ORe – A simulation model for Organising Refurbishments

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The problem of interferences due to the refurbishing activities of a complex building, carried out in parallel with the daily activities that characterize it, is not to be underestimated, especially when talking about a hospital structure. Consequently, the benefits that would be obtained by reducing the presence of construction activities result important in terms of safety and health of users, above all hospital patients. Setting the best solution of Gantt in the early stages of planning can be a winning strategy, as well as being able to recognize the safest and fastest path (e.g. predicting which is the fastest way to reach the rooms taken into consideration by the refurbishment). At the same time, being able to check which activities are most penalized by the presence of the construction site and to set which are essential for the survival of the activities that characterize the environment to be refurbished, e.g. the hospital ward, is a valid support tool for the healthcare staff. The proposed tool aims, on the one hand, to help designers by proposing the best possible Gantt solutions in relation to the management of daily activities that can not be suspended and on the other hand to support healthcare staff in the organization of these latter.

Keywords: *Refurbishment, Complex building, Construction site, Space syntax, Bubble diagram, Gantt*

INTRODUCTION

The main aim of this research is to propose a tool to support the organisation phase of the refurbishment showing to the professionals a classified list of best Gantt solutions according to their needs and the relative data supplied.

The refurbishment and modernisation of complex structures (e.g. schools, hospitals, airports, offices) are often in the condition of having to be carried out without having sufficient time to plan the relocation of activities and users at other locations [Ross et al. 2011].

Moreover, many activities of the construction site can be considered highly risky for the health of the users who are hosted by these structures (e.g. the immunosuppressed patients of a hospital ward are at high risk of fungal infections due to dust) or they can compromise the perfect performance of the activities (e.g. the loud noise can compromise a student's understanding of a teacher's lectures);

The complex structures already foresee by default an important series of safety procedures to be followed and which are to be intensified with the installation of a building site within them. If we talk about hospitals, an example that can clarify the level of this problem is the following: a hospital aisle to comply with safety procedures is designed according to certain construction rules and its sharing/subdivision, on the construction site side creates the difficulty of ensuring the assigned part is hermetically sealed, while on the hospital side the narrowing of the corridor section can create problems both in the case of a strong flow of patients (e.g. emergency, fire) or for simple walking with a wheelchair or for traveling with the litters (the corridors of a hospital are sized to allow simultaneous passage in both directions).

STATE OF ART

The spread of the use of BIM helped professionals during the early design phase to reduce the geometrical interferences thanks to the clash detection [Eastman 1992] but in the context of refurbishment design for complex buildings (e.g. hospitals, airports, universities), the question of the logical-operative interferences between construction activities and daily operations, not to be suspended, it should not be underestimate. Therefore, being complex buildings characterized by multiple renovations activities, it is necessary to be taken as to ensure that work routines can take place in parallel to the construction work.

The main method to facilitate the continuity of the service of a complex structure (e.g. a functioning hospital structure) in the presence of a construction site inside it is the reduction of construction time. Among the various tools available, the Planning is indispensable, as it allows the multidisciplinary coordination between the different actors involved (e.g. hospital staff, workers, designers), providing for the partition of the project into steps and defining for each of them priorities, times, interconnections and resources. This work is schematized and outlined through a time schedule, which is highly recommended to be supported by a Gantt [Truffo 2008]. For these reasons our tool works to provide the best possible Gantt solutions based on the data provided at the beginning of the design phase and the needs of the organizers of the hospital activities. Indeed, through our tool, we have tried to expand the Gantt in order to allow a contemporary view of the construction site activities according to a sequential bar graph (typical of the classic Gantt) adding a planimetry that shows the areas involved in the refurbishment work, all according to the activities considered to be essential by the hospital staff.

METHODOLOGY

The main aim of our research is to reduce the negative impact of construction activities due to the long presence of those activities on the surrounding building environment where they are operating and, at the same time, due to the wasted time caused by interferences between those activities and the daily operations. Our workflow follows those 7 steps:

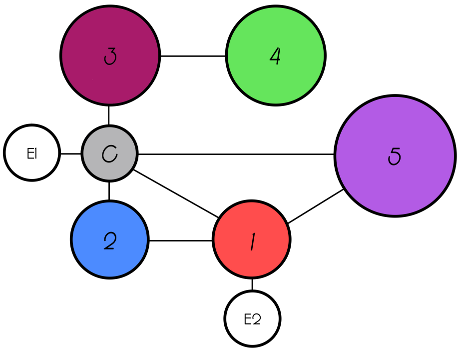


Figure 1
Bubble diagram

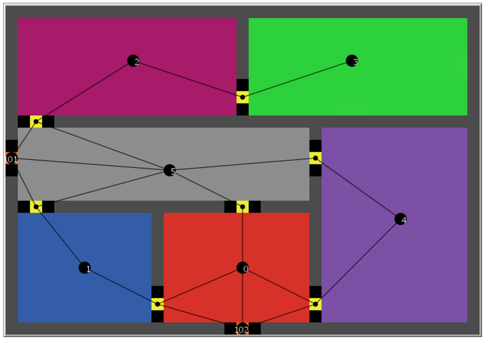
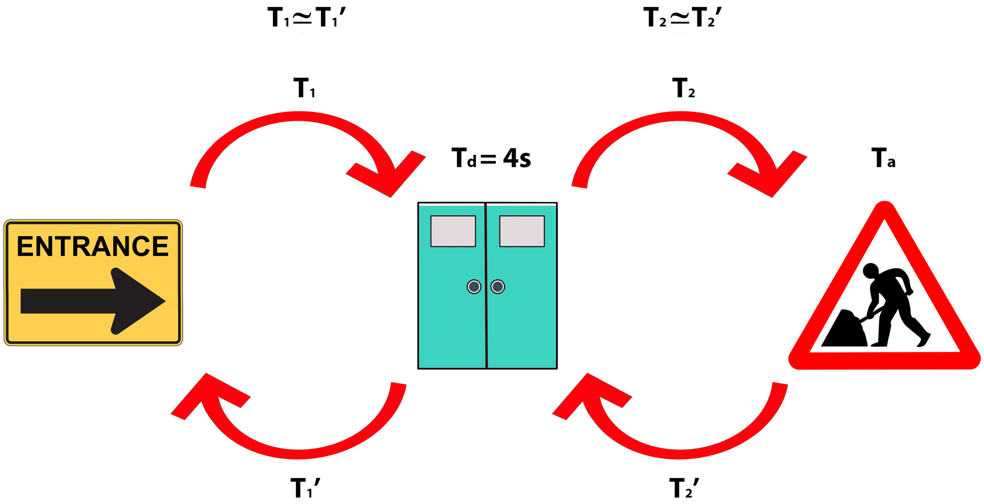


Figure 2
Connections

Figure 3
Simplified scheme of time related to path and activity



Step 1: From the spatial model to the schema, first of all we have to export a schema of each floor from BIM or CAD as bitmap of 1/3 [m] per [pixel];

Step 2: Import the schema, we analyse the bitmaps schema. Rooms are colour-coded (for each room and aisle a different colour was set). Moreover, each colour-coded-room is linked to a combination of daily operations. For example, in a ward composed of 5 rooms, the daily operation-colour-coded schema could be the following: Room 0 (red; operation A), Room 1 (blue; operations A and B), Room 2 (magenta; operations B and C), Room 3 (green; operation C), Room 4 (purple; operations C and D), Room 5 (light grey; aisle - connection), the Doors in Yellow and the Entrances in Orange;

Step 3: Bubble diagram. Starting from the schema we create a Bubble diagram by analysing adjacencies (see Figure 1). We look at the yellow cell (door) and connect these to the surrounding rooms. Moreover, we also take the entrances and connect them to the centre of the adjoining room or aisle. Furthermore, we connect entrances to adjoining doors if the distance of these is smaller than the distance to the room/aisle centre (see Figure 2).
In our case, using NetLogo software [Blikstein et al. 2005], through the setting of agents (called turtles) as activities and the connections between them (called links) we were able to do a paths analysis.
This step allows us to manage a lot of info in an effortless way to represent them graphically.
Analysing the diagram, we can find the topological relationship between rooms and aisles. Two rooms or aisles a and b ($a \neq b$) are one of: Adjacent (= connected by a door), touching (connected by a wall but no door), reachable via other rooms or aisles, Isolated (=not reachable because no path exists between a and b) [White 1986].

NB: the automation of this last phase will be taken into consideration for future works.

Step 4: From Paths analysis to Distance and Time analyses, adding the calculation of the shortest distance to tackle to connect different spaces [Wurzer

et al. 2011], e.g. rooms, aisles, we obtain the shortest time of impact due to the construction activities in the environments surrounding.
We can consider this step composed of 3 sub-steps. The first one, through the bubble diagram, allows obtaining the analysis of paths [m], considering all entrances (E1 and E2) as the starting points.
With the next sub-step, converting these data from distances [m] to time [s], we can obtain the table of times necessary to face these paths (the average walking speed is 1-1,5m/s but 1m/s is acceptable considering a male worker with a normal weight carrying a tool [Browning et al. 2006]). In the last one, adding also information related to the time to carry out activities (e.g. following a schema like this: Path - Door - Activity - Door - Path, calculated from both E1 and E2), defines the final table of the Times (distances and activities).

NB: to simplify, we considered the value of 10s for the transport activity of construction waste materials (Ta) and of 4s for the opening and closing of the door (Td) (see Figure 3).

Step 5: Setting up of exceptions, thanks to the topological relationships, our algorithm is capable of setting up the eventual exceptions that may emerge during the design phase between the different environments-functions (e.g. concerning to two rooms, A and B, in communication between them but with only the room A linked to the aisle, in case it is decided to start the refurbishment with the room B, we have to consider impassable also the room A because it will be occupied to the passage of workers and products from the aisle to room B and vice versa) or regarding the exceptions due to habits of construction activities (e.g. we can suppose the schema of the refurbishment of 2 rooms like Door A - Room A - Door A/B - Room B, it could become Door A - Room A - Room B, namely we could consider the Door A/B or locked as open or removed, depending on the construction activity. It would be right if we were talking about a standard construction site but, in our case, considering the special environment of a hospital without suspending its daily activities and therefore with the construction site very close to the users, especially patients, the doors were considered closed and open by workers only when necessary);

Step 6: From Bubble diagram to Gantt solutions, starting from the Bubble diagram and following the logic of Dynamic programming, our tool is able to compile all the tables regarding which rooms should be renovated before or in parallel with the others. Therefore, the algorithm outputs all the Gantt solutions feasible, depending on the settings of which activities as being required;

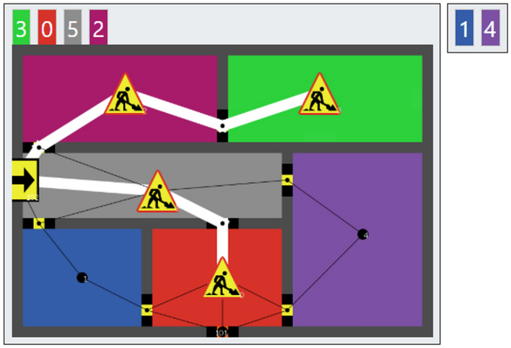
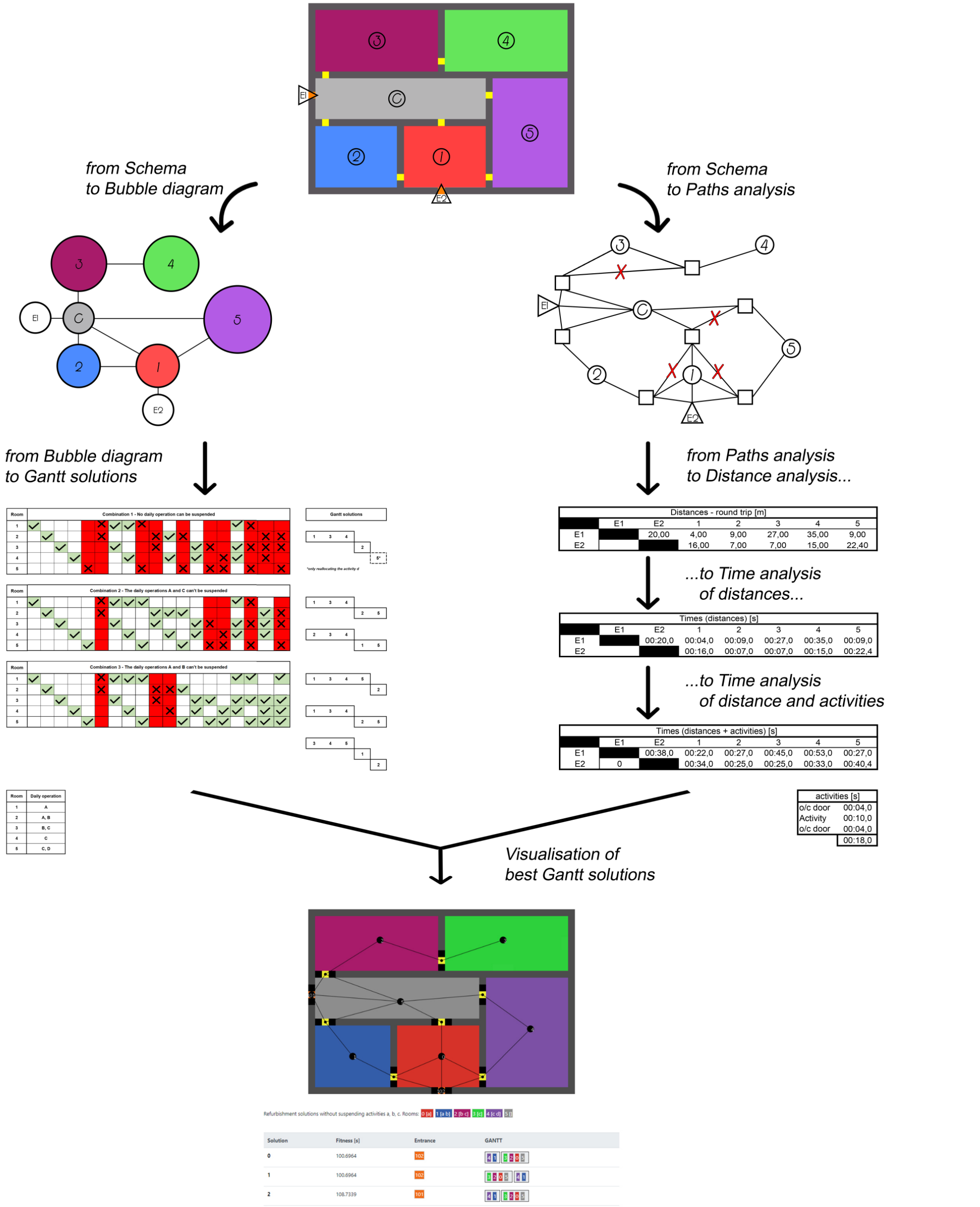
Fitness [s]	Entrance	GANTT
100.6964	101	

Figure 4
Visualisation of one of the best Gantt solutions

Figure 5
the whole workflow
algorithm



Step 7: Visualisation of best Gantt solutions, filtering all the Gantt solutions acquired in the previous step with the data of the times table through the cross-check, our tool is able to highlight and suggest, the list of best Gantt solutions, sorted by the shortest path (in seconds [s]), depending on which activities we set as not suspendables. This list is shown through a specific html page where every solution is accompanied by the entrance, selected for that solution, and the phases characterising it (visualisable on an additional screen) (see Figure 4).

The resume of our whole workflow algorithm is given in Figure 5.

CONCLUSIONS AND FUTURE WORKS

The aim of our tool is to reduce the wasted time and helps both hospital and construction staff to design a well-organised refurbishment, providing a list of the best Gantt solutions in terms of time, distances and expected activities.

The next step of our research will concern the implementation of the algorithm within the 3D environment, taking care of the relations between rooms not only on the same floor but also between different floors.

Moreover, through the interpolation of the Bubble diagram and the paths analysis, we will able to extrapolate the useful data to obtain from our tool an Adjacencies matrix automatically.

Furthermore, considering the context of refurbishment design of complex buildings and their maze of rooms and aisles, we evaluate extremely opportune to tackle the question of the interferences due to the reallocation of activities and tools (Staff & Stuff) in case of need of a temporary rearrangement in another place, in order to allow the correct carrying out of the construction activities and to ensure the continuity of services related to the daily operations.

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