Dependable Wireless Collaboration in Mixed Realities

Application to the VERDIKT Research Programme

submitted by

Institute for Energy Technology, Halden, Norway

in cooperation with

Østfold University College, Halden, Norway

Kyoto University, Japan

Example Scenario 1:

The freely accessible geospatial information in Halden holds a very high standard. Based on this content and the proposed technology, the municipality enters a model of the house (garage, church, etc.) into the automatically-generated online 3D model of Halden. Both the public and the authorities can inspect the plan in Mixed Reality (MR) on-site using their preferred wireless device, and give feedback.

Aim: Enable clearer public and decision-maker perception of plans before construction and offer better feedback mechanisms.

Example Scenario 2:

A truck carrying ultra-hazardous gas is involved in a severe accident on the E6 motorway. In the 20 minutes before the emergency services are on site, members of the public in the accident vicinity can communicate vital MR information (position, pictures, video, text) about the situation. Warnings can be broadcasted to all mobile phones in the vicinity to inform drivers to stay in their cars, close windows, and turn off air conditioning. Map-based guidance on how best to leave or avoid the affected area can also be provided.

A simple Bluetooth measuring device connected to the emergency teams' mobile phones takes gas concentration measurements continuously transmits location-based data to refine the common decision-making data available.

Summary

The proposed project on Dependable Wireless Collaboration in Mixed Realities is a joint effort by the Institute for Energy Technology (IFE), Østfold University College (HiØ) and the Kyoto University.

The prime objective of the proposal is to develop technologies and services for secure and dependable wireless user collaboration in mixed reality (MR) applications. This should manifest itself as cross-platform software modules for wireless inspection, editing, and creation of MR content, embedded in a cross-context dependability framework. Low-cost applications running on the users' choice of device will be central in the project demonstrator.

The project will be interdisciplinary, and research topics include cross-context dependability, automatic content adaptation (data reduction, scene simplification, advanced Level-of-Detail (LoD)), cross-platform user interfaces for MR content, 3D scene generation, collaboration management and version control as well as advanced positioning methods. Context awareness will be central in this work, extending the present term of location-based services (LBS) into context-based services (CBS).

The project will form the basis for a PhD study, as well as a Post. Doc.

1 Motivation

Wireless technology is no longer for the privileged few, and in Norway, members of an average family carry three or more mobile phones, in their bags, pockets or cars at practically all times. Most of these phones are high-technology devices with much more functionality than the basic ability to make or receive phone calls.

With these new technologies in everybody's pocket, the demand for and willingness to deploy advanced LBSs is increasing. Obvious examples of such services are GPS roadmaps with navigation assistance and local weather forecast updates. In this work, we wish to extend the concept of LBS to Context-Based Services (CBS), reflecting also the user's situation, device and agenda. In Example 2, (front page) CBS would imply e.g. escape route information (agenda) with automatic content adaptation to the users mobile phone (device), to users in the affected area only (location) and dependability to match the emergency (situation).

Mixed realities [1][4][5] arise when a wide range of rich content is combined with real reality to constitute a user's perceptive environment. Such content can visualised in the form of virtual reality[1] (VR) or augmented reality[2] (AR), but also as digital geospatial information and a wide range of other visual (photo, video, graphics etc.), audio, or haptic content. A simple way of delivering MR is to use a mobile phone or a portable computer; another way is to use devices such as head-mounted displays (HMDs) and wearable computer systems.

The range of applications of MR technologies that is technically feasible is rapidly broadening. Nevertheless, ICT advances have not only opened doors to new possibilities, but also to new challenges. A particular challenge has been to make MR applications more available beneficial, and economic to use for the wider population, especially ordinary users with little or no knowledge about the underlying technologies. The advance of wireless ICTs has greatly contributed to the growing ubiquity of MR technologies, however it has also increased the need to resolve issues such as platform independence, scalability, and dependability:

- Many existing services are based on pushing content, but there is also a need to focus more on user collaboration and user-created content.
- Proprietary platforms prevail but have not interfaced with each other satisfactorily to support multi-way user collaboration, scalability, and interoperability.

[1] The field of virtual reality encompasses certain groups of visualisation techniques that deal with interrelated representations of a reality, while allowing humans to interact with these representations in real time.

[2] Augmented reality refers to viewing the real world enhanced by digital, often 3D, information and objects.

However, the international efforts towards open standards, open source code, and open formats now make it possible, through an approach as described in the proposed project, to achieve such scalable cross-platform functionalities.

Further:

- Wireless ICT-driven applications usually have a very high focus on certain dependability factors such as availability, accessibility, efficiency and flexibility, at the expense of others[3] such as security, maintainability, accountability[4] and safety. For many purposes, such a focus is sufficient. However, problems arise when attempting to use the same applications for purposes that are critical with regard to the down-prioritised or neglected factors [9]. As far as wireless MR applications are concerned, in order to further develop the state of the art, the challenge is not just to achieve a "mediocre" balance but the most optimal one. Clearly, such a balance is highly purpose- and context-dependent.

It is evident from the above, that the dependability aspects of a wireless MR application are affected not only by the implementation of various features enabling multi-user collaborative work in the application, but also the various user-driven or society-driven purposes the same application is expected to contribute to.

To illustrate, a supermarket chain's response to its customers' expressed needs and demands could be an offer to customers to subscribe to updated merchandise-information. This could include a ranking of the categories of merchandise recommended for a certain group of customers such as children of certain age range or senior citizens, in addition to the usual product information such as category, manufacturer and price. This could help customers to filter product information to identify products that interest them. To extend the example towards safety-related aspects involved in using wireless MR features, consider that one of these product categories could be a list of prescription-free vitamins, pain-easing drugs, etc., with a view of the corresponding section in the supermarket (dependent on the supermarket's location), a photo of the drugs and a description, all accessible only on the customer's demand. Erroneous information related to this product category could jeopardise the health of the target customers. As errors cannot be completely avoided, the wireless and dependable MR features could provide means for the users, in this case, the customers, to communicate with supermarket staff, so that they can ask questions, for example. The questions may uncover errors that can be subsequently corrected.

As the example above implies, the potential of wireless MR applications, as well as their associated vulnerabilities, and risks to individuals and society, are endless.

2 Objectives and Approach

The prime objective of this proposal is to develop technologies and services for secure and dependable wireless user collaboration in MR applications. This should manifest itself as cross-platform software modules for wireless inspection, editing, and creation of MR content, embedded in a cross-context dependability framework.

The sub-objectives are as follows:

- To provide tools for and demonstrate wireless MR applications on low-cost devices for a broad group of users
- To provide tool support for qualitative and quantitative dependability, and risk analysis and assessment, of wireless MR applications reflecting user needs for interaction and collaboration
- To provide and demonstrate functionality for dependable content creation by users
- To provide tools for and demonstrate platform-independent collaborative work in wireless MR by deploying both high-end and low-end technology (HMD, mobile phone, etc.)

In order to meet this objective, a strong and early focus on context and context management is required. The proposal also acknowledges the interdisciplinary nature of the research topic chosen,

[3] In this proposal, the factors belonging to the former category are called "soft", whereas those belonging to the later category are called "hard".

[4] A system's accountability is usually used to address a quality of a system that makes it possible to trace a security breach (related to Confidentiality, and/or Integrity, and/or Availability (CIA)) caused by an artefact uniquely to that artefact.

and recognises a need to combine different disciplines, competences and achievements. The effort must therefore be truly interdisciplinary, and though some work tasks naturally belong inside one of the partners' fields of research, good communication and feedback from the other areas will be vital throughout the project duration.

3 Research and Development Topics

This chapter addresses the research and development topics of the proposed project. As this is a research project, and also includes a PhD, and addresses a long time-span with regard to the state of the underlying technologies, this is not a complete specification, but provides a firm indication on the directions the research efforts should take.

Figure 1 shows a simplified overview of the main issues and their connections. Approaches and software services are shown as dark green, with modules, and sub-modules in lighter shades of green. Content and meta-data are illustrated as pink ovals. Note that the size or position of an illustrative item is not related to the significance or the magnitude of the represented task.

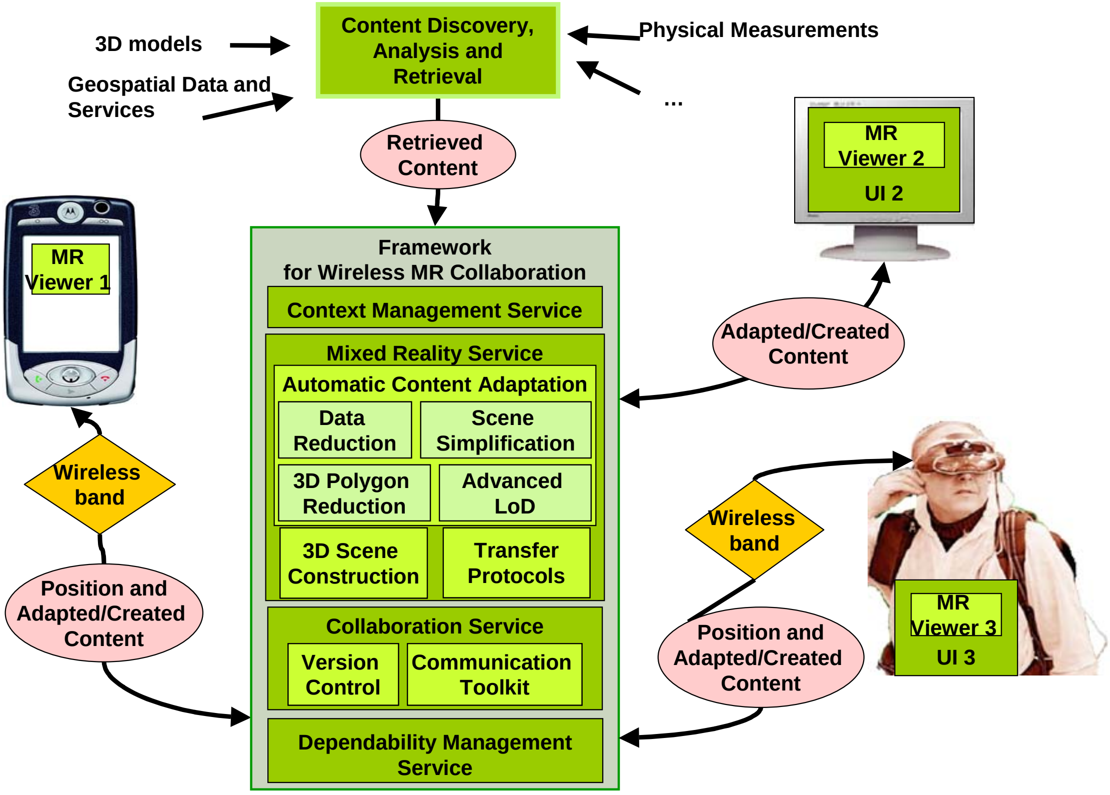

Figure 1: Diagram of required methods, services and tools for dependable collaborative wireless MR.

3.1 Context-Awareness

Making wireless cross-platform collaboration effective and feasible depends on high context-awareness in methods and design. Existing context-based mobile applications are important evidence for this, as one of the specifics for all mobile applications is that they must work in a rapidly changing context. The context may consist of many aspects including the user's location, time, situation, and scope of interest. The wireless device used is also a significant part of the context in this setting.

The Context Management Service will be a central unit in the proposed framework.

The issues to be considered here encompass dependability analysis, MR and collaboration. The context management and context-awareness must therefore be a central joint effort of all the consortium partners. The work will not only be a challenge in design and engineering, but a choice of meta-data format must also be made, in accordance with existing meta-data standards.

Positioning will also be a part of the context retrieval process. Adequate and flexible positioning of the mobile device is central for location-based services. Depending on the context of use (indoor/outdoor, noise, light, etc), effective positioning methods, or combinations of methods, must be identified[5].

3.2 Cross-platform management of Mixed Reality content

In order to achieve full cross-platform management of MR content, a rendering device interface must be available, along with standards and tools for content adaptation moving between high and low resolution clients.

The Mixed Reality Service (MRS) will include a set of modules for automatic content adaptation. Two important and challenging issues in this research will be automatic 2D/3D scene simplification and data reduction. One of the tasks at hand will be to generalise a method developed in Project OneMap [2][3] for combining 2D range queries and line simplification, enabling real-time zooming and panning of huge geo-data repositories, containing hundreds of millions points[6]. A 3D version of the method should be developed, and applied to VR/MR scenes. Real-time polygon reduction and advanced LoD management will also be important and challenging aspects of the automatic content adaptation.

3D scene construction and transfer protocols will also be central subjects. Other engineering issues include protocols for cross-platform exchange of MR content, and effective flushing and tiling to avoid memory overload.

User Interfaces (UI) must be appropriate for each collaborating device, including viewers for MR content and input devices for navigation, feedback and manipulation. The UIs of mobile and wearable devices are usually different from the traditional desktop PC UIs. To compensate for the lack of large displays, keyboard, and mouse, other means of visualisation, input and manipulation must be provided. This provides the interesting challenge of composing a user interface optimal for MR content on small devices. Additionally, the users' focus and typical situation varies with the choice of device. The user interface must therefore embrace the challenge of the influence of the environment in which the user operates.

The Collaboration Management Service (CMS) will consist of a version control system sufficient to handle multiple user contributions and actions in a MR setting. Proper interfaces and methods for collaborative work must also be identified. These can be based on VISIT experiences with VR control room design and MR extended teamwork for nuclear maintenance support.

The Dependability Management Service (DMS) will involve identifying the most critical dependability factors related to various scenarios for wireless MR applications by analysing and assessing a wide range of relevant dependability factors. This analysis and assessment will be based on information from the scenarios, the context management service, and available historical dependability data. Next, the accepted level of these factors, eventually altering the functionality and operational modes of the context-decided features of WMR applications, is decided by a model-based vulnerability and risk analysis and assessment (hence including models of the features, and qualitative as well as quantitative analysis) together with available historical data [6][7][8]. Once the levels for the most critical factors are decided, other related dependability factors are analysed and their level adjusted under the condition of preserving the level for the critical factors. The results are dependability profiles tailor-made for various wireless MR

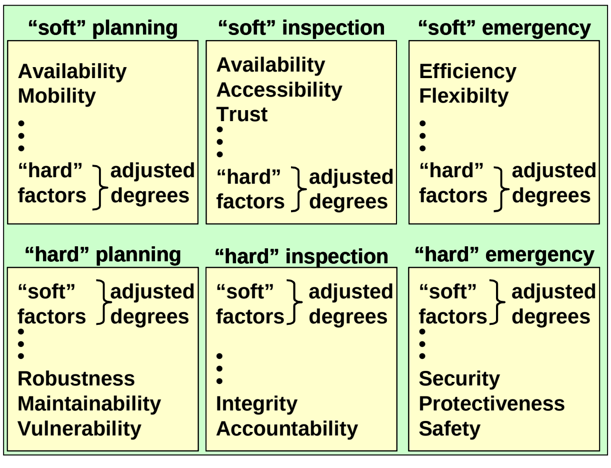

Figure 2: Dependability profiles dependent on WMR applications and scenarios.

[5] Examples are GPS, RFID, ultra sound, visual markers, Gazetter, Meta Data (ex: Dead Reckoning), Cell ID, WLAN, BT, and many others.

[6] In short, this method makes it possible to perform a combination of a rectangular range queries with a line simplification in near logarithmic time. In practice, this means that it is possible to zoom and pan in a global map, consisting of hundreds of millions of points, in real time on a thin client connected via a narrow bandwidth channel to a server repository.

applications with various purposes, such as planning, inspection and emergency. This is illustrated in an exemplified collection of application- and scenario-oriented dependability profiles with different focus on most critical dependability factors as shown in Figure 2.

The DMS will therefore include a generic dependability analysis and assessment unit, and a generic model-based vulnerability and risk analysis and assessment unit. The internal and external communication paths for the service are shown in Figure 3.

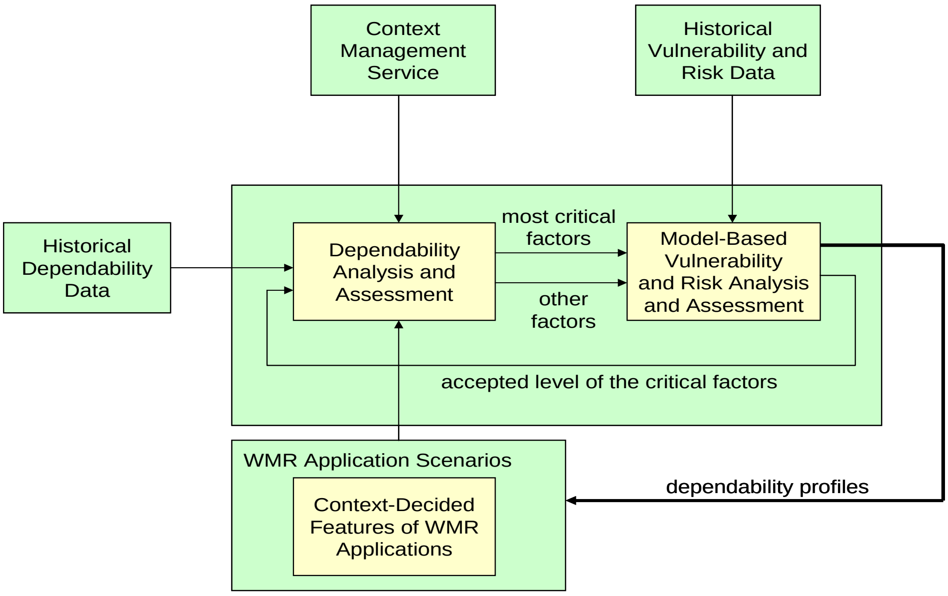

Figure 3: Dependability Management Service for WMR.

3.3 Content

An existing approach to distributed **Content Discovery, Analysis, and Retrieval** is the dynamic registries of geospatial web services. These services are based on a family of web service specifications from the Open Geospatial Consortium (OGC). A similar but adapted approach for MR content will be studied in the proposed project, ranging from geospatial information to weather data to 3D objects.

Some of the involved data will be for invisible phenomena such as time, physical conditions (pollution, temperature, etc.) or calculated information such as risk assessment. Visualisation of the invisible is thus an important feature of the MR Service, and the **3D Scene Construction** module should generate 3D descriptions for visualisation not only of geographical data, but also of invisible phenomena in relation to the geographical location.

4 Deliverables

4.1 Recruitment of Research Resources

An important outcome of the proposed project will be a PhD on *Dependable Wireless Collaboration in Mixed Reality*. The PhD candidate will be employed by IFE, and will be working primarily in Halden. The candidate should spend 6-12 months at the Kyoto University during the project period, and the university has committed to supervision and assistance of a suitable candidate in this period. In addition to external supervisors at IFE, Kyoto and HiØ, the University of Oslo, Department for Information Technology will be able to provide formal supervision.

A Post Doc on *Dependable Wireless Collaboration in Mixed Reality* will also be recruited to the project, from Norway or internationally. Additionally, one 6-month and one 9-month international guest scientist, who will be invited to participate in the project. Finally, a position as research scientist within the project's main topics will be included.

4.2 Methods and Software Framework

Methods and a framework of software modules will be developed for wireless Mixed Reality content retrieval, inspection and creation. The systems will operate on and between a selection of low cost, easily available devices.

Methods and modules for collaboration and dependability support in wireless mixed realities will also be part of the system.

Suitable software modules will become open source contributions.

4.3 Scenario demonstrator

Cases for a scenario demonstrator will be designed in the early project phases. Case studies will be performed several times throughout the project period. The demonstrator cases should be of varying scale with regard to data sets, 3D visualisation, user platforms and dependability profiles.

4.4 Dissemination

The project will place a high priority on dissemination, where PhD results will be a significant part. Additionally, one publication a year in refereed journals, regular conference contributions, and at least one popular interdisciplinary publication will be a part of the dissemination. The subject of Wearable Mixed Realities will also expand the present Master education curriculum of wireless communication at HiØ.

In addition to regular consortium project meetings, an international workshop on Dependable Wearable Mixed Realities will be arranged during the concluding phase of the project.

Contributions to and discussions with international communities such as OGC, CORAS User group, IAEA, NKS, and the Open Source Java Community will also be important.

4.5 Project Organisation and Management

The proposal is for a joint project between Institute for Energy Technology (IFE) in Halden, University College of Østfold (HiØ), and the Kyoto University in Japan. The interdisciplinary nature of the approach puts great demands on the choice of project responsible and project manager. Accordingly, we propose a project manager who has broad expertise within the development of ICTs as well as within dependability analysis for ICTs, through long experience from academic, research, and industrial (telecommunications) environments:

Project responsible: Safety-MTO, Institute for Energy Technology (IFE)

Project manager: Atoosa P-J Thunem, PhD, principal scientist, SElab, Safety-MTO, IFE

<u>Atoosa P-J Thunem</u>: MSc in computer science (1992) and PhD in joint computer science, control engineering and reliability engineering (1996). She has more than 15 years of experience, as research scientist and assistant professor from the research and higher educational community, and as senior analyst with technical management responsibilities from the telecom industry. At IFE, she has several key roles and responsibilities, amongst those, main responsible for the MTO department's research activities within ICT dependability, and advising the management on positioning towards ICT-related and security research programmes. During 2003-2005, she was the Norwegian representative in an international advisory group of six experts, established by IAEA to compose a technical recommendation document for cyber security considerations in computerised systems at nuclear power plants.

In the proposed project, the four different research departments will be contributing from their specialised fields of research. The following contacts will lead the defined work packages and provide the needed management:

- Atoosa P-J Thunem (PhD, Principal scientist, SElab, IFE),
- Grete Rindahl (MSc, Research scientist, VISIT, IFE)
- Gunnar Misund (MSc, Associate Professor, HiØ)
- Hirotake Ishii (PhD, Research Associate, Kyoto University, Japan)

At IFE, the *Software Engineering laboratory* (SElab) has advanced competence within dependable development and dependability analysis of ICT-driven systems, and the *Visual Interface Technology Department* (VISIT) has a long time expertise on collaboration in virtual and augmented reality. HiØ will contribute on the issues of Geospatial Technology, digital maps and handling of large amounts of data/filtering, along with sharing several years of experience on programming of handheld devices. The Kyoto University has internationally renowned expertise on advanced positioning techniques and general MR, and will at own expense allocate researchers to contribute on these issues.

4.6 Work Packages and Schedule

The project will start up January 2006, and end December 2009. Based on the discussion in Chapter 3, a set of main work packages are proposed as illustrated below. In addition to project management, the administration task will include the establishment of an advisory group from national and local authorities as well as industrial branches early in the project. To facilitate coordination and improve quality assurance in the software design, development, and documentation, the European Space Agency's Software Engineering Standards (PSS-05) will be adopted for the project.

WP	**Delivery**	06 I	06 II	07 I	07 II	08 I	08 II	09 I	09 II
1. Project Administration a. Establish Advisory Board b. International Workshop c. QA d. Dissemination	Reports, Contact-list, Guidance and dissemination. SW dev. doc. Publications	x	x	x	x	x	x	x	x
2. Context Management (A.P-J.T., IFE) a. Context Format b. Context for Dep., MR and Collaboration	Open Format for Context identification Methods and SW modules	x	x	x	x	x	x	x	
3. MR platforms and protocols (G.R., IFE) a. User Interfaces incl. MR Viewers b. Transfer Protocols c. 3D Scene Construction	Methods and SW modules	x	x	x	x	x	x	x	x
4. Content Adaptation (G.M., HiØ) a. Data Red. & Scene Simplification b. 3D Polygon Reduction c. Advanced LoD	Methods and SW modules	x	x	x	x				
5. Dependability Management (A.P-J.T., IFE) a. Dependability analysis/assessment unit	Methods and SW modules and tools		x	x	x	x	x		
b. Model-based vulnerability and risk analysis/assessment unit					x	x	x	x	
c. Dependability profiling					x	x	x	x	x
6. Collaboration (G.R., IFE) a. Version Control	Methods and SW modules				x	x	x	x	
b. Collaboration Support		x	x	x	x				
7. Content Discovery, Analysis and Retrieval (G.M, HiØ)	Methods and SW modules					x	x	x	x
8. Positioning and Advanced Devices (H.Ishii, Kyoto University)	Methods and SW modules	x	x	x	x	x	x		

4.7 Budget

The applied contribution from RCN (in KNOK):

Category	**Year**				**Total**
	2006	2007	2008	2009	
PhD	574	574	574		1722
Post.doc	338	676	676	338	2028
Researcher	676	676	676	676	2704
Guest researcher		273	168		441
Over-sea		21	21		42
Hours Salary	600	1107	938	600	3245
Operating (Travel)	300	240	300	480	1320
	2488	3567	3353	2094	11502

The funding is complemented by:

- IFE: Research and infrastructure through the activities towards HRP
- HIØ: Research and infrastructure through the educational programme
- Kyoto: Research and infrastructure through the educational programme

In total, this can add up to about 2.5 researchers per year, resulting in approximately 10.000 (in thousands).

5 Description of the Project Participants

5.1 IFE

IFE is an independent foundation established in 1948 with departments at Kjeller and in Halden. With a staff of about 550, IFE is an international research centre for nuclear and energy technology, with a considerable focus directed towards profitable and environmentally acceptable techniques for oil and gas production, power generation and supply, and energy use. Collaboration in reactor- and information technology is mainly through the OECD Halden Reactor Project (HRP), in which IFE cooperates with about 100 organisations in 19 countries.

The proposed research will be carried out in the *Software Engineering laboratory* (SElab) and the *Visual Interface Technology Department* (VISIT) in Safety MTO, one of IFE's five sectors.

The SElab consists of scientists with main background within computer science, telecommunications, statistics, dependability (safety, security, availability and reliability) analysis and management, and risk analysis and management. All the activities within the lab are towards dependable development and dependability analysis of ICT-driven systems. SElab is responsible for one of the main chapters of the joint programme for the HRP, in addition to having been participating in several national, Nordic and international research projects. SElab is also engaged in consultancy projects towards the Norwegian industry.

The VISIT division has been working with VR and MR since 1995. The main research focuses on scalable, desktop based, cross-platform solutions. Main application areas include control room engineering and verification, training simulators, work planning and visualisation of invisible phenomena. The division has contributed with developing, testing and reporting bugs to the open source community for several years[7]. The division has a well-equipped laboratory for virtual and augmented reality research.

[7] It is especially worth to mention the open sourcing of their navigation code to the Java3D community, which later was adopted by the Web3D consortium and included in the XJ3D code-base. This code is now embedded in the XJ3D-browser, and deployed by users worldwide.

5.2 Østfold University College

Each year, approximately 35 students are enrolled in the master study at the Faculty of Computer Science[8] at Østfold University College. The largest master specialisation is “Mobile Applications”, an interdisciplinary cooperation focusing on dependable local-aware applications and services. The group is currently involving four associate professors, two PhD candidates and two scientific assistants, and 15 master students.

One of the main activities within ”Mobile Applications” is Project OneMap, a long-term solution oriented effort contributing to the fusion of standard web technologies and geographic. As a spin-off from this project, an incubator project, Locus Lab, will be launched August 2005. Locus Lab will develop location based software and services for the mobile phone market. The other main R&D direction of this specialisation is the Critical Systems Development group, which will participate with focus on methods and approaches for risk management, i.e. risk analysis and fault tolerant designs.

Resource contributions include a new campus, with new buildings, infrastructure and new laboratories as well as a variety of wireless equipment.

5.3 Kyoto University

The Graduate School of Energy Science was established in 1996 and mainly focused on a research to establish ideal energy systems harmonizing with natural and human environments. It includes various kinds of studies such as a development of accurate tracking systems designed for Mixed Reality and psychological evaluation experiments of Mixed Reality human interface to optimize the usability. The main contribution from Kyoto University will be on Mixed Reality and positioning. Especially, the Graduate School of Energy Science has developed a new positioning system for Mixed Reality under the collaboration with IFE in early 2005 and it was adapted to visualize virtual buildings to check how the new buildings are going to change the landscape. The demonstrator was a great success and it was introduced on local newspaper and TV news. A part of the technology realized in this study can be applied to the Wireless Mixed Realities project. And in 2004, the Graduate School of Energy Science has also developed a field operator support system that is intended for use in nuclear power plants. This system employs Mixed Reality and RFID system for visualizing a variety of information and identifying targets with high reliability. The know-how obtained in this study can be applied to the Dependable Wireless Mixed Realities project.

6 References

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[8] The faculty has an academic staff of approximately 25 (full professors, associate professors and assistant professors), making it one of the largest academic communities within Computer Science in Norway.