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Dynamic 4D Space Planning Using Chronographical Modeling

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Abstract

Over the past decade, many studies and software have combined the 3D digital models of the BIM (building information modeling) with the traditional Gantt / Precedence scheduling networks to simulate a 4D modeling for construction projects. These simulations demonstrate the sequences of the work implementation with the aim of correcting scheduling errors, resolving execution conflicts and optimizing the work plan. Originally, BIM models were intended for design perspectives. However, when applied to the construction and operation phases, they require significant efforts to revise the schedule and the BIM model, particularly to characterize the spatial nature of the projects. Modeled with a method that demonstrates a bar Chart, better known as Gantt diagram, that uses the Precedence logic, construction projects schedules represent graphically the activities, their constraints, their floats and the critical path. Despite the almost exclusive popularity of this method, its representation of the construction operations remains deficient. This logic ignores the spatial site occupation aspect related to operations and teams' rotation, traffics and intermediate stocks. Space planning schedules methods represent a good solution to these gaps. The Chronographic modeling, a space planning method has the ability to alternate between visual representations approaches using a set of graphical parameters. Each approach can help to model adapted schedules for different project types and specialties, shows valuable information in a clear and comprehensible manner and facilitate solving construction site problems visually. The purpose of this paper is to present a communication strategy between a 3D-BIM model, the Chronographic Modeling, and a 4D simulation tool. The development process consists of four steps. The first is to set the numerical parameters to adapt the model to space construction management perspectives. The second studies the different possibilities of communication between the three models. The third presents the scheduling through the Chronographic Modeling and the last one concerns the 4D simulation.

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Keywords: BIM; 4D; Chronographical modelling; Scheduling; Space-planning.

1. Space management on construction site

Space allocation and management during the construction process of building projects have a direct impact on the time, the cost and the security of a project [1]. Despite this fact, project managers often underestimate this discipline [2]. One has to consider that space management on building sites remains a difficult task. On one hand, space occupation can vary according to the type of use, namely, the site as occupied by process, including storage, circulation and access to the site, or the site as occupied by products [3]. On the other hand, these spaces will evolve according to the different construction phases [4]. Moreover, each construction project is unique so it is difficult to establish a universal method for construction space management.

Several studies have investigated construction space management. Some of them suggest characterizing spaces by occupation state (free, occupied) [5], some depending on their purpose (storage, work, traffic) [3] or according to the different contractors'/subcontractors' needs. Some models describe the area patterns as dependent on the tasks to

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accomplish [3] or according to their physical evolution [6]. The common objective of these studies is to identify space congestion in order to avoid delays. In fact, the negative impact of space congestion on site productivity is a well-known problem in construction. Since 1989, [7] has estimated an efficiency loss of about 65% due to space congestion.

According to leading research, one can identify two main categories of spatiotemporal conflict detection: i) the algorithmic approaches [5, 6], and ii) the visual detection method with 2D representation [3, 8, 9, 10].

2. BIM and 4D simulation

Since the arrival of Building Information Modeling and 4D simulation, it has become possible to confront the project schedule with three-dimensional representations in order to detect planning errors and conflictual situations. To do this, it is necessary to create links between construction activities and the 3D geometric model. These types of simulations could help schedulers better comprehend site management and project constraints [11]. In addition, 4D simulation allows for the study of different scenarios [12]. Even though the first commercial tools appeared in the 1980s [13], the arrival of BIM has made this discipline considerably easier, especially with the capability to reuse BIM to simplify the creation of links between activities and the 3D objects [14]. To perform 4D simulations, specialized commercial software has been developed. Navisworks software links the schedule activities to the geometrical component of the 3D Revit model to help to review the scheduling, analyze conflicts, communicate execution process, coordinate disciplines, resolve clashes and plan the project before construction begins. The 4D simulation process then requires many round trips between the two programs to process the changes [15]. Synchro software uses the Critical Path Method logic directly, then the scheduling and the 4D simulation are in one unique tool. Vico's software uses a linear diagram to model the spatial dimension (Location Breakdown Structure) with the schedule.

These 4D simulations model either a bar chart diagram, with precedence constraints that hardly represent time-space constraints, or a linear diagram scheduling method that does not suit model-building projects. Indeed, it is hard to show the spatial aspects and circulation on the construction site [4]. Tools that apply the Gantt chart rely on communication with planning software such as MS Project or Primavera to complete the schedule.

3. The Chronographical modeling

The Chronographical method [9, 10, 16] is a more complete graphical model for construction schedules. The Chronographical approach describes how schedule information can be communicated using tabular and graphical interfaces to manage specialties, locations, means, processes and constraints on different strata. It can be shown either separately or together using layering, sheeting, juxtaposition, alterations or permutations while allowing for groupings, hierarchies and classification of project information. This graphical modeling has the ability to alternate from one visual approach to another by manipulation of graphics via a set of defined graphical parameters. Each individual approach can help to schedule a certain project type or specialty, show valuable information in a clear and comprehensible manner and facilitate the management of construction site problems visually.

The conceptual framework defines the physical entities (work, resources and locations), their properties and the logical constraints, execution process and organizational models that allow for various groupings, hierarchies, scales and attributes. These modeling strategies allow planners to alternate between different planning modeling approaches. The Chronographic method also defines the workspace management process according to the different phases of project execution. For this purpose, the method identifies five (5) distinctive phases: space creation (new floors), systems (ventilation ducts), division of spaces (partition walls), finishing trades (paint) and space closure [4].

4. Research objective

This study proposes a communication strategy between 3D BIM modeling software and the VBA Excel Chronographical scheduling application with the objective to respond to the deficiencies of existing software and scheduling methods.

5. Experimental analysis and case study

The communication strategy developed in this research aims to link the building components of the digital models to the different physical entities of the Chronographical modeling. Hence, it will be possible to define a more comprehensive schedule by combining the products, process, work, materials, tools, equipment and space. The

developed process considered the communication constraints between the BIM model, the Chronographical scheduling and the 4D model in each stage. The case study, a fictive four-story building construction project (figure 3), has been used to validate the strategy and conduct a critical review of its use.

Navisworks allows for creating automatic rules between the 3D BIM model and the corresponding schedule activities and thereby facilitates the creation of a 4D model. However, to adequately meet the requirements of the VBA Chronographic Planning application, it implies the addition of several customized parameters in order to obtain the desired breakdown structure. Indeed, these parameters can be exploited to obtain accurate amount of work by floor, phase, area and sector to facilitate the representation of the space-planning model. Dynamo (a Revit add-in) has been used to allow communication between Revit and the Chronographical application. The developed scheduling process (illustrated in figure 1) is realized with 4 different tools and is divided into 5 steps:

- Preparation of the BIM model, using Revit, to represent the construction perspective by adding personalized information on the building components.
- Data extraction, using Dynamo, from the numerical model to aliment the Chronographical application.
- Scheduling of the construction process with the Chronographical method. This step, more detailed in the next section, results in the creation of a schedule showing the construction process and coordination between executors, works and the construction areas.
- Return of the added information, using Dynamo, from scheduling phases to the BIM Revit model.

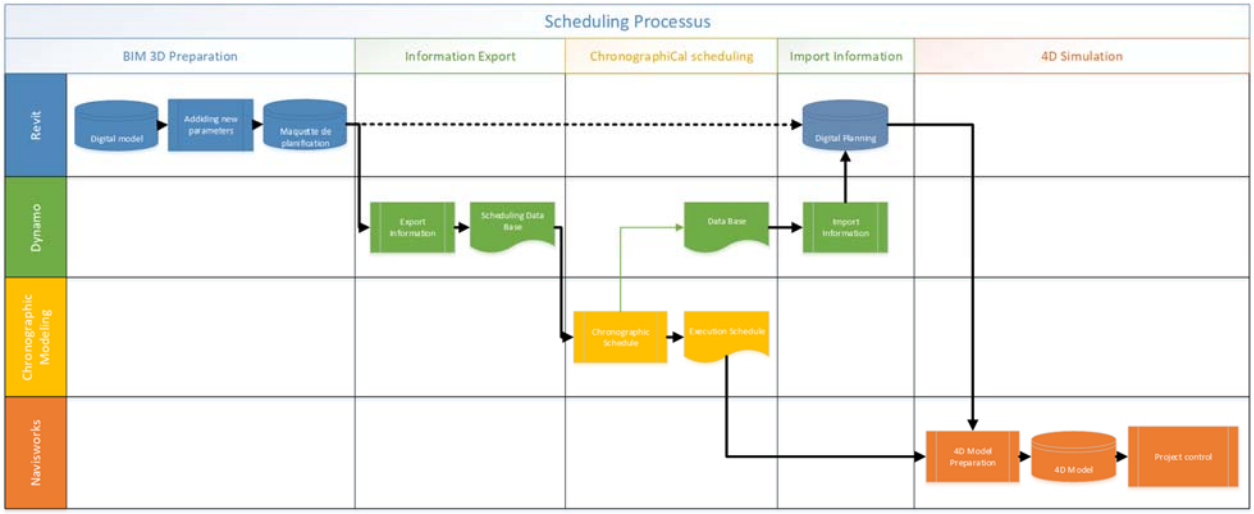


Fig. 1. 4D simulation schedule process

The 4D model is created, using Navisworks, by automatically linking the 3D BIM model and the realized developed schedule. This model shows the construction sequences of the different construction areas. This 4D simulation helps to check for space use conflicts and to calculate the site's utilization rate in order to optimize the project schedule. This tool is also a strong communication tool to explain construction sequences.

6. Preparation of the 4D simulation using the Chronographic modeling

The process aims to create a project schedule using the Chronographic modeling by exploiting the data extracted from the BIM digital model. The planning of construction projects, through the use of different presentation approaches, has already been tested in various research projects conducted in the MGPlan laboratory. The extracted

data from the BIM digital model, with the Dynamo script, are shown on independent worksheets corresponding to the Revit object categories. This application, therefore, offers the possibility of modeling the project scheduling through different complementary views.

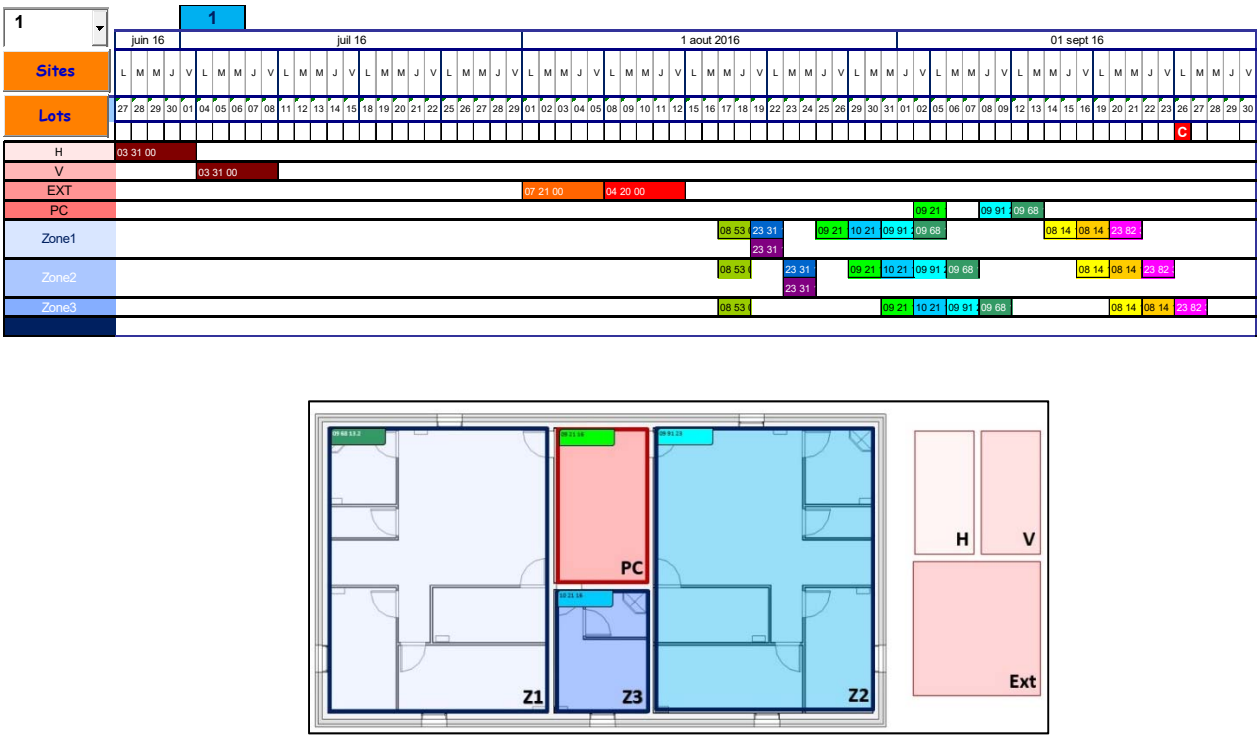


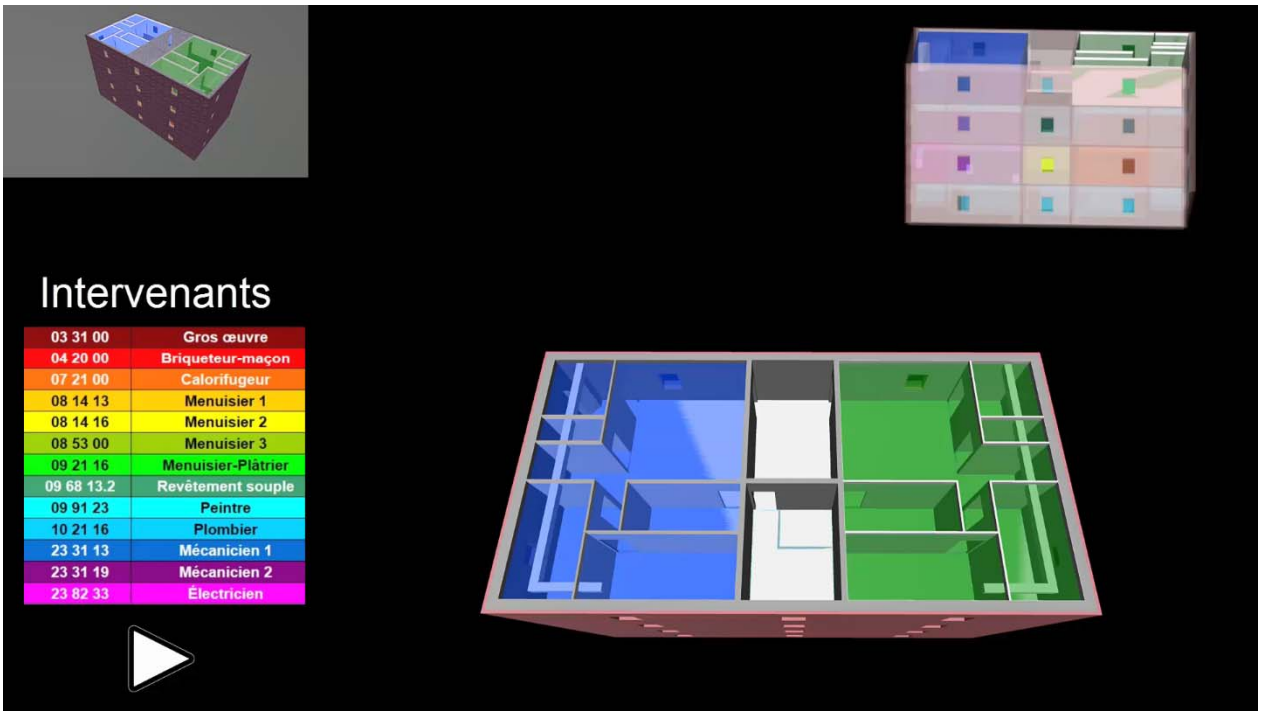
Fig. 2. (a) Grouping by site; (b) Schedule by floor

The version used in this project includes five (5) different approaches:

- A bar chart presentation that demonstrates the process of accomplishing each activity.
- A grouping by specialty for a particular floor. A modeling that vertically represents the different work zones and horizontally the time. The zones are represented by filling the activity bars with a predefined color code.
- A grouping by location for a particular floor (see figure 2.a). A modeling that vertically represents the different areas and horizontally the time. Specialties are represented by filling the activity bars with a predefined color code.
- A plan of the selected floor (see figure 2.b) on which the different areas of the floor are represented and colored according to the predefined color code. Activities are graphically represented within the different zones for a given date. This view allows for apprehending the sequence of work within a floor and calculating the site occupancy rate.
- A grouping by specialty that shows the entire building's floors. This view demonstrates the Takt scheduling [17] of the different specialties on all floors. Customizing this view allows for filtering specialties and floors.

The BIM 3D model will then be updated by returning information from the planning process exported in CSV format via a Dynamo script. The 4D model is built on Navisworks using the Timeliner tool's auto-attach feature. This model makes it possible to distinguish the different spaces in which the works intervene. The functionality of Navisworks has been exploited to demonstrate the evolution of construction in the different workspaces of the model using the predefined color ranges. This feature relies on creating elementary volumes representing spaces. From this feature results the possibility to visualize during the 4D simulation what specialty occupies which workspace over time as illustrated in figure 3.

Fig. 3. 4D Dynamic space planning



7. Conclusion

In conclusion, the use of Chronographic modeling to simulate the 4D process facilitates graphical representation of the dynamic evolution of workspaces occupied by the specialties. The research, therefore, combined the Work Breakdown Structure using the master format codes with the Location Breakdown Structure using the Chronographic space-modeling concept. On the same principle, other breakdown structures could be also used. The strategy could also be adapted to address other aspects of project planning in the implementation phase, such as the representation of circulation and traffic or the evolution of intermediate storage. The addition of colors could also provide information on the occupation type of the space (occupied by a process or a product, or used as storage space). Thus, the user could then select the appropriate views to help him or her properly manage and coordinate the project.

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