AUTOMATION OF ROAD CONSTRUCTION – THE STATE OF THE ART IN EUROPE

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Abstract: Due to the development of 3-D techniques and methods, the utilization of different automated and 3-D based working methods has increased a lot in Europe during last few years. In the paper, this present situation is introduced based on the practical observations and tests gathered from five different Europe countries. Different experiments as well as achieved benefits are described. Conclusions about the important role of automation in road construction is outlined. Next major development challenges connecting to the model of automated total process are introduced.
Keywords: Road construction, automation, 3-D machine control.

1. INTRODUCTION

Full-scale integration of information technology into the civil construction process enables increasingly important innovations in the implementation of the individual phases of construction. The work process will digitized, the information will be organized and managed using 3-D geometric data, conventional work processes will be broken down into sub-processes, re-organized and mechanized in new ways, while the level of automation will increase to combine previously separate and unconnected operations to achieve smoother and more efficient cooperation. At the same time, the work process is a generic model development process in the course of which the original models created out of input data measurements are upgraded, expanded and exploited throughout the operational process.

2. AUTOMATION OF ROAD CONSTRUCTION

2.1 Modelling automated total process

Automation of infra construction is greatly based on the use of different information models in the different phases of total working process (Fig. 1). For example, the machine control models (“control model”) needed can be processed from the product design (“product model”) in question. Product model is possible to be designed and optimized on account of measured “initial data models”. Constructed structures and products are measured and stored as “as-built models”. After that the controlled use and maintenance of products will be need different functional measurements (“maintenance model”). In the end of product life cycle the situation is found by residual value measurements. This information (“residual value model”) can be utilized in a long term development of products and working processes.

The process of automated road construction starts with input data measurements carried out on the site. In road construction projects, the key input data includes variations in terrain and elevation and soil features. Over the past few years, laser scanning from an aircraft, helicopter or on the ground has developed greatly and become increasingly popular. A laser-scanned cloud of 3-D points adjusted to the relevant coordinate system can be imported into a semi-automatic analysis application that can be used to model not only the contours of the terrain but also the tree stands, road alignments and buildings. However, 3-D modeling of underground soil features and their conversion into a digitized format is technically far more complicated than over ground terrain modeling. A large research project focused into that problem is just now ongoing in Finland (University of Oulu, Technical Research Centre of Finland).

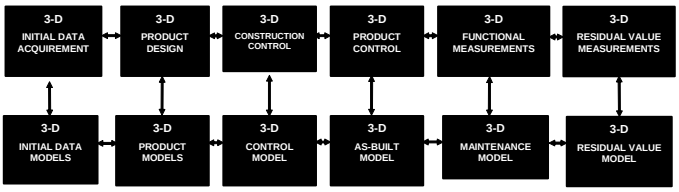

Fig.1. A model for automated total process of road construction.

In product design, a model and instructions for the implementation of the product are created out of the input date. Very typically, the products are large 3-dimensional objects. If the input data is 3-dimensional, design can be carried out 3-dimensionally using CAD tools. The 3-D geometric model can be used to produce images for 2-D drawings. With improved efficiency in design, it is also essential to be able to make use of the design model for construction purposes. If the geometric model is accurate and readily positioned in the site coordinate system, it can be used directly for controlling measurements and construction machines. This imposes additional requirements on the quality and accuracy of design. Similarly, an online connection between the CAD application and 3-D measuring technique is feasible.

In the future, there is a very strong view that machines used in civil construction will be more and more controlled by automated systems. As is known, the most advanced systems presently available permit partial automatic control of the machine blade based on 3-D positioning and 3-D models. However, the functional performance of the systems varies, usually because they only make use of geometric data that is not managed completely. Full control of the 3-D geometric data and, in particular, inclusion of other property data in the control system are still things of the future.

Previous research and experiments indicate that the control of construction machines and blades requires active coordination by the operator. In this system, the blade position is adjusted automatically with reference to the control model, permitting the operator to select among various options to optimize the process according to the situation at hand. Evidently, pre-calculated paths of travel can seldom be followed.

Typically, 3-D point, curve and triangulated surface model models provide sufficient geometric control data for finishing surfaces. However, their data content is not enough for a control model for work operations such as the reinforcement of the road bed or stabilization of structural layers, where the objective is to modify the properties of the materials.

For example, in pile driving, the pile may be broken when the soil type and its penetration resistance change as the pile pierces new layers. If the 3-D geometric model provided information about penetration resistance, it would be possible to control the driving force when penetration resistance reaches its maximum while ensuring that the tensile stress inside the pile does not exceeded its capacity.

2.2 Experiments

In the research the state of the situation of the use and exploitation of automation in the field of construction was studied by visiting three road construction sites in Sweden, Norway and the Netherlands. In addition, the automation news from Poland were also received from Poland. All of these studies were made as a part of a large research and development project ongoing in Finland (University of Oulu, Technology Agency of Finland, companies). Due to these R & D activities also the situation of Finland can be well introduced.

3. OBSERVATIONS AND RESULTS

According to the evaluations and the information gathered from system developers and main contructors, in all 2500 different 3-D control systems are today in practical utilization in infra construction work of Europe (situation 2005). The contribution of Skandinavian (especially Norway and Sweden) is very strong or about 1000 systems. In Finland there are today about 40-50 systems. The experiences have been very positive. According to main contractors the implementation of automated 3-D control has improved produtivity a lot, the efficiency of work has increased, working errors have decreased and economically the benefits have already paid their investments several times back. The operators tested the 3-D systems have without exceptions wanted to use 3-D systems in their machine work. Today the most part of different earth moving works are operated using 3-D control systems (Skanska Norway). In Sweden it is today unlikely to get any work contract without having a 3-D control system (Vägverket, Sweden).

In 2005 we visited the road construction site of Uppsala-Medeheby motorway construction site, in Sweden. The main contractor was Vägverket Produktion. The first part of the conrtract was 38 km long part of motorway (total 78 km), having 67 bridges, the budget of 140 M€. In the site about 52 different 3-D controlled (RTK-GPS) work machines (excavators, graders, compacting machines) were in practical daily use. No traditionally controlled machines were in the site. According to the site office, in Sweden it was proven to be unlikely to get earth moving contracts without having 3-D controlled machines.

Fig. 2. The user-interface of the 3-D control system of excavator used in Sweden 2005.

In 2005 we had also a visit to road construction site in the Netherlands, where 3-D machine control was also proven to be today broadly in real use. Trimble's 3-D systems were used fro the machine control tasks. Also orderers operate their quality control using 3-D systems in the Netherlands.

Fig. 3. Using 3-D control (Trimble, two GPS antennas) for grader in Holland, 2005.

The third visit was in 2006 to Norway, where we met the main contractor Skanska Norway. Skanska has already 6 years utilized 3-D control in site construction. Today almost all of the earth moving works are made using 3-D machine control. As results, labour productivity has improved a lot, work has come faster having at the same time less errors.

According to our interview of a project manager of Skanska Norway, they have used digital data in civil construction over several years. Today they use Microstation Inroads to produce digital data for machine guidance, mass calculations, documentations, 3D models etc.

In Skanska Norway, machine guidance was started in the tunnels. The road data was delivered from designer on VIPS-format (Novapoint Road) and the surveyor constructed the tunnel section and imported this on the machine computer. Until today it has further developed to a complete systems with digitals drilling plans as the operator drilled the tunnel after. Today they have a cooperation with Via Nova (Novapoint) and Bewer Control to establish Novapoint Tunnel. This program will be used by the designers to produce a 3D model for the complete tunnel including all elements in the tunnel, ready to be exported from PC to total station and tunnel rigg computer. Drill loggs (scanning, bolts, drilldata etc) from drilling can be exported from the drilling operations and back to designer.

Skanska Norway has got the savings and quality effects of the machine guidance from tunnelling operations. Today this spreads towards guidance of graders, excavators, dozers etc. This was simply systems given the machine operators exact information of the slopes and levels for the road. But also for these operations they have seen savings and better quality.

For marine operations Skanska Norway has had co-operations with Prolec in UK. According to their report, the investment they have got it back several times. The vessels are operated with GPS and moving sensors and they use 3-D models from the designer. The vessels operates without any survey assistance after they have established the GPS-base on land and have imported the model in the vessel computer.

Skanska are now testing different 3-D systems for excavators. They have used simular systems the last few years, but these new systems gives the operators much more information. He can see his machine in the model on the computer. He has all the information he need on the computer in the machine. Surveyors uses digital data from the designer. In the future they don't need to do anything with the data as we have done before. This is simular for dozers and graders, and will also be implemented on drilling rigs for blasting works outside tunnels. Today they are planning to use 60 3D systems if we get the new large project in the south part of Norway.

The key to have successful flow of digital data is to have engineers on the project which takes responsible for the 3D data flow. The main challenge is not the machine guidance systems or the GPS. The main challenge is to have control of the flow of 3D data from designer to construction.

Fig. 4. One of the most advanced machine control system for excavation (Georog by SBG Svensk Byggnadsgeodesi AB, Sweden, using BPS sensor system of Axiomatic Technologies, Finland).

To meet this challenge it is of very importance to organize units in the projects in such a way that we have control with the 3-D data. Skanska Norway has established Skanska Survey and given them responsible for 3-D data flow in the civil construction projects. Survey is a project specialized in surveying, GPS, machine control, 3-D data, terrain models etc.

When Skanska get a bigger civil construction project Survey starts up all surveying works. Surveyors establish GPS-systems, starts measuring existing terrain, establish machine guidance systems, starts surveying etc. They also takes responsible for Survey Manager position in the project. All surveying works for bigger civil construction projects are being cost-calculated by Skanska Survey in the tender period.

In 2006, it is remarkable to notice a new 3-D machine control investment made in Poland for Skanska Poland (possible on of the world's biggest 3-D machine control order). The investment was made for the Europe's largest road project being started. In all Skanska bought 50 Georog machine control systems including also different modules of SBG Geo softwares, too.

Until 2006, there has been made a lot of research and development work in the field of road construction automation in Finland. The use of different 3-D methods in measuring, design, machine control and as-built measuring has increased al lot. New results of research and product development can be find for example from laser scanning, 3-D ground penetrating radar, 3-D modeling and design softwares, 3-D machine control systems, the development of an integrated total process model for comprehensive automation, etc. Still the use of 3-D machine control systems has until today not very broadly increased. About 40-50 3-D machine control systems are used in the construction sites.

Fig. 5. A 3-D control system in a real excavation work in Finland (Finnish Road Enterprise, Axiomatic Technologies Oy, University of Oulu).

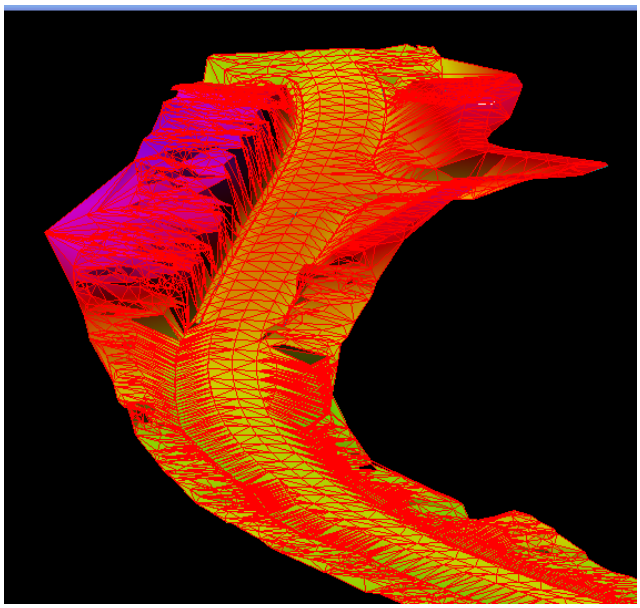

Fig. A 3-D machine control model for excavator (Finland 2005, University of Oulu).

4. CONCLUSION

Automation is today broadly used in the infra construction in Europe. Automation has proven its efficiency and benefits on account of full-scale site tests in different European countries. Today there are increasingly efforts on the development of total working process by the aid of 3-D automation. It is also the main focus of our automation research group.

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