A Collaborative Framework for Distributed Winter Testing

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Abstract: A clear trend within the automotive sector is that more and more functionalities are being built into the car with the help of software; however, all this new technology must be rigorously tested under realistic conditions. By introducing a framework for distributed winter testing, based on distributed engineering tools combined with telematics, visualization of temperature data from a test vehicle can be conducted at another location 1,500 km away. Despite the distance, car manufacturers can follow the tests at the test site in real-time, communicate interactively with very high quality, and collaboratively interact with test engineers situated at the test site with the incoming stream of test data. The presented system enables a new way of working with winter testing of vehicles, allowing companies to simplify the testing procedures and get a quick response and an understanding of the process.

1. Introduction

At a time when computer aided engineering and production are continually shortening development times for new automobiles, the demands on testing activities are ever increasing. A clear trend is that more and more functionalities, i.e. new types of electronics and software, are being built into the car with the help of software [1, 2]; however, all this new technology must be rigorously tested and proven before it can be practically used. Soon all tests must be done in one season, while the number of data measurements only increases. Another trend in the automotive industry is telematics, i.e. telecommunication functions that originate or end inside automobiles [3]. Telematics can be used as services to the user of the vehicle or in the testing and verification process. To fulfil the different demands of vehicle testing, tests are often done in extreme conditions (hot, cold) where the test facilities are located in desert or arctic areas and are therefore often situated in remote areas of the world. The tests provide important feedback to the designers, but rudimentary communication tools are often used between the design department and the test facility, separating the test activities from the design process.

This paper describes the results of two projects within the Regional Program for Innovative Actions (RPIA), Distributed Collaborative Engineering in Heterogeneous Environments and Telematic Testrange, which are efforts to approach the challenges described above by creating a framework for distributed winter testing. The framework is based on distributed engineering tools combined with telematics and has been implemented and further developed to change the work process in winter testing. How heterogeneity issues can be solved when using different types of networks and communication hardware is also presented.

2. Background

Product development today is seemingly becoming more globalised while distributed collaboration is very common. A crucial concern of distributed design is the process of reaching a shared understanding of the domain, the requirements, the artefact, the design process itself, and the commitments it entails [4], for which a distributed collaborative design environment can be used to do and establish a common ground. The environment should work as a virtual meeting place, where members of a product development team can meet, share, and interact with engineering information (e.g. geometry, design documents, results from simulations and animations) as well as use high quality conferencing techniques [5, 6].

Broadband network technology is now a mature area whose cost to interconnect two collaborators with broadband infrastructure is rapidly decreasing. However, very few applications utilize the full potential of the existing broadband networks in Europe. Wireless network access technologies offer increased opportunities for distributed collaborative teamwork by enabling mobile team members to participate in synchronous and asynchronous information exchange processes [7].

The combination of collaborators using broadband connections as well as mobile connections creates a heterogeneous environment where mobile narrowband applications must co-exist with broadband applications running on powerful workstations. Combining these types of tools is presently difficult; if one user works with a low bandwidth application, all other users are forced to use the same "low quality" representation. The issue of heterogeneity is even more important when communicating with companies over very large distances or with countries lacking a well developed infrastructure. To enable distributed teams of engineers to collaborate using highly heterogeneous environments, the collaboration software needs to be highly scalable and adaptive in terms of bandwidth consumption and CPU utilization. Therefore, it is important to combine state of the art mobile and broadband technologies, and to develop applications that can be deployed in very heterogeneous environments.

3. Objectives

The traditional way of doing vehicle testing is by documenting all tests in a test specification, detailing all tests and how the test procedures should be done. The tests are then performed by test engineers at the test site and the results are sent to the design office where engineers try to interpret the results. If the results are insufficient the test engineer has to repeat the tests, this iterative process can take several days.

The hypothesis was that by introducing distributed collaborative teamwork, empowered by state of the art information and communication technology, as well as broadband communication networks, communication between the test site and the design department will change significantly, test cycles will be faster, and fewer errors will occur.

4. Methodology

The research approach is based on an iterative approach where the researcher observes, analyses, and intervenes. The aim is to develop knowledge founded on an understanding of the present, and then intervene and change the present into a more desirable situation.

The chosen test bed is the automobile winter proving ground Arctic Falls, outside Vidsel in northern Sweden. Here, tests are conducted during the winter on vehicles from many automobile manufacturers. By merging knowledge of winter testing at Arctic Falls with that of distributed engineering at Luleå University of Technology, a prototype framework for testing was designed by combining telemetric technologies, distributed VR, and broadband conferencing. This prototype was then tested and evaluated under realistic conditions in cooperation with a car manufacturer.

5. Technology

The system contains three main components, i.e. the telematic system for data collection, the distributed VR-environment for result presentation, and the conferencing environment. An overview of the systems can be found in Figure 1.

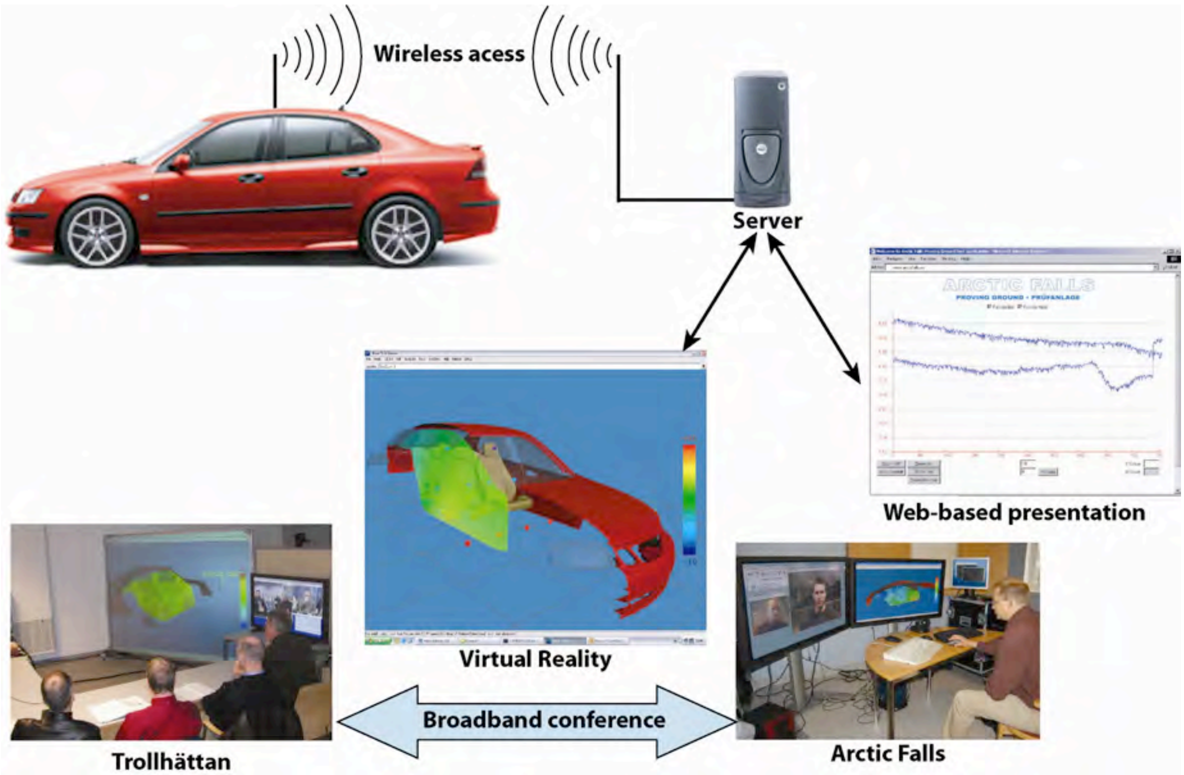

Figure 1: A schematic figure over the test system.

At the proving ground, measurement data is sent from a computer inside the automobile to a server, where the results can be collected via web interface or a distributed 3D-model. The network backbone used in the demonstrator was a combination of the DITRA [8] network and the Swedish university network (SUNET) [9] with a bandwidth of at least 1 Gbit/s.

5.1 The Telematic Testrange system

The system for wireless transmissions of measurement data was developed by the Telematic Testrange consortium. At Arctic Falls, a two-way wireless infrastructure is used to communicate to the test vehicle equipped with a computer designed to interface numerous sensors and test-boxes, such as GPS, accelerometers, CAN-interface, and analogue and digital inputs. The wireless link is based on standard IEEE 802.11 products, slightly adapted for field use and for real-time requirements. The communication is encrypted with a strong encryption.

The measured data is sent from the computer inside the automobile to a server, where all data are stored in a database. Users can interact with data directly via different types of analytical tools (Matlab, statistical programs, etc.). To access the data remotely a web interface is used where the user can access ongoing test sessions as well as previously recorded data. Also, automated e-mail and SMS notifications can be used if monitoring channels reach critical levels.

In the climate test from the demonstrator, temperature data was recorded from 16 sensors placed inside the car, and positioning data from the GPS was stored.

5.2 The Distributed VR-environment

To enable a synchronous discussion regarding temperature distribution, a distributed VR-environment was used together with a conferencing system. This approach was first presented by Törlind et al. [10], and further developed to fit the specific requirements for temperature visualization. In the distributed application users can visualize the temperature data by moving a clipping plane through the car, where the temperature is represented by colours. By combining the 3D-visualisation with time based temperature plots from the web based system, see Figure 2, an understanding of the heating process could be achieved.

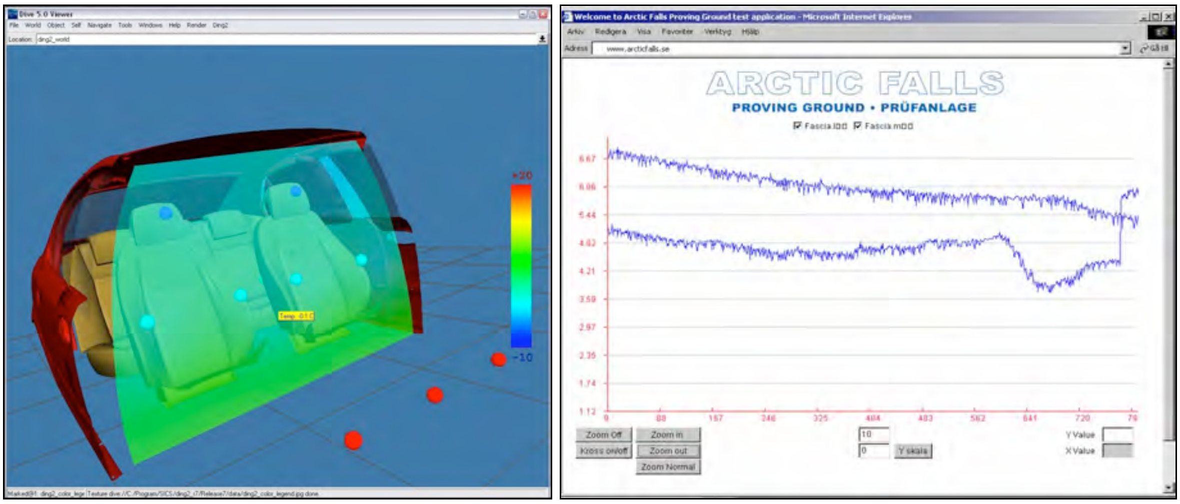

Figure 2: Temperature presented in the VR-environment and in the web interface.

The application is based on the Distributed Interactive Virtual Environment (DIVE) [11, 12], developed by the Swedish Institute for Computer Science (SICS). DIVE is an Internet-based multi-user VR system where participants navigate in 3D-space and can interact with other users and applications.

In many collaborative virtual environments, the same virtual world, i.e. CAD-model or dataset, is displayed to all participants. However, in an engineering environment, it is important to use multiple perspectives [13, 14] or at least different viewpoints, with views that can be shared to all users or kept private.

In earlier work [10], users were represented and interacted through avatars reflecting the actions and movements of each other; the avatar was also used as a visual reference to determine the size of the model. In this application the avatars confused the users who were familiar to the size of the car (avatars were flying around in space), so instead a simplified iconical representation was used. The iconical representation is very useful in determining how users interact with the distributed model. All users can have their own viewpoints, or follow another user and share the same viewpoint. It is also possible to point in the shared environment or probe for the exact temperature at any point within the car. In Figure 3, the user interacts with the model and points using a 3D-pointer.

The temperature is interpolated from the temperature values in the sensors located inside the car (represented by spheres in the visualization model). The interpolated values are visualized on a clipping plane with a colour map representing the temperature.

The temperature data can be viewed in real-time or by doing a playback of an earlier test, when the user can decide if the test shall be played in “real time” or at a higher rate.

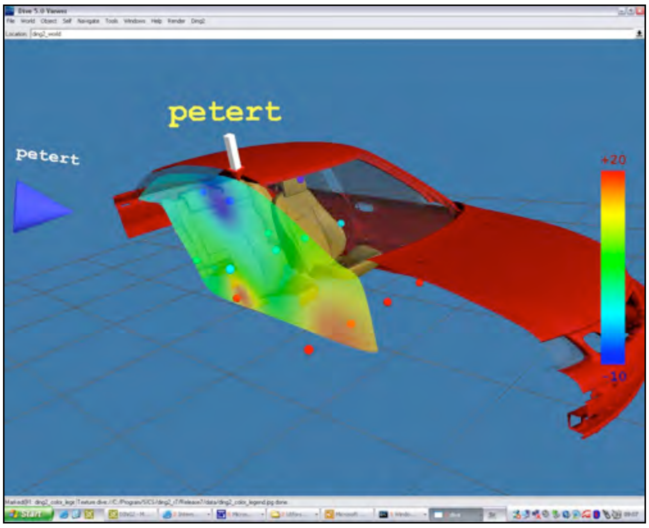

Figure 3: Interacting with the distributed VR-system.

5.3 Conferencing environment

For conferencing, the software Alkit Confero [15] supported on a wide variety of hardware platforms including PDAs, laptops, and workstations was used. An IP-based audio-/videoconferencing system from Alkit Communications, Confero was developed to take full advantage of the bandwidth available in high speed network environments and provide the high-quality interaction necessary in a distributed engineering situation. The teleconferencing tool supports audio and video communication as well as text messaging, remote camera control, and functionality for session initiation and management.

6. Results

The system was first presented in the spring 2003 and has since then been tested, evaluated, and further developed. The results indicate the possibility to follow a test in real time from a distant location while collaborating with the engineers at the test site, discuss the measurements, anomalies in the test results, etc. Figure 4 shows a collaborative session, the video quality at this moment is full PAL (768x576) resolution and a frame rate of about 25 fps.

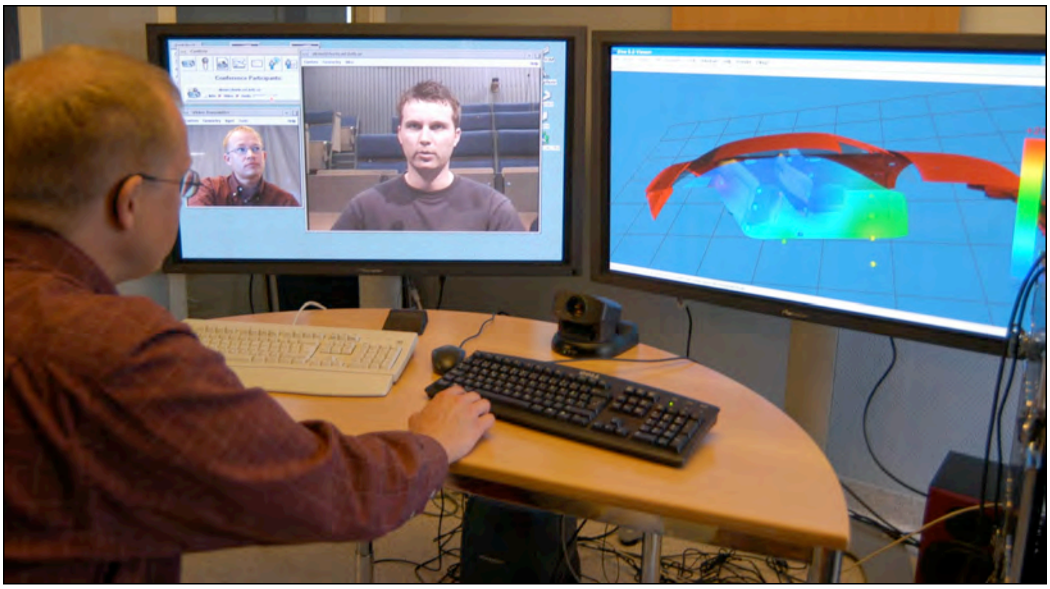

Figure 4: The collaborative setup at Arctic Falls.

In one of the tests a strange temperature reading was recorded in one of the sensors at the back of the car, the temperature was about 10 degrees warmer than the rest of the car. In a normal test the temperatures from this sensor would have been discarded or the test may have been classified as useless. In this case the engineer in Gothenburg asked the test driver about the problem, to which the test driver replied that the sun was shining through the rear window. Hence, this type of collaboration is definitely an advantage of the new system.

Within the project, various types of software for distributed engineering work were adapted for a heterogeneous environment (network, access points, and diverse hardware). The test location includes various types of access nets with different characteristics (broadband, wireless, and narrowband nets). Bandwidth to the vehicle varied from 500 kbit to 5 Mbit. Between Arctic Falls and the car manufacturer in southern Sweden (about 1,500 km away) a broadband infrastructure with a minimum bandwidth of (100Mbit/s) was used. Simple terminals were used inside the automobiles, while powerful workstations were used at the permanent work sites.

To communicate with the test driver inside the car running on the test track, wireless network conferencing was tested. Due to its sensitivity to delay, real-time communication is usually based on unreliable transport protocols like UDP, since retransmission of lost packets is considered too time consuming. In wired networks bit-errors are extremely rare; however, for wireless networks bit-errors can be relatively frequent. To enhance the quality and robustness of conferencing on the wireless network, an error correction algorithm was developed [16]; results show that the adaptive error control scheme improved the robustness of the video communication. However, for a truly heterogeneous solution layered video transmission architecture must be used [17]. Today, this mode of operation is highly experimental and will require additional development efforts to be fully operational.

7. Business Benefits

The benefits of the presented system are higher quality, shorter lead times, and lower costs.

- *Higher quality;* the system automatically stores all data, creates automated documentation, and simplifies test re-iteration.
- *Shorter lead times;* by having instant data access (locally and remote), it is easy to evaluate tests. The hand-over between different test engineers can be shortened because all old test setups and results are stored. Problems can be easily traced.
- *Lower costs;* one of the main issues with distributed tools are that less travelling is needed, along with a reduction of non value activities at the test site. By doing faster and more accurate tests fewer prototypes are needed. After the demonstration and testing of the system, the car manufacturer concludes "*by using these types of technologies, we can save €500 000 each winter*".

By introducing the system new opportunities arise:

- By extending the "alpha" tests (first prototype series) and combining the test with data-mining, the number of prototypes is further reduced. This approach demands less administration and gives more possibilities for analysis.
- By using distributed engineering systems, engineers from the company (located at several different sites) can collaborate and follow tests in real time, review tests, and recreate old tests in a completely new way.

8. Conclusions and further directions

The project presents a new system for distributed engineering, where visualization of temperature data from a test vehicle can be done at another site located 1,500 km away. Despite the distance, car manufacturers can follow the tests at Arctic Falls in real-time, communicate interactively with very high quality, and collaboratively interact with test engineers situated at Arctic Falls with the incoming stream of test data.

The presented system enables a new way of working with winter testing of vehicles, where companies can simplify the testing procedures and get a quick response and understanding of the process. The car manufacturers that tested the system concluded that this type of system can save time and travel and will be essential in the future. However, more extensive studies are needed to fully substantiate this.

The project has also demonstrated several broadband applications that utilize the potential of the broadband networks in Europe. This is of great importance because companies in rural areas can now provide new services so that engineers can use high quality multi-media communications to collaborate at the test site just as at their home office.

Further enhancements to the system are to use other types of measurements than the demonstrated climate test, e.g. handling, complete vehicle etc., by using the GPS data and other sensors such as accelerometers to determine the position of the car. By combining a detailed model of the test site with location, speed, and acceleration of the car, engineers can then follow the car at the test site from the distributed VR-environment. The results can be used to judge the road-holding qualities of the vehicle. By replaying different situations engineers can study the behaviour of the car in detail. This can also be used for traffic control over the test fleet at the proving grounds.

Tests can be done in a wider area by extending the telematics system with the use of other mobile technologies [3] such as GPRS (General Packet Radio Services) or UMTS (third generation mobile communications systems) [18]. Using automated data-logging in a fleet of company cars permits the finding and identifying of small software problems that may occur under some special conditions and are very difficult to find in small scale testing.

Combining distributed engineering tools with telematics has revealed to be an interesting area with many possibilities. The framework presented is built upon existing standards and can easily be used within another area. A new project will include areas other than automotive testing such as military and product testing.

9. Acknowledgements

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