Collaboration in automotive winter testing

Real-time simulations boosting innovation opportunities

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Abstract. The performance of cars has during recent years become increasingly dependent on complex electronic systems used especially for safety but also comfort, performance and informatics. Automotive winter testing activities in northern Sweden is vital to test and try out those systems. A contradiction to increased performance is that faulty software also causes 30 % of severe malfunctions in the functionality of the car. To deal with these problems, as early in the design process as possible, innovative methods to cope with digital abstraction and the physical world in a unified way seems promising. One useful approach, in automotive winter testing, might be to support the possibilities for real-time vehicle simulations of the car in motion.

The closer collaboration in the automotive industry might be an incitement for investing in technologies for knowledge sharing. Besides enhancing the product development process, additional knowledge might support innovations. Today, instead of providing parts similar to their competitors and relying on one or two automakers, successful suppliers focus heavily on innovation and on collaboration with a number of manufacturers on a global market. Due to the possibilities to visualize whole processes, the use of simulations seems to support a 'seeing first' approach to innovations.

Thus, the purpose of this paper is to describe an as-is scenario and a to-be scenario for automotive winter testing to highlight how the use of real-time simulations facilitates innovative methods.

1 Introduction

In the northern part of Sweden the winter season starts in November and lasts into March, temperatures in the range of - 40 degrees Celsius are common in some lower areas 1. The natural asset - cold weather - is considered as a possibility and has become a backbone in many companies' business concepts and particular in services for winter car testing. The four municipals, Jokkmokk, Arvidsjaur, Arjeplog and Älvsbyn, constitute a vast region where collaboration is important to support the automotive test industry 2. The collaborative effort takes place in terms of providing overall services surrounding the test industry, in terms of for example logistics, accommodation, food and leisure activities. Within this region, a number of automotive winter test service companies are established.

The area is sparsely populated, but this fact is also turned into a potential to provide added value for the testing industry. Besides many kilometers of a wide variety of low traffic public roads and ice tracks on natural lakes, huge proving grounds especially designed for automotive winter testing are provided for testing of cars and components 13,4.

In this setting, the automotive test entrepreneurs' services are vital in the collaborative efforts in the design and development of cars, e.g., automotive manufacturer and suppliers. Automotive manufacturers, i.e., Original Equipment Manufacturer (OEM), are for instance, General Motors and Fiat 3. Suppliers, in this case, are usually those who provide main parts, i.e., Tier 1 suppliers, meaning that they, in turn, purchase components from small part makers. Examples of main part providers are Haldex 3, Knorr-Bremse 4, TRW Automotive 5, Bosch and BMW with own test facilities. Automotive manufacturers in the United States are reducing the number of suppliers to compensate for lower market share. For example, Ford is halving the number of suppliers from which they buy seats and wiring 6. Furthermore, Ford has identified 43 suppliers for close collaboration, 13 of those have been contracted on a long-term basis or where contracts already exists these has been extended over many years 5. This closer collaboration might be an incitement for investing in technologies for knowledge sharing. Besides enhancing the product development process, additional knowledge might support innovations. Today, instead of providing parts similar to their competitors and relying on one or two automakers, successful suppliers focus heavily on innovation and on collaboration with a number of manufacturers on a global market, 6. Due to the possibilities to visualize whole processes, the use of simulations seems to support a 'seeing first' approach 8 to innovations.

The performance of cars has during recent years become increasingly dependent on complex electronic systems used especially for safety but also comfort, performance and informatics. Automotive winter testing activities in northern Sweden is vital to test and try out those systems. A contradiction to increased performance is that faulty software also causes 30 % of severe malfunctions in the functionality of the car 9. To deal with these problems, as early in the design process as possible, innovative methods to cope with digital abstraction and the physical world in a unified way seems promising. One useful approach, in automotive winter testing, might be to support the possibilities for real-time vehicle simulations of the car in motion.

Thus, the purpose of this paper is to describe an as-is scenario and a to-be scenario for automotive winter testing to highlight how the use of real-time simulations facilitates innovative methods.

1.1 Functional Product Innovation – a framework

A framework for the plausible to-be scenario is found within a Functional Product Innovation (FPI) vision. The vision is a joint academic and industrial construct to capture a widening in view among manufacturing companies, the view widens from focusing mainly on the physical artifact to also entail a view on product development where the performance of the physical product is provided as a service. The goal is to take cross-company knowledge domains of engineering, business and production into account in the design phases. This vision puts an emphasis on additional knowledge and information in early design phases, for example understanding of the actual use of the product and the environment where it is going to be used is important, since these aspects needs to be designed into the final product. Life-cycle perspective and close cross-company collaboration in the design and development of products constitutes a basis for realization of FPI. The collaborative efforts and widening in view are thought of as a facilitator for innovations to arise. Furthermore, a simulation-driven approach in early phases to support decisions in product development, by the same token, try out those solutions in numerous of what-if business scenarios, is also included in the vision. Mintzberg and Westley 8 write; *"…As Mozart said, the best part of creating a symphony was being able to see the whole of it in a single glance in my mind"* (p.90). A 'seeing first' approach 8 is vital in an innovation process and visualization is an underpinning idea in presentation of simulation result. As a complement to validation, the early use of simulations is thought of as supporting a virtual structure to combine and recombine knowledge from the collaborative partners.

1.2 Innovations - a wider perspective

An understanding, we are not attempting for a definition, of the word innovation seems a useful starting position for this paper. The word innovation is used oftentimes as new physical artifacts or commodities, i.e., *new things*, which has reached a market and satisfy some sort of needs. In a FPI context, the extended product definition adds *new services* to the word innovation. In turn, in the service performance, the users of the service act as co-producers in the development process. Hence, *new processes* and *new methods* to carry out design activities arise and can be included in the word innovation. Such a collaborative product development brings in the qualities *new knowledge* and *new ideas* into the understanding of the word innovation.

The word *new* can here be interpreted as in beforehand 'poorly understood' or 'unknown' and as a fact, exceeding what was intended from the beginning, thereby understood as innovation. The frame for discussing innovations in this paper is delimited to new methods such as new methods for performing automotive winter testing.

2 Method

In general, empirical data for the study presented in this paper has been generated during informal and formal meetings with companies in the automotive winter testing industry. People from OEM, Tier 1 suppliers and service entrepreneurs have been involved in these meetings. The form of data generated by participation in these meeting is mainly qualitative, e.g., an interpretation of something in the context where it occurs 10. Due to the participative approach, this study might be described as related to action research 11.

A survey, for generation of both quantitative and qualitative data, has been performed in addition to this, also including all three levels of actors. The qualitative part result of this survey is used in this study to build the as-is scenario and to discuss the to-be scenario, as well as a complement to the findings in the meetings. The results from the survey as a whole will be presented in a forth-coming paper.

The technological set up for simulation to support collaboration is built on the work of Larsson et al 12, Larsson and Larsson 13 and Törlind 14, and an initial technical description for real-time simulations can be found in Nybacka et al 15, 16.

3 Automotive winter testing facilities – views from the actors

Compared to their competitors, entrepreneurs in the northern Sweden test region highlight *"relatively stable winter"* and *"big areas on lakes for ice tracks"* as important advantages to provide and enhance the test services. Moreover, entrepreneurs think that the ability of the locals to speak not only English, but also German can be considered as an advantage for the test region as such.

The entrepreneurs say that the fact that large Tier 1 suppliers are established and located in the area is an important contribution to the competitiveness, since they attract OEMs to accommodate their automotive winter testing activities in the region. One entrepreneur says that *"firmly established big Tier 1 suppliers function as a magnet for the OEMs"*. The entrepreneurs perceive the transportations of cars from other parts of the European Union as easy, but they also consider the poor travel possibilities for people (flights and long distance to the testing area) as a negative aspect. The entrepreneurs bring together sub-contractors who are directly involved with working to keep the test tracks, etc. in good condition, along with additional firms that provide added value to leisure time, e.g. firms that provide snowmobile safaris or dog sleighing tours. The entrepreneurs perceive a risk in that the increased leisure events take capacity from the test activities.

In a future perspective of five years, the entrepreneurs believe that they will probably sell more services and that the OEMs will join and share test facilities. Furthermore, they hope that there will be summer testing and that the test activities will continue to positively develop.

For automotive winter testing in the northern Sweden, Tier 1 suppliers express the advantages as having OEMs together. *"This enables us to have demos with significant number of participants and it also helps collaboration in development within customer projects"*. One of the respondents expresses that the entrepreneurs offer *"perfect service"* and that they *"know what the customer needs"* and provide well-prepared facilities. Another respondent emphasizes the climate as an advantage for winter tests, *"Northern Sweden has a climate that is very suitable to winter testing. It is guaranteed to get cold, new snow and big temperature variations if you stay approximately seven to ten days"*. This is a reason why this respondent prefers the northern Sweden test facilities in favor of competitors in Finland and Canada.

However, the OEMs and Tier 1 suppliers highlight that traveling to the test sites is time consuming, and that it is difficult to get hotel rooms, especially with short notice.

OEMs and Tier 1 suppliers see changes in the test processes as two-fold. Firstly, they forecast a reduction in the number of products, but an increase in the total amount of testing hours. This seems likely because, as they express, *"more time will be spent on each product that should be tested"*. Secondly, they see a general reduction of testing activities, since tests can also be performed in cold climate chambers. However, they find the first trend as plausible because, as one of the respondents reflects on changed processes, *"I believe that the tests will be standardized with well-defined methods, which in turn will reduce the number of people needed for the test. With good methods for performing winter testing, I also believe that the tests could be outsourced to the entrepreneur. This will reduce the costs"*. He continues that if the entrepreneur is hired to perform the tests, the car can run *"life length test for a longer period and in turn reduce costs and get more value from the test season"*.

4 A setting for a component test – a typical case

The OEM provides the cars where the test equipment is mounted by the Tier 1 supplier. The Tier 1 supplier is responsible for the testing as such. When a test is accomplished, the OEM receives a test report from the supplier's head office.

Typically, the component test involves groups of people performing the test assignment. The Tier 1 supplier testing activities take place on site, e.g., on the proving ground in the North of Sweden in collaboration with off site staff, e.g., the product development head quarters located outside Sweden. On site staff, are for example:

- Test drivers possessing expertise about specific components.
- Team leader who coordinates the test sessions and sends or transfer test data to home office.
- Mechanics that repair or mount test equipment and extract data from test vehicle.

Tier 1 supplier off site staff are for example, managers and system experts related to the electronic control system, but also engineers and designers.

The service entrepreneur operates locally on site being responsible for providing a purposeful proving ground, e.g., communication, different kinds of tracks, preparation of tracks, gas stations, garages, car washes, cold chambers and transportation within the area. They are also providing information about e.g., track surface conditions (ice tracks on natural lakes changes constantly due to weather conditions), weather forecasts, and booking services for travel and accommodation.

One or more cars are driven at the test facility and different types of data are gathered depending on what is under scrutiny, for example data about steering, speed and acceleration. The test driver usually change parameters during a test run, however, if any larger corrections are needed, the test driver has to pull up to the garage and stop the car so that the team can make those corrections.

5 As-is scenario – current test procedure

Different types of sensors record and sample data from the vehicles. The logging of data is done independently in each vehicle, and is gathered from the vehicles respectively after the test drive. Thereafter, system experts put together and analyze the data, which are visualized in tabled or graph form. In general, the test process is conducted in steps; test driving, analyzing the data and decision-making, see Figure 1. Decision about whether or not a new test is needed, is based on what is found. The conditions for that new test have to be in resemblance to the previous test. Similar conditions are considered as hard to reproduce. The conditions can be according to one aspect or a combination of aspects, for example outside temperature and/or the ice surface topology. Finally, the system experts write a report presenting data and findings.

Several problems can occur during the tests, for instance failing sensors, control systems and/or human errors. These problems can be hard to notice by the test driver even in those cases when they have a laptop computer on the passenger side displaying test data. The test driver has to focus on driving the car and cannot simultaneous analyze what is displayed. Therefore, despite having a laptop, the test drivers may not receive any direct feedback of the recording process when driving the car; hence, failing sensors or systems are discovered after the drive. Due to a lack of feedback to the test drivers, they do not have any possibilities to directly stop or change the test drive, the control system or analyze the situation.

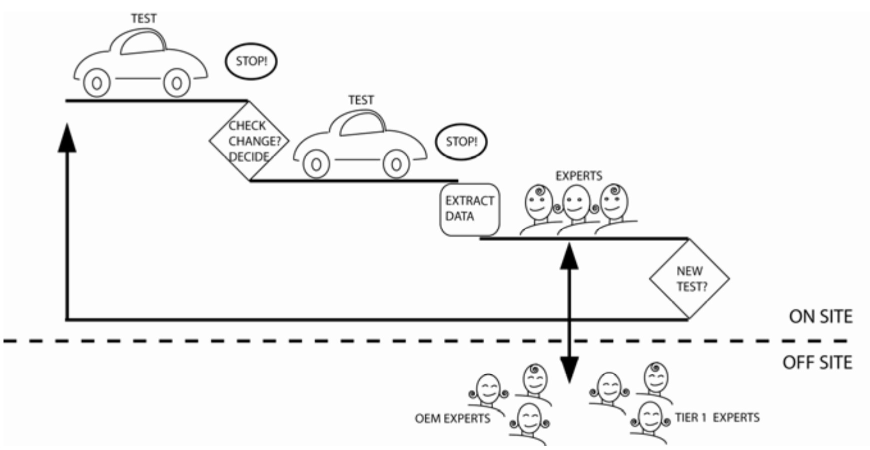

Fig. 1. An example of as-is procedure.

6 To-be scenario – discussing a future test procedure

The way automotive winter testing are performed, a test driver sitting in the car driving on tracks and experts sitting outside the car, even though on site, are by its nature distributed, i.e., there is a physical distance between the actors. The basic idea for a future component test scenario is to create a real-time visualization application to support the distributed work technically. By doing so, off site staff at the home office as well as other experts from locations all over the world can be included into the test sessions in real-time. Since divergent knowledge areas, as well as organizations (OEM, Tier 1 and entrepreneur) need to collaborate, the communication can be viewed as crossing boundaries. Visualization, or a 'seeing first' approach to decision-making is supportive when the situation is new 8. The distributed real-time visualization application seems to be a way to support collaborative decision-making and enhance the concurrency between activities.

The structure for this suggestion for how to support automotive winter testing activities is web-based. In Figure 2, an overview for the suggestion is shown. Data from the test vehicle are transmitted by a wireless access, recorded and stored at a server from which data are retrieved for analyses. The ability to see the result of the test in 3D can be provided by the use of advanced 3D engines, such as AgentFX™ 17. A unique advantage of AgentFX™ is that it allows complete control over the rendering process, allowing creation of advanced user interface, with 2D overlays and augmented 3D views. This capability can support a new test to be set up in a similar way as a previous one.

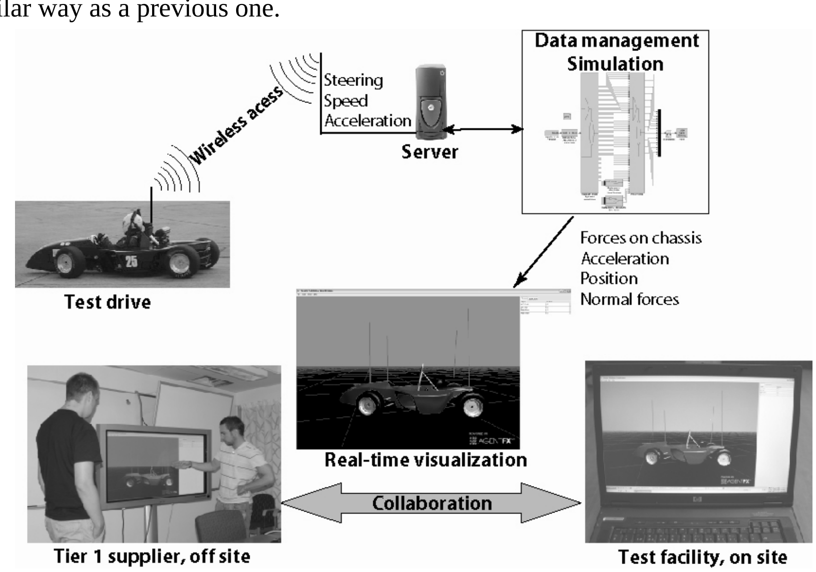

Fig. 2. A structure overview.

The technical structure and the real-time distribution of measurement data have been tried out during a winter testing session at Arctic Falls test track 1. The measurement data were temperature data from the car that were visualized in a virtual environment 14. The framework with dynamic simulation software, Matlab/Simulink and Java based visualization application viewed in figure 2 have been and are currently further tested in laboratory settings 1516. In addition to this, cooperation with another research project [18] resulted in a successful test of saving streamed visualization, video and audio data synchronized.

In a to-be scenario, the test driver log-on via a laptop to a secured website where the visualization application is hosted. During the test, all staff, on site and off site, can in a 3D environment follow the test; this direct feedback verifies that the test is being logged and analyzes of the test data can start concurrently in a more direct and collaborative way. Moreover, the test staff can directly discover extreme system behavior and potential errors. Besides representation of data in 3D, regular data presented in graphs or tables can be used. On the basis of these analyses, the system experts can decide if a retest is required, thus more easily done during similar conditions. The system experts can via a video or audio link to the test driver give instructions for e.g., retest, where 2D overlays and augmented 3D views support setting up and performing the test under similar conditions as a previous test.

Due to the direct connection from the vehicle to the server, data can be stored in a structured way and also be replayed after the test session. Besides making it possible to further analyze a noted problem, the recently logged data can be compared with past data.

In this way, the test procedure has changed from being sequentially performed to being performed concurrently with the analyses and decision-making processes, see Figure 3.

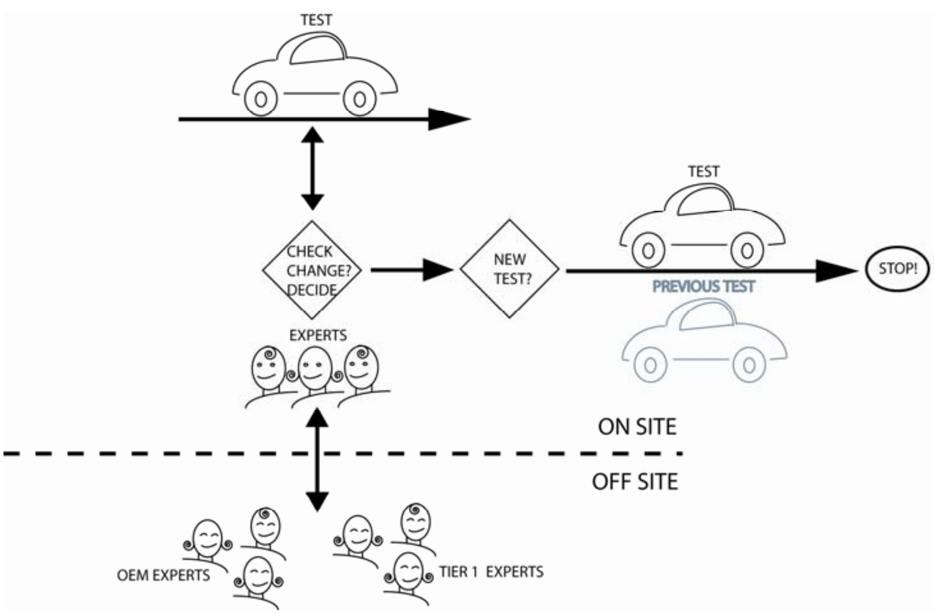

Fig. 3. An example of a to-be procedure.

This distributed technical solution supports a new test procedure. Besides, probably, bringing with it innovations in terms of both software and hardware products, it opens up for new services which the entrepreneurs might provide. One respondent, from the Tier 1 supplier and OEM group, have expressed a change in testing activities as becoming standardized and with well defined methods. He sees that the number of people needed for testing will be reduced and believes that the entrepreneur could run the cars for life length test for a longer period. In this way, the entrepreneurs become more involved in the actual vehicle tests, and this might give possibilities to build up technological capital, i.e., a base for new services, and to extend the activities at the test site during the rest of the seasons.

The respondents have expressed travels as a bottleneck, because of taking too long time. A distributed solution enables people to collaborate, but travel less.

7 Concluding remark

In this paper, an as-is scenario has been described and a to-be scenario of automotive winter testing has been presented and discussed for the application of real-time simulations as a facilitator for innovative work methods during automotive winter testing. By supporting the to-be test procedure with real-time simulations and 3D visualization in particular, the way of conducting the tests radically changes to a more concurrent test process. Also, distributed collaborative work is made doable. In addition, the approach enables decision-making to become a more concurrent activity since off-site experts can take part simultaneous with the testing activities. The approach raises opportunities to extract rich information of vehicle and its systems, which provides a good basis for well informed decisions. The possibility to save streams of visualization, video and audio data synchronized from the vehicle facilitates gathering of drivers' actions and feelings which can be linked to the behavior of the vehicle displayed in the 3D environment. The connection between the vehicle running the test and the development office will be a good base for new future innovation concerning vehicle validation and development. In turn, your car will be safer to drive.

Besides continuing evaluation and verification of this research, further considerations on how to apply the principle of distributed work supported by real-time simulations in other areas are interesting within the FPI vision. In the light of a simulation-driven approach, where simulations are thought of as supporting a virtual structure to integrate divergent knowledge areas, e.g., business, engineering, production, in order to drive product development - how can results from real-time simulations drive the design of next generation products and can it be used to enable new business concepts?

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