g. the use of maps) as well as its versatility among different platforms and support of several 3D modellers. This resulted in a stable development environment, with relatively simple components to be connected.

A. 3D model

The model of the car and its decoration were modelled in Autodesk VIZ, a CAD package with appropriate exporting opportunities to Director's Shockwave 3D format. The model contains 41 components (including chairs, dashboard and rudimentary blocks for the engine. In total, the assembly has a polygon count of 28.000 faces in total. This could be rendered in real-time on the Tablet PC (>10 frames per second). It was necessary to flatten the scene hierarchy so that components could be rendered with different transparency levels.

B. Content

Instead of a floating dialog window as shown in the Microsoft example, we chose to implement the content browser as a fixed, Internet Explorer object at the right hand side of the screen. While this reduced the capabilities of concurrent window handling compared to the original example, it established a simple content development mechanism based on HTML build-in rendering.

In a regular word processor, an initial description of the OAMK Prius project was documented, based on interviews and local literature as mentioned in Section 3.1. This resulting document included pictures and simple formatting (headers etc). Subsequently, it was converted to HTML and

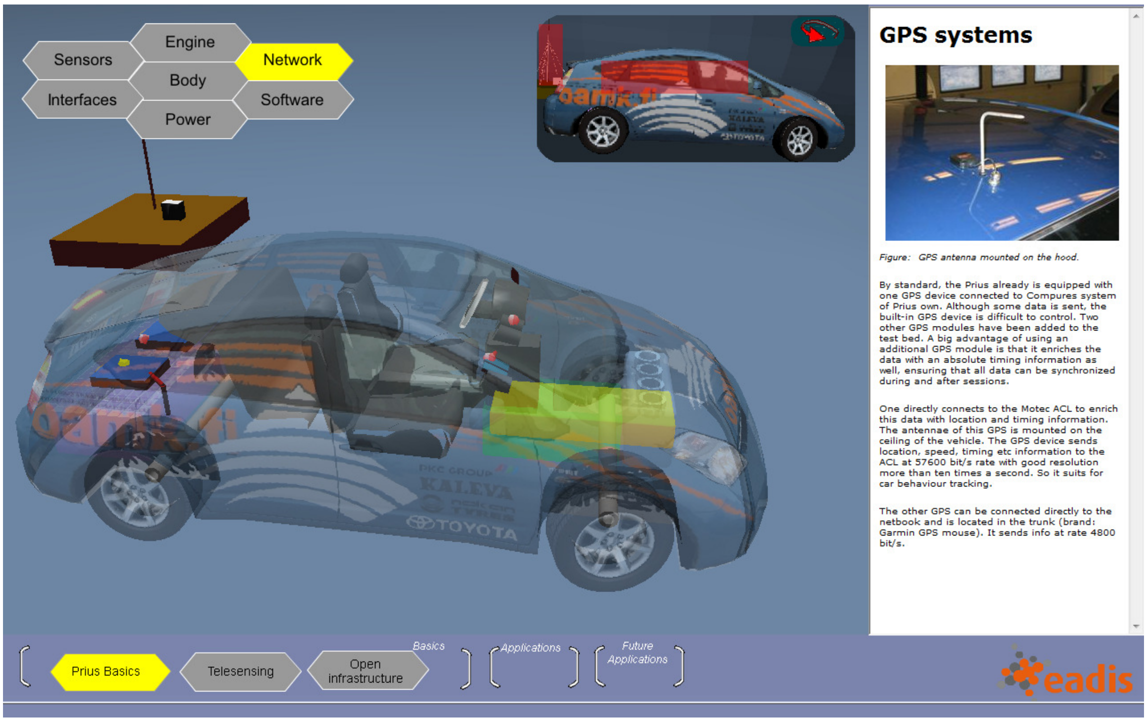

Figure 9 . Screenshot of the prototype implementation.

sections were split into separate files to facilitate hyperlinking and scrolling within LOs.

C. Annotations

In the initial implementation, annotations were added to the 3D model as yellow spheres, while stored in separate-files (one per topic). The following data format was used:

```
<annotation-id>, Location(<x>,<y>,<z>),
    <layers>, <hyperlink>
```

The *annotation-id* represents a unique number, *x,y,z* specify coordinates in 3D space. The *layers* string lists for which set of layers the annotation will be shown (cf. section 3.4), the names of the layers are separated by semicolons. Finally, the *hyperlink* string is a common HTML browser link to another page.

The hiding and showing of annotations was controlled by selecting a topic and activating a layer. When another topic was selected, all existing annotation objects are removed from the scene graph and subsequently the active ones are added. In the case of activating another layer, the existing scene graph is re-evaluated to hide or show annotations according to its layer property. A finger tap or mouse click on the annotation will load the annotation hyperlink in the browser window.

D. Maps

In this case, 3 maps were implemented: side, top and far view. The latter was used to access server software components. For each, a bitmap and a set of hotspots were determined. Hotspots map a 2D position on the map to a 3D camera view (position and orientation). When tapping on the map, the nearest hotspots were determined and a target camera view is interpolated, based on the 2D distance from hotspot to the original finger position. In the implementation maps were distributed among different frames of the Director timetable. Tunnels were implemented as semi-transparent rectangles: when tapped, a script moved the Director player to the corresponding frame.

To evoke user interaction, we added a turn-feature (red arrow located at the top-right of the map component). This function automatically navigated to each visible annotation from the current map, while loading the corresponding annotation content in the browser window. When no annotations were visible, a flythrough around the vehicle was animated.

4. DISCUSSION

The pilot implementation was evaluated informally by senior automotive designers and telematics experts in several sessions. Findings are discussed below. A more formal comparison with a traditional e-learning platform is planned in the coming period.

4.1. Usability Issues

Both automotive designers and telematics experts appraised the novel user experience, and the way of interacting with 3D engineering content. There were some issues with navigation and browsing of the annotations, both discussed in some greater depth below.

The pilot implementation only allows 3D navigation through the 2D map views, whereas some users first start tapping the 3D model to move around. Initially, we did implement free 3D movement in this mode, but this proved to be overcomplicated in combination with interacting with annotations. The result seems acceptable, yet it might be good to explore blended versions; e.g. when tapping outside the 3D model, a rotation or translation/zoom could be initiated – possibly by multiple finger gestures.

Browsing through the annotations proved to be more difficult than initially thought for two reasons: 1) the visualization of the annotations as spheres provides little insight on their content before activating them and inspecting the related content in the browser, and 2) when annotations are clustered, activating a specific one requires target practice. To deal with the first, we could visualize the type or title of the annotation by colour/icon or 3D text labels. Hisarciklilar and Boujut (2008) propose various alternatives to differentiate between annotation types and symbolic relationship between the notes as arguments in engineering decision making that might be applicable in this mobile learning context. To deal with the second issue, a more sophisticated selection mechanism could be developed to allow selection in clusters, for example the clustering of nearby points of interest in Google Earth.

4.2. Didactic issues

The development of the case study was based on visits, email correspondence and collaborative writing of the case study database. The conversion from this raw database to the final set of topics and annotations took considerable time (approx. 2 man-weeks work). This process can be optimized, primarily by adopting the semantic network depicted in figure 8 as a template.

Although the learning content and setup prove to be appealing for a while, issues concerning engagement needs to be addressed. Gross Davis (1993) specifies two preliminaries for case studies in education: involvement of instructors, and possibilities to enable group learning. Both haven't been explored yet in this pilot implementation. Mechanisms are available to deal with these issues, for example social networks and avatars; one can easily imagine learning agents that keep track of learning behaviour and patterns of discovery such as outlined in the original EADIS content as Learning Supervisor (Unit D4 in figure 1).

4.3. Technical issues

Graphic Performance and memory usage proved to be sufficient in this particular example. However, when more complex 3D models are used, the polygon count can become too large to be rendered in real time on mobile devices such as TabletPCs without extensive graphics support.

Although the development platform allows flexible adjustments of the implementation, several elements are hard-coded in director, specifically those corresponding to the semantic objects *Access* and *3D navigation*: the topic and layer selector were equipped with fixed labels, whereas the 3D model and 2D maps were embedded in the director cast as described in the section 3.5. Most Director scripts are model-independent, with the exception of the hiding/showing of components of the 3D model when layers are activated.

5. CONCLUSIONS AND FUTURE WORK

As indicated in the introduction, the incorporation of spatial learning content in mobile and ubiquitous systems is important for complex design and engineering examples. We have developed a specific prototype to explore user interaction and productivity. The learning content features work of Mechanical Engineering students on tele-sensing of a hybrid car and the spatial structure of the vehicle is used to navigate through the information. The user interface and the content were evaluated informally by senior automotive designers and telematics experts, which appraised the novel user experience. A more formal comparison with a traditional e-learning platform is planned in the coming period.

As section 3 highlighted, the implementation of the prototype allows repurposing and extension, by separating the 3D model, annotations and rich content in separate physical files and through the use of typical web technologies. Although similar user interfaces have been presented elsewhere, the contribution of this work is the information design and didactic approach, which facilitates the future development similar e-learning experiences.

ACKNOWLEDGMENTS.

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