MODEL FOR AUTOMATED ROAD-CONSTRUCTION CONTROL

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ABSTRACT: A survey of current practices revealed that very little control is normally done in earthmoving management. A model to control road construction projects was developed. The model is based on the concept of automatically measuring performance, by measuring locations at regular time intervals, and converting them into controlled parameters. According to this concept, control algorithms convert the measured locations to produce two types of real-time control data: progress and productivity. Locations are measured with a Global Positioning System (GPS). Field experiments conducted with the prototype of the GPS measurement system prove its suitability as a Location Measurement Module.

KEYWORDS: Automated Data Collection; Benchmarking; Control; Earthmoving; GPS; Monitoring; Road Construction.

1. INTRODUCTION

A major obstacle for automated project performance control is measuring the various project performance indicators such as cost, schedule, labor productivity, materials consumption or waste, etc. Advanced technologies, which can be used for on-site measurement and control of project indicators, are emerging and their costs are declining. The work presented here is part of the Technion's initiative called Automated Project Performance Control (APPC). This area broadly refers to the activities taken by the project (or company) management in order to ascertain that the performance of the project is as close as possible to the desirable one. The performance is measured in terms of Project Performance Indicators (PPI). Current efforts focus on automated-data-collection based project performance control, both in building and in earthmoving operations.

The present paper uses a concept of automatically evaluating performance, by measuring indirect parameters and converting them to the controlled variable. The system described herewith will measure the locations, as function of time, of all members of a fleet of earthmoving equipment and convert them to produce real-time control data. The locations will be measured with a Global Positioning System (GPS).

2. INFRASTRUCTURE-CONSTRUCTION CONTROL - STATE-OF-THE-ART

The extent of controlling PPI in infrastructure construction projects is still limited. Current

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methods normally use manual data collection. The area where Automated Data Collection (ADC) is used for real-time monitoring is quality control and methods that provide data to the equipment's operator, making its manipulation easier.

2.1 Manual Control of Infrastructure Projects

Current practices of project management control in Israel were surveyed in 12 leading construction companies whose main line of business is infrastructure, road construction and earthmoving. The survey was done to assess the state-of-the-art of project management control and the need for it. Most of the surveyed companies admitted that they were not doing any control, but they agreed that if such tools were to exist they would be very willing to use them.

Some of the companies control progress by following up the flow of materials to the site. The bills-of lading are collected and sent to the main office where the quantities are plotted as functions of time and compared to the planned values. The users of this method are generally dissatisfied, reporting that this procedure is inaccurate, error prone (because of the manual data input), and labor intensive. One of the reasons for the inaccuracy is that the planned material consumption assumes theoretical cross-sections, ignoring the difference between the design and the actual physical measurements of the road structure.

2.2 Real-Time Control in Earthmoving Projects

Most previous attempts to automate earthmoving operations are surveying-oriented, yielding impressive results in quantity and quality control. Another aspect of heavy equipment automation is monitoring the operation of the equipment, making its manipulation by the operator easier [e.g. Lee et. al 1997, Peyret et. al 2000, Kannan and Vorster 2000, Bouvet et. al 2001]. The present paper presents the first attempt to automate the control of earthmoving project management.

Lee et al. [1997] proposed a real-time control system to improve the productivity and the quality of asphalt paving operations. The system has four modules using RTK (Real Time Kinematic) GPS. Another model that uses the same technology is called IMPACT [Tserng and Russell 1997]. The model was developed for planning and controlling earthmoving equipment to improve its productivity and safety. The productivity improvement can be achieved by better planning, using simulation. The safety can be enhanced by position measurement, using RTK GPS and controlling the movement to avoid collision.

Recently several other applications of GPS for earth moving equipment control were introduced - most of them with RTK GPS. Peyret et al. [2000] describe a 'Computer Integrated Road Construction' (CIRC) project, aiming at introducing a control and monitoring tool for road pavements construction. The new tools were designed to bring to the sites significant improvements by creating a digital link between the design office and the job site.

Krishnamurthy et al. [1998] describe an automated paving system for asphalt pavement compaction operations. A semi-automated path-planning real-time guidance system that aims towards automating the paving operation was developed. This system accepts relevant paving project inputs, generates appropriate path plans for the compactor, performs a graphical visualization of the generated path plan and offers real-time guidance capabilities using GPS technology.

3. AUTOMATED CONTROL MODEL FOR ROAD CONSTRUCTION

The development of the concept of automatically monitoring performance, by measuring indirect parameters and converting them, was developed in recent years at the Technion [Goldschmidt and Navon 1996 and Navon and Goldschmidt 1999]. This Section sets the theoretical framework of the model and describes the model.

3.1 Conceptual Framework

The system will measure the locations of all members of the fleet of the earthmoving equipment at constant time intervals. An algorithm, described below, will convert these locations to produce two types of real-time control data: progress and productivity. The location will be measured with GPS. The system will use these locations together with data extracted from a Project Model (PM)[4] to determine the activity the equipment is engaged in, its progress, and its productivity. The result will be compared with the planned progress and productivity to give an early warning on deviations as they occur, and will enable the analysis of the causes.

3.2 Model

The model (Fig. 1) compares between the planned and the actual values of progress and productivity variables. The model has two main sources of data: (1) The Project Model, containing the planned schedule, the productivity, and all the data regarding the physical design of the road (layout, cross-sections, etc.). (2) The Location Measurement Module (LMM), using GPS. This module measures the location for each member of the fleet at regular time intervals. The module records the time of measurement, the identification of the equipment and its location.

The model includes four interfaces, which extract all the relevant data from the PM. These interfaces are: Schedule Interface (SI), Geometry Interface (GI), Quantity Interface (QI) and Productivity Interface (PI). The SI begins the process by extracting all the pending activities - these are all the activities whose predecessors are completed, which means that they can be active on the given day.

Specific Work Envelopes (WE)[5] are calculated for each pending activity, based on information in the Knowledge Base, which includes a typical work envelope database, and on the geometrical information extracted by the GI interface from the PM. The WEs correspond with planned work sections, as represented in the schedule. Next, a geometrical calculation associates each of the locations to these specific work envelopes, by checking if the measured location is included within the WE. This, together with Decision Rules from the KB[6], enables the model to determine which activities are actually being performed. Once the model identifies that a new activity has started, it also determines which of the activities are completed. The cycle ends by determining the actual time spent performing each activity, and the productivity, which is based on this time and the completed quantities, extracted by the QI. These data serves as a basis for the output of the model.

The output of the model compares the actual performance, as measured and calculated by the model, to the planned one. It includes:

• A comparison between the actual productivity and the planned one, extracted from the PM by the PI.

• A comparison between the actual progress and the planned one according to the updated schedule extracted by the SI.

The output of the model serves a variety of managerial functions, such as monitoring and taking corrective measures.

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[4] The Project Model includes a physical description of the road and a description of the activities needed to construct it.

[5] A work envelope is defined to assist the association of the equipment's location to a pending activity, as follows: an area, or volume, where a piece of equipment, working on the road, could be located. The shape and type of a work envelope depends on the nature of the activity, on the construction method, or technology, and the type of equipment.

[6] The decision rules are designed to (1) help associating locations not included in a work envelope, or included in more than one envelope. (2) Determine completed activities.

4. CONCLUDING REMARKS

The first stage of the development was to ascertain that there were no technological barriers. Consequently, a feasibility test of the LMM was carried out. The experiment was planned to check the suitability of GPS, and the pertinent software. The feasibility test is not described here due to space limitations. The experiments confirm that GPS is suitable for the purpose of controlling progress and productivity of earthmoving operations.

The Technion's Automated Project Performance Control (APPC) group is currently engaged in a number of research projects relating to Automated Data Collection. The most notable direction of the group is that of measuring locations at regular time intervals, or other indirect parameters, and using them to automatically control productivity and progress.

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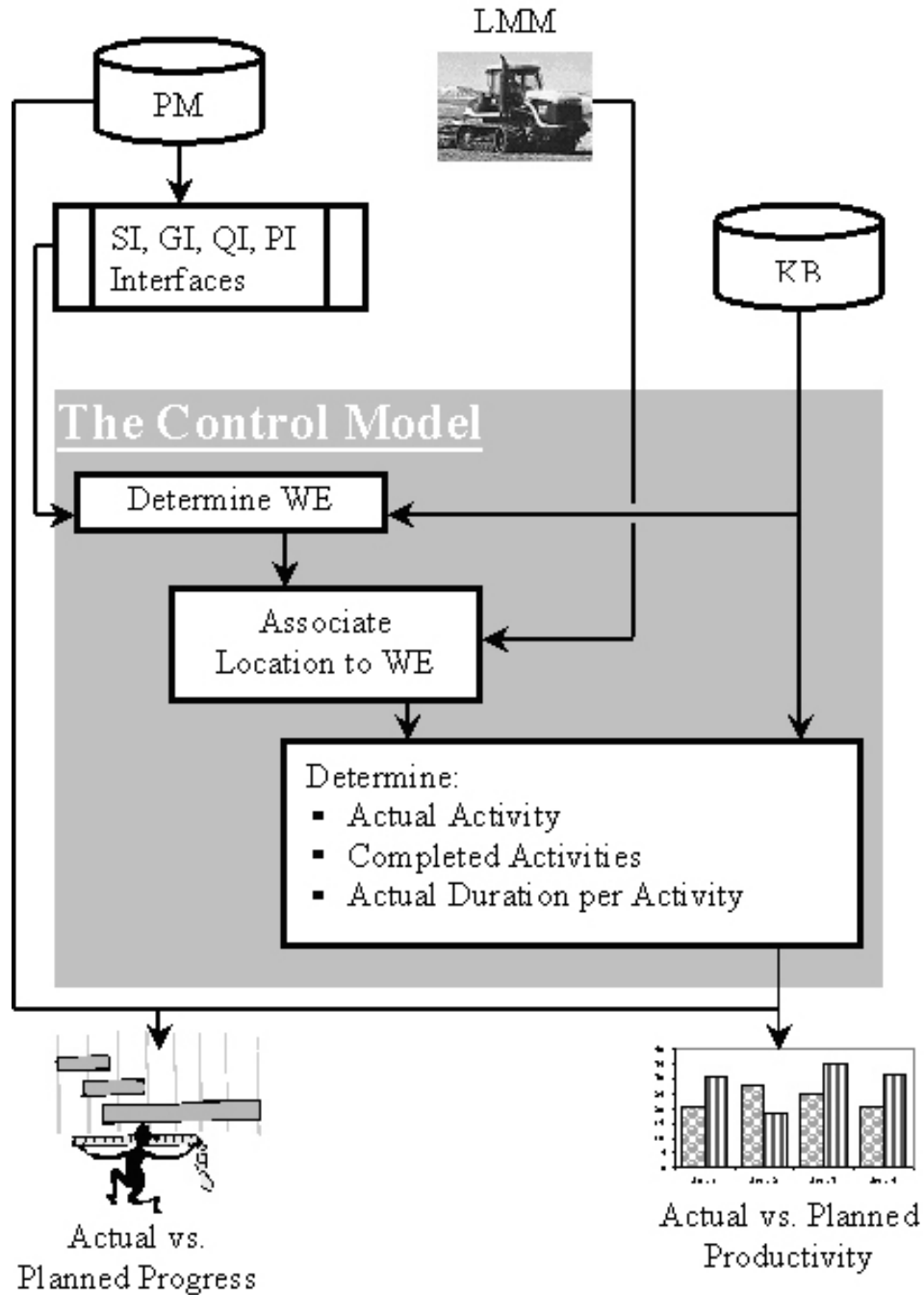
Figure 1: Model Architecture