Intelligent Road Construction Site – Development of Automation into total Working Process of Finnish Road Construction

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ABSTRACT: Numeric road construction processes and their parts are today developed worldwide. This paper describes research in Finland, which is conducted with companies using national technology funding in a research and development project entitled ”Intelligent Road Construction Site”. In its entirety, four public research projects and two product development projects are today ongoing. One development project has already been completed, producing a Finnish version of an automated 3-D blade control system of road grader. New projects are in design and starting. In total, there are four research units and 16 companies or other infra organizations carrying out these activities. The financial investment into this research and development is EUR 2 million for the years 2001-2005.

KEYWORDS: road construction, automation, 3-D CAD, 3-D measurements, 3-D machine control systems

1. INTRODUCTION

Different types of machines are used in earth moving tasks. In recent years, the effort in developing automated control systems for this machinery has been constantly increasing. One of the most important perquisites for this regeneration is the development of 3-D measurement technology. With the aid of robot tacheometers, mobile machines can today be positioned with a high degree of accuracy. Using the RTK-GPS measuring method it is also possible to achieve comfortable dynamic positioning accuracy. Again, real-time connections to the design phase and models are at present. Today, 3-D design models can be used directly in dimension and control measurement tasks on site. In the near future the aim is to connect design to control machines. The first implementations and tests have started also in Finland.

Around the world, automated control systems have been studied and developed for very different machines and working methods. Fully automated systems have not been presented in such projects. Mostly, the role and task of these control systems is to aid the operator and measure and document the work. As an example, the control system in an instrumented pile machine can be examined (UK), in which the operator is informed of the depth as well as the rotation speed of the auger. In Europe, the automation of pavement work has been studied in CIRC and OSYRIS projects. In the United States, different control systems for the measurement and control applications of excavators have been developed. NIST (U.S.A.) has studied the automated control and navigation of mobile vehicles, the 3-D control of cranes, 3-D laser scanning technologies, 3-D visualization methods and the new possibilities generated by them and their utilization in construction. The control systems of excavators have also been studied in Italy and Poland. In Japan, unmanned construction systems and their economy have been studied. The connection of CAD models to machine control systems have received surprisingly little study. [Ban], [Budny], [Madhavan], [Malaguti], [Mure], [Peyret].

Perhaps the best way to be familiarized with marketable automation technology is to visit international technology exhibitions such as INTERMAT (Fig. 1) and SAMOTER. According to our general observations, it is remarkable that at these exhibitions the amount of machine control systems for earth moving machinery has continued to increase. The most noticeable product presentations have been made by TRIMBLE, LEICA and TOPCON. At the INTERMAT’2003 Paris exhibition, different 3-D machine control systems were presented (more than ever before) and nearly in all of the most typical earth moving machine types that have been introduced.

Figure 3. INTERMAT'2003 Paris – a touch to the global development of earth construction automation.

2. THE FINNISH EFFORT IN R&D – INTELLIGENT ROAD CONSTRUCTION SITE

The aim of the project entirety "Intelligent Road Construction Site" (Fig. 2) was set up to develop the Finnish road construction industry towards the level of numeric and automatic working processes. The main objective is to model the numeric total working process of road construction. In subprojects, publicly used road and bridge design CAD programs, measurement planning software as well as 3-D measurement technologies are studied (the total process research, Fig. 2, University of Oulu, Construction Technology). The Construction Technology Research Unit has also evaluated automation possibilities and potentialities of the most used road construction methods in Finland. According to this research, automation has real potentialities for road construction. One goal is to develop a modular control system for road construction machinery (the MODU research, Fig. 2, VTT Electronics). VTT has developed and tested different hardware and software modules and the interactive communications between them. Based on the modular "technology pack", differently applied numeric control processes and automation systems will be further developed in product development projects. These will include machine control modeling programs, positioning links for working machines, blade control systems and product quality control systems. The parts will be finally tested in actual construction projects on site.

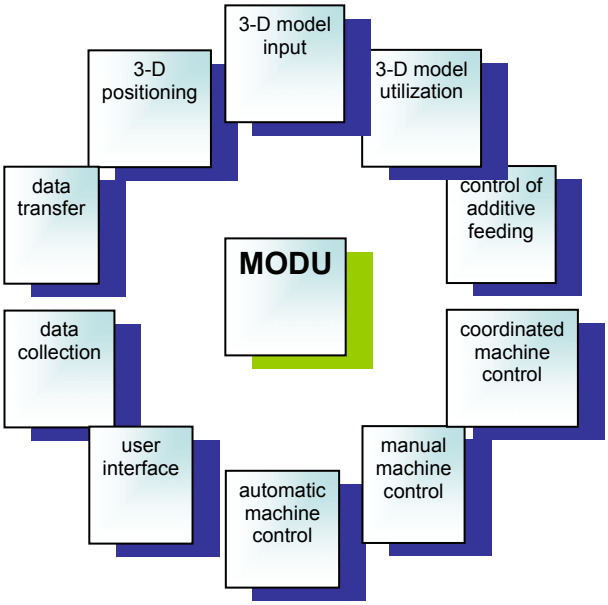

Figure 4. A scheme of the functional components of the modular machine control system (VTT Electronics).

In the domain of mechanical engineering 2-D and 3-D control systems are modeled and simulated for road graders, milling machines and excavators (the SIMULATION research, University of Oulu, Mechanical Enigneering, Fig. 6-8). A study concerning wireless road construction sites is also in the ongoing work phase (Fig. 2).

In the "Intelligent Street" product development project a laser scanning technology has been experimented with as a process part in street design as well as whole town modeling processes (Helsinki). In the "Intelligent Bridge" product development project new 3-D design methods are to be developed. The detailed results are described in a separate paper. The aim of the project is to take 2-D bridge design into spatial modeling extents and also connect 3-D bridge models to control 3-D measurements on site. A study of the effects of automated machine control on the quality of road structure has also been started (Fig. 2).

3. SOME FIRST RESULTS

The blade control system of road graders is the first result of the Intelligent Road Construction Site entirety (Fig. 5). In the system the 3-D location and position of the blade is continuously measured by a robot tacheometer and several position sensors. Measured data is compared with the 3-D road geometry model. On account of a kinematic inverse solution the adjustment and control data for hydraulic work cylinders is calculated. All of the possible blade movement possibilities are at hand also in automatic control mode. The role of the system is to help and assist the operator. Full automation has not been the aim of this development. The road grader system has been tested in three motor road construction projects. The test results have been excellent. Achievement with the control system has increased 100 %. The best-achieved geometric accuracy of road structure layers has been ± 1 cm. The development project of the next age of road grader system has been started (Road grader II, Fig. 2, Roadsys Ltd).

Figure 5. Automated control system of road graders on a motor way construction site, Salo, Finland, 2002.

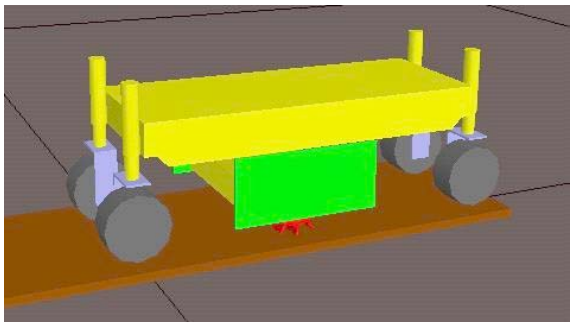

Figure 6. Simulation model of milling machine (Figure: University of Oulu, Mechanical Engineering Department).

Figure 7. The real milling machine in the field tests (Figure: Andament Ltd).

In the research concerning milling machines (Fig. 6-7) two different automatic control modes have been simulated and tested. The 2-D control mode has already been preliminarily tested on site. A product development project on a new smart 3-D control system is just now in its starting phase.

Excavators are very widely used machines in road construction. In the entirety of Intelligent Road Construction Site the research and development work of the control automatic systems for excavators have been started (Fig. 8). Excavators are used for very versatile and demanding tasks. To enable automated control using the CAD model, we need a totally new mathematical solution for total freedom of movement. According to the simulation models and tests, the development of this kind of control system seems to be possible.

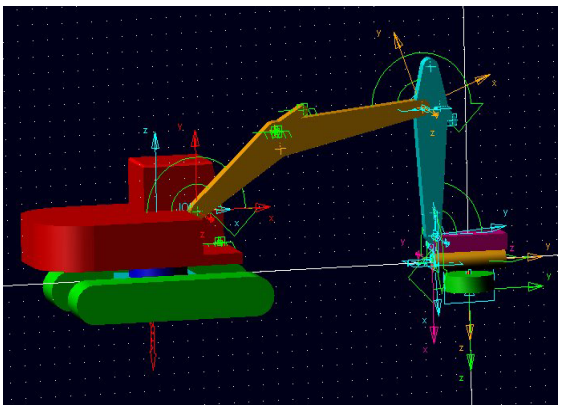

Figure 8. Simulation model of excavator (Figure: Tomi Makkonen, University of Oulu, Mechanical Engineering Department).

More digging intelligence could be achieved by connecting different GPR radar measurement technologies to detect underground canals, pipes and other structures. These types of control systems have already been tested in other parts of the world. In such developments it is always essential to look for any benefits generated by new automated control systems. They could be, for example, the detection and localization of previously assembled cable lines to information of the operator, the geometrical control data for digging new excavations or automatic documentation of operated materials. The pay back period of a digging control system could be very short, for example due to escape of only one cut of pipe or cable line.

4. CONCLUSION

Intelligent Road Construction Site is the Finnish research and development effort towards functional earth moving automation. According to the first results, automation seems to have very great effects and possibilities in the processes of earth construction. It is essential that this, traditionally a very low-tech evaluated industry, starts to utilize the most modern and newest technologies and applications. In Finland this awakening has been expansive in the domains of Finnish infra industry, Finnish Road Administration, the National Technology Agency and also the Road and Transport Ministry.

The effects of road grader automation on the processes of road construction have been studied for two years in a real construction project: labor productivity has doubled and accuracy has been beyond any criticism. It has also been also essential to notice the exhilarating effect of the control system on the key operatives: the designer has detected to control machines by his design model; the operator has received a new smart grader, which has brought to common work some very interesting and useful properties. The appreciation of other operatives has also increased. Again the direct information link from design to site operations is a very essential point. We assume automation technology to be full of different possibilities in earth construction.

5. REFERENCES

[Ban] Ban, Y., 2002, Unmanned Cosntruction System: Present Status and Challenges. ISARC'2002, 19th International Symposium on Automation and Robotics in Construction, 23-25 September 2002. Washington, DC, the United States of America, pp. 241-246.

[Budny] Budny, E. & Chlosta, M. & Gutkowski, W., 2002, Optimal Control of and Excavator Bucket Positioning. ISARC'2002, 19th International Symposium on Automation and Robotics in Construction, 23-25 September 2002. Washington, DC, the United States of America, pp. 481-488.

[Heikkilä & Jaakkola] Heikkilä, R. & Jaakkola, M., 2002, The Efficiency of a 3-D Blade Control System in the Construction of Structure Layers by Road Grader – Automated Design-Build of Road Construction in Finland. ISARC'2002, 19th International Symposium on Automation and Robotics in Construction, 23-25 September 2002. Washington, DC, the United States of America, pp. 475-480.

[Madhavan] Madhavan, R., 2002, Terrain Aided Localization of Autonomous Vehicles. ISARC'2002, 19th International Symposium on Automation and Robotics in Construction, §23-25 September 2002. Washington, DC, the United States of America, pp. 511-518.

[Malaguti] Malaguti, F. & Zaghi, S., 2002, Force Sensor by Driving Hydraulic Cylinders: Identification of Inertial Parameters and Tests. ISARC'2002, 19th International Symposium on Automation and Robotics in Construction, 23-25 September 2002. Washington, DC, the United States of America, pp. 431-436.

[Mure] Mure, N. & Scott, J. N. & Seward, D. W. & Quayle, S. D. & Calyton, C. R. I. & Rust, M., 2003, Just-in-Time Continuous Flight Auger Piles using an Instrumented Auger. ISARC'2002, 19th International Symposium on Automation and Robotics in Construction, 23-25 September 2002. Washington, DC, the United States of America, pp. 455-460.

[Peyret] Peyret, F., 2002, Standardization of Data Flows on Earthworks and Road Pavement Sites using Information Systems. ISARC'2002, 19th International Symposium on Automation and Robotics in Construction, 23-25 September 2002. Washington, DC, the United States of America, pp. 305-310.

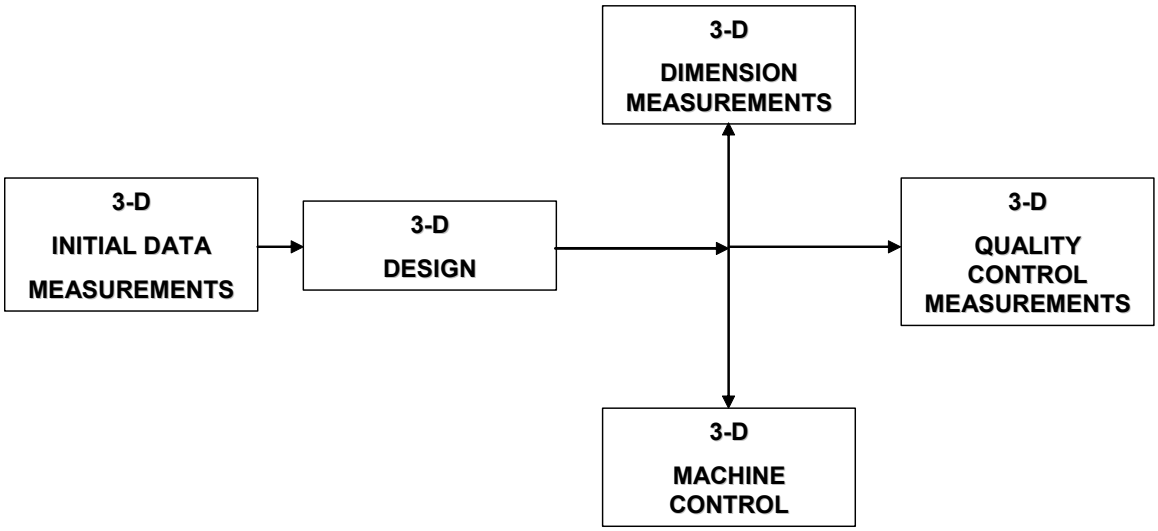

Figure 1. The total information process of 3-D road construction – one description level.

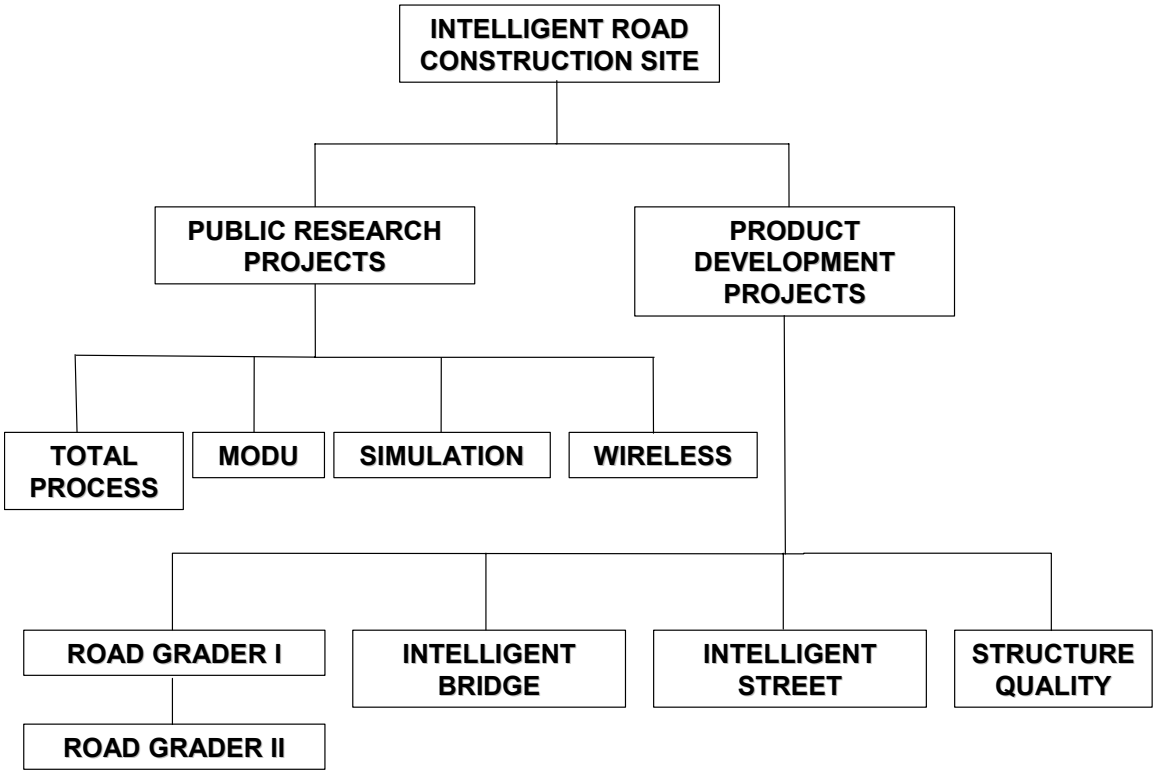

Figure 2. Ongoing projects - the project entirety of Intelligent Road Construction Site. The Finnish effort in road construction automation development.