STANDARDIZATION OF INFORMATION SYSTEMS FOR CIVIL-ENGINEERING SITES

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Abstract

More and more civil-engineering sites, and especially road construction are experimenting all over the world new kind of systems aiming at improving quality and efficiency of the construction tasks.

These systems make profit of the new technologies of information and communication, still rarely used on the sites. Most of them bring partial solutions but are not compatible. This diversity, of shape and sometimes of principles, and this incompatibility are a serious barrier to their development at an industrial level and a strong demand for standardization exists as well from the contractors side as from the machine manufacturers side.

The authors start by setting the background of this standardization activity, which is discussed in the frame of a new working group of the ISO TC-127 committee. They introduce an important concept which is the concept of “road product model”, becoming more and more important for those who try to unify the digital representations of the road all along its lifecycle.

Then, they present the differences between logical and physical modeling and explain why they propose to start the standardization discussions at the logical level. The core part of the paper is the presentation and comment of the logical model of an information-controlled road site which can be applied to any kind of system of this type. They finish by giving some indications upon how to use this model in the following of the work.

Keywords : information technologies, civil-engineering sites, computer integrated construction, product model, logical analysis

1 Introduction

The physical tools and the human know-how which are necessary to build good quality infrastructures are nowadays at the right level. Equipment is powerful, techniques and tools are accurate, people are skilful. However, still much time and money are lost all along the various phases of construction, during these phases and in between, due to the lack of information and the very poor quality of the management of this information, making very small use of the new available Information Technology. Clearly, the new challenge in the construction world is now the information management.

The work that will be presented in this paper deals with the preparation of a new step in the general process of modernisation of civil engineering activities (in particular road construction activities). For about 10 years now [1], novel execution support systems, making profit of information and positioning technologies, have been developed all over the world to improve the efficiency and quality of work of the construction equipment such as rollers, pavers, graders, bulldozers, etc. These systems generally apply the same scheme (computer integrated construction) which consists in real-time use of the "to-be-built" information, coming from electronic CAD systems, together with positioning information (generally GPS or robotised total stations) for the execution support and the documentation of the as-built to be fed back to a kind of site monitoring and quality control high-level system. Many systems of that kind are now used or are in the process of being introduced on the market: CAES systems from Caterpillar and Site-Vision from Trimble in the USA, "Virtual Stringline" from Topcon and others in Japan, CENTAUR from Vinci-GTM in France, European CIRCOM and CIRPAV systems, marketed by PGES, etc. [2] [5].

In these systems, the main objective is the support to the machines and to the operators, the information management itself being a kind of second level functionality. On the other hand, people have become aware of the value of all the relevant data that can be collected from such systems, for instance for quality assessment and relationships with the road owner, and of the necessity to standardise the information exchanged. These new issues will launch a new domain of research and development which is less focused upon hardware and more of software, which can be called "information-controlled construction sites" [3] [4].

2 Background of the standardization activity

Under the initiative of the Japanese delegation at the ISO TC-127 standardization committee, in last October in Rio de Janeiro, was made the decision to launch a new working group, focused on the scope of "Worksite data controlled earth-moving operation". This group, gathering experts from Japan, USA, France, Germany, Sweden and Italy, met for the first time in Tokyo at the beginning of March 2001 and output some main decisions from their discussions:

- to focus upon road construction works,
- to start with the standardisation of the definition and content of the information exchanged, then to study the format, then the protocols,
- to stay close to the site, e.g. not to study, in a first step, the higher level exchange of information between road authorities and the contractors.

LCPC, which has sent two delegates to this first meeting, has been committed, until the next meeting which will be held in Italy in September 2001, to propose comprehensive logical and physical models that could be used to support the further discussions inside the group.

3 The road product model

Before presenting the core result of our work, we have to place it in the general context of the modelling of the road. In the global life cycle of a road, 4 main phases can be identified, as presented on Figure 1.

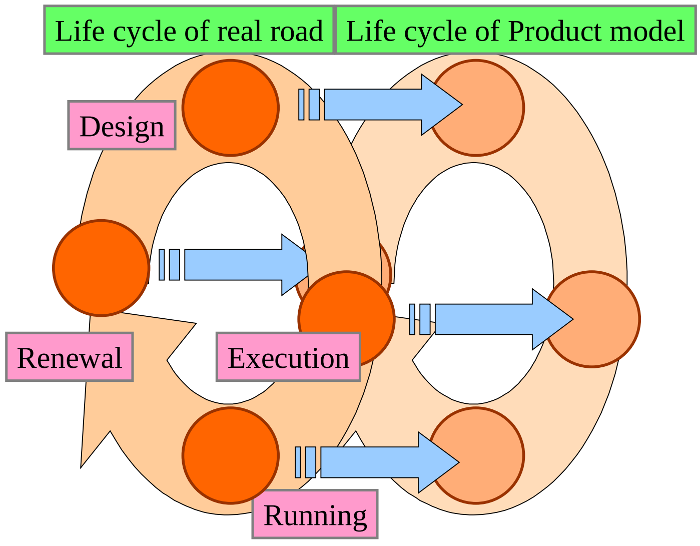

Figure 1: the life cycle of the real and of the virtual road

Each phase uses, for its own purpose, a modeling of the road, which is based upon different ways of doing and, for the moment, are incompatible. However, the product which is concerned remains the same (the road) and, at each level, more and more researchers and engineers are developing new concepts to propose in the future a unique and common way of modelling of the road. Ideally, these models are to be used by everybody, at each phase, dramatically facilitating this way the exchange of data and reducing the important losses of information which are deplored nowadays. These new concepts are called "product models".

A product model is one kind of information model, e.g. an abstraction of objects and relationships in purpose to aid understanding. Generally, information models are conceptual, that is to say independent from the instantiation form, but describing real world objects and associations between them.

Product model is one type of information model that is specified to some purpose. This purpose is defined by the information model and model functionality. Generally, functionality offers basic management of the information through several interfaces and some analysis tools for further manipulation and utilisation. In our case, the road product model is designed to store and manage information related to the product "road".

On Figure 1 can be seen the life cycle of the real road on the left-hand side and the corresponding life-cycle of the "virtual" road, also called road product model, on the right-hand side. In the lifecycle of the product model, there are also 4 main phases: design, execution, running (including maintenance to keep it in specified conditions) and renewal.

4 Logical model of an information-controlled site

4.1 Information-controlled sites

The objective of our work has been to propose a figure presenting all the main information flows which are (or will be soon) existing in a road construction site making profit as much as possible of new information technologies. This kind of site has been called "information-controlled site". Another way of depicting these sites could be: a road construction (or road maintenance, or earth-moving) site using a "computer integrated construction" system such as CIRC, OSYRIS, Topcon, CAES, CENTAUR, etc.

As already mentioned, these physical systems roughly apply the same paradigm, but are realised differently, using various technologies and implementations. Some rely upon robotised total stations, others upon GPS, sometimes the computation and the commands are elaborated on-board the machine, sometimes on the ground, some systems emphasise the documentation functionality, others don't, etc. The target machines, supposed to make profit of these systems, are also different, although they all share the same basic function which is to modify the shape and consistency of the landscape by moving, removing, compacting or bringing additional materials to, the existing ground.

4.2 Logical versus physical analysis

An analysis and a modelling of a information-controlled site at the physical level would have been dangerous for a standardization activity, in the sense that it would have given the preference to the specific technological solutions used by this system, impeaching this way other competitive technologies to develop.

The only way to avoid that is to analyse the information and the exchanges in the logical, or functional, dimension. We explain here what we mean by physical and logical models and give a simple table indicating the main differences between the two types.

Table I: differences between logical and physical model

	Logical model	Physical model
Basic element of model	System (& sub-system)	Component
Concept of location & timing	No	Yes
Purpose of modelling	Relationship of functions	Location of functions

The basic element of a logical (or functional) model is called "system". A system is a group of functions providing a service (can be an action but generally a piece of information) as answer to a demand (always a piece of information). Each system contains some sub-systems in it.

The basic element of a physical model is called "component". A component is a set of devices (hardware and software) which are located at the same place (generally a kind of "box"). The notions of location and timing are predominant in physical models. If there are two sets of devices which have the same function but in different places, they are different components. Each device in the components and the components themselves must be physically connected together to work for the same purpose and these connections are also kind of components (physical and software interfaces).

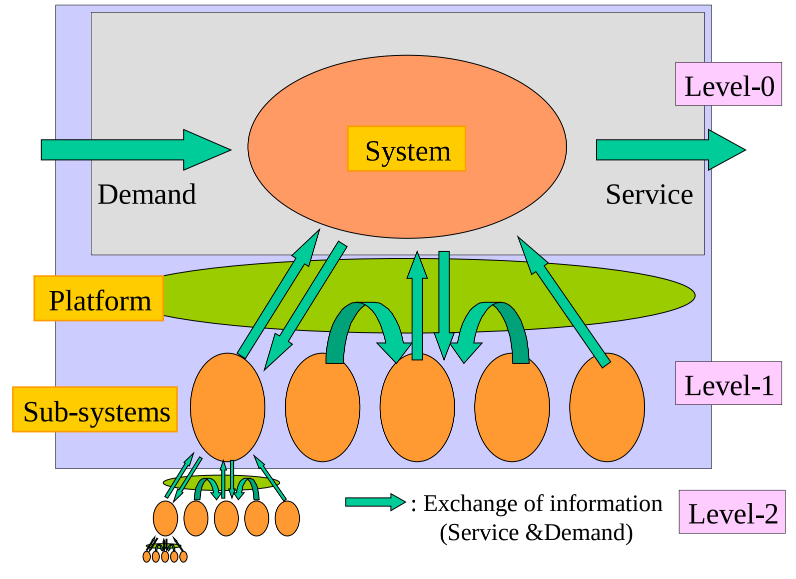

Figure 2: the fractal structure of a logical model

There are different levels of systems, as illustrated on Figure 2. The level-0 system is the global process, which is in our case the "information-controlled site". The level-0 system is composed of various sub-systems in the level-1 which are also providing services either to the upper level system or to another sub-system. Under this level are other levels of the same kind, thus giving a fractal structure to the representation. Each system can be sub-system for the upper level system. The difference of nature between system and sub-system is not absolute but relative.

The system and sub-systems in the logical model exchange information through the so-called "platform". The platform is not a connection component. It is composed of the rules and protocols which are necessary to exchange information and has no physical body.

4.3 The methodology

To carry out our work, we chose to use the following methodology:

- to list all the main functions coming from the OSYRIS functional design,
- to group and to organise these functions on a comprehensive logical map,
- to confirm the validity of the map by checking that all the OSYRIS functions as well as functions coming from other existing physical systems, such as CIRC or Topcon system are represented in the map.

We are now in the phase of confirmation and will present below the logical model we have designed.

4.4 The logical model

Figure 3 presents the global model.

Outside of the system are placed:

- the other information systems exchanging information with the site information system, which are called "permanent product model management systems" (*permanent* means here that it is not affected by the execution of the work),
- the real world, that is to say the physical objects (machines, instruments, etc.) and the site materials the tools of the machines are working on.

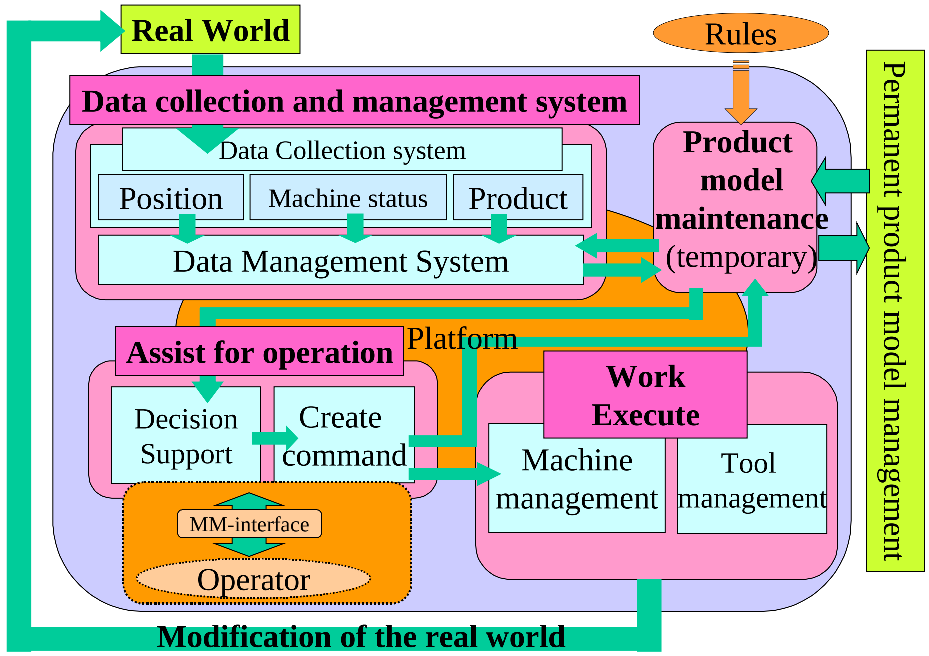

Figure 3: the logical model of an information-controlled site

The purpose of the system (level-0 service, according to our terminology) is the modification of the real world. The system modifies also the virtual world by updating the objects inside the permanent product model.

In the level-1 system, there are 4 sub-systems: "data collection and management system", "product model maintenance system", "assist for operation system" and "work execute system".

The "data collection and management system" collects data sets from the real world and from the product model and combines them to make information. The data sets which are collected from the real world are data about position, machine status and product (materials). Then, this system provides the elaborated information to the "product model maintenance system".

The "product model maintenance system" constructs temporary product model in the system. This system collects the information about virtual objects from the permanent databases which exists out of the system and about real objects through the "data collection and management system". This system always and continuously collects information to update its content. So we named it "maintenance system". Temporary product model contains only the information which is necessary to work in the execution phase. It stores temporary information, for example the temperature of the site at every moment and everywhere. Most of this information is not necessary to the other phases of the life cycle. For the other phases, only the information at special moments is necessary, for example the temperature of the asphalt material during some specific phases. This system also collects all the rules which are necessary to achieve correctly the work and forwards the elaborated information to the "assist for operation" system.

The third sub-system is the "assist for operation system". This one makes decisions concerned with the work. It compares the present status of the object and the ideal status which is based on the design information, finds the difference between them and makes decisions. In this system, the operator sometimes plays an important role. When the operator is concerned with the decision, he provides information through the man-machine interface (MMI). When the decision is made automatically, the operator is not necessary. It depends on the design concept. Sometimes we can consider the operator as part of the system, sometimes not. This system creates commands. They are provided to the "work execute system" and also to the "product model maintenance system", to record the commands which are information how the real world should be modified.

The last sub-system is the "work execute system". Only this system can modify the real objects. This system consists of two parts: machine management and tool management. Tool is the component which affects to real world directly. Machine is the component which helps the activities of the tool.

These 4 sub-systems exchange information through the platform and they work whenever they should work.

5 Application to physical systems

Logical analysis helps to comprehend physical systems. Generally, the difference between all the information systems which are developed by the different manufacturers is a difference of design concept, that is to say a difference in the location of functions.

Through the logical analysis, we can see the real figure of the system.

To illustrate that, let us take the example of the control by an operator of a construction machine such as a paver.

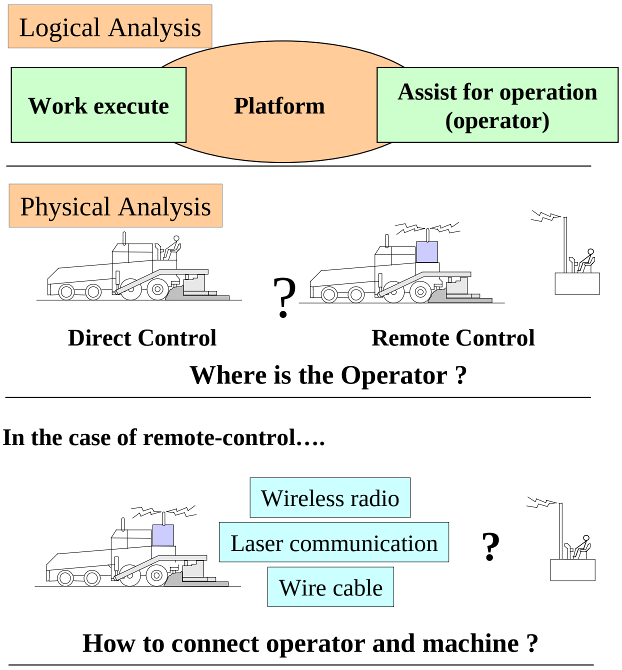

Figure 4: comparison between logical and physical analysis

Figure 4 illustrates different ways of controlling a machine: remote control or direct control. Remote control of the machine is totally different from direct control in the physical model. In the case of the remote control, we can also consider many different ways to transfer the commands to the machine, e.g. wireless radio, laser communication, wire cable, etc. The differences among these systems are the differences of the kind of communication components.

But, as a matter of fact, all the differences are at the level of the location of the different components and there is no difference as far as intrinsic functions are concerned. So, in the logical model, these two machine control systems are the same and can be represented (upper part of Figure 4) by an exchange of information between the two sub-systems: "work execute" and "assist for operation", through the platform.

Using the logical model to represent the functions and the flows of information existing in real systems, it should be much easier to understand how they work and to identify the real functional differences between them. It should be also more efficient to discuss about the content and the format of information to exchange between the components (which is the goal of standardization) at the logical level, before transposing the results of the discussion at the level of physical components. This is finally our proposal, at the present state of our work.

6 Conclusion and perspectives

LCPC has been asked by the standardization group WG 2 of TC-127 committee to propose a logical (or functional) model of the information-controlled road sites. This model has been established by using the functional design of an ambitious system of this type, under development in the frame of a European project, called OSYRIS.

The logical model produced is composed of four main sub-systems which play well-separated roles in the global process: "product model maintenance", "data collection and management", "assist for operation" and "work execute" systems.

This model is currently being confronted to some existing systems, such as the one proposed by Topcon company in Japan, in order to check that it can represent any kind of site information system.

We think that it may be useful during the work that will be achieved inside the standardization group, as an analysis tool to understand and compare the existing systems and as a general framework to support the standardization proposals.

7 References

[1] F. Peyret, H. Philippe, "Towards Computer Integrated Road Construction", *Proc. 9th International Symposium on Automation and Robotics for Construction*, Tokyo (1992), 859-868

[2] Peyret F. , Jurasz J., Carrel A., Zekri E., Gorham, B. (2000), "The Computer Integrated Road Construction project", *Int. journal Automation in Construction* , vol. 9 (2000), 447-461

[3] Nitta Y., Hirashita H., Ebara M., Emoto T., "Study of the overall system architecture of construction equipment support information system", *Proc. 17th International Symposium on Automation and Robotics for Construction*, Taipei (2000), 867-892

[4] Muramatsu T., "Site Information system in Japan", *Proc. 2nd Civil Engineering Conference in the Asian Region*, Tokyo (2001)

[5] Peyret F., Hintzy G. (2001), "Civil-engineering equipment: still powerful but intelligent too thanks to GNSS and information technologies", to appear in: *Proc. NavSat 2001 Conference*, 13, 14, 15 November 2001, Nice Acropolis, France