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What is Dynamic Scheduling?
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What is Dynamic Scheduling?

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Abstract

During discussions related to an ongoing research for the prospects of using dynamic scheduling concepts in construction industry in several forums, we received in many cases a similar question: *What is dynamic scheduling?* This is mainly because the dynamic scheduling topic is quite new in relation to construction field; despite of its wide applications in manufacturing and other industries. So, we thought of presenting a quick briefing about the dynamic scheduling's concepts, approaches, strategies, policies, and applications.

1. Introduction

Most probably when you hear the term "*Scheduling*", especially if your background is construction, then the first thing which comes to your mind is *Predictive Scheduling,* or preparation of a good quality optimized baseline schedule which is constructible and easy to maintain. This is of course correct; but in real world, and again especially in construction industry, real-time events extremely disrupt the integrity of schedules. And if the responsible project management team does not act dynamically to mitigate the impact of these events, schedules can become very easily neither optimized nor realistic.

Accordingly, the presence and implementation of a predefined *Dynamic Scheduling* strategy to mitigate real-time events' disruptions is a must for the successful implementation of projects planning. *Dynamic Scheduling* is the process of absorbing the effect of real-time events, analysing the current status of schedule, and automatically modifying the schedule with optimised measures in order to mitigate disruptions.

Dynamic Scheduling, as many other scheduling concepts, started and developed in the manufacturing industry; consequently, the majority of approaches, strategies and policies presented in this context were mainly focusing on manufacturing systems and applications. The following sections will briefly review the general dynamic scheduling systems' components.

2. Dynamic scheduling categories

The effect of any of the above mentioned real-time events to the efficiency or even the correctness of a predefined schedule might be drastic; which, in some cases, might require a complete rescheduling of the project. *Dynamic Scheduling (DS)* defines the strategy of how to generate the original baseline and the strategy of how to respond to real-time events.

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There are three main DS categories (or strategies) which have been listed in the reviews of *Aytug et al (2005)*, *Herroelen & Leus (2005),* and *Ouelhadj & Petrovic (2009)*:

a) *Completely reactive scheduling*

In this category, no baseline schedule is required, and real-time decisions are made locally, on the resource level, where the next activity to be executed by the resource is selected based on its priority (or predefined criteria) from the list of activities ready for execution. The benefits of this approach can be clearly acknowledged from the extremely low computational burden required for the analysis; in addition to the ease of explanation and understanding of its concepts and rules to the system users.

This scheduling type is mainly used in manufacturing for on-spot scheduling of machine operations, and termed as *"Dispatching" [Bhaskaran and Pinedo, 1991]* or *"Priority Rule-based Scheduling" [Haupt, 1989]*. Extension to this approach was introduced by *Wu and Wysk [1989]* allowing the system to select the dispatching rules dynamically based on the current system conditions (approach introduced).
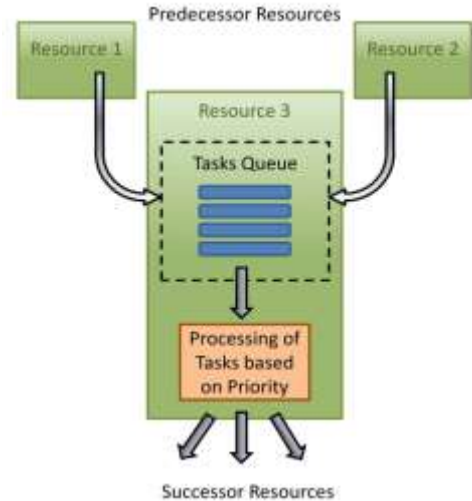

Figure 1: Completely Reactive Scheduling

b) *Robust pro-active scheduling*

This scheduling approach is based on building predictive schedules with studying the main causes of disruptions and integrating them into the schedules; which, predictably, can accommodate changes in a dynamic environment. The disruptions are measured based on actual completion measures compared to the originally planned completions; then the mitigation of these disruption are mitigated through simple adjustment to the activities durations. *Mehta & Uzsoy [1998, 1999]* and *Vieira et al [2000-a, 2000-b]* proposed various analytical models for predictive schedules preparation. This was followed by the development of a mathematical programming model by *Herroelen and Leus [2004]* for the generation of a stable project baseline schedule.

Figure 2: Robust Pro-active Scheduling

c) *Predictive-reactive scheduling*

This is the most common DS approach used in manufacturing systems *[Ouelhadj and Petrovic, 2009]*. The main concept of Predictive-reactive Scheduling is that a simple (or predictive) baseline schedule is initially generated, then rescheduled (logically revised) based on real-time events. The time, triggering event type and the magnitude of the schedule revision

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should be predefined in the system through a rescheduling policy and strategy (as explained in the next sections). See Figure 3.
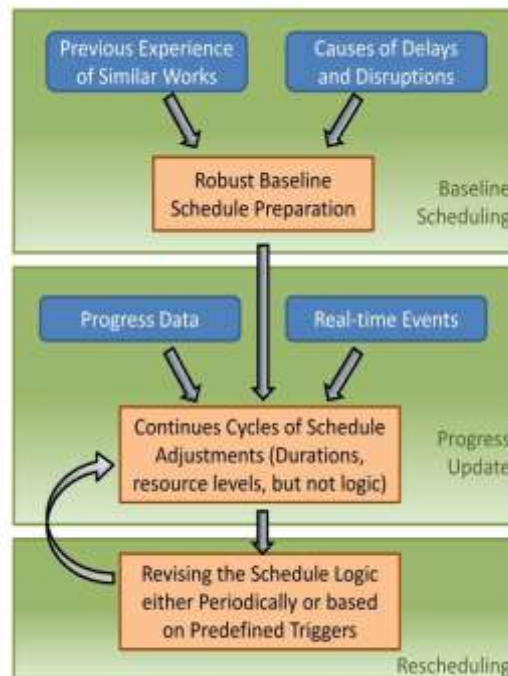

Figure 3: Predictive-Reactive Scheduling

3. Rescheduling policies

The rescheduling policy, in general terms, is an answer to the question of *when* to respond to real-time events. Three policies were presented in this context *(Church and Uzsoy, 1992; Sabuncuoglu and Bayiz, 2000; Vieira et al, 2000-a, 2003; Aytug et al, 2005)*:

- *Periodic rescheduling policy:* Where the rescheduling process is started every predefined time interval regardless of the amount of real-time events occurred during this period.

- *Event-driven rescheduling policy:* The scheduling process is triggered with the occurrence of any disruptive real-time event.

- *Hybrid rescheduling policy (Rolling time horizon): T*he rescheduling process takes place periodically regardless the in between events; however, certain predefined events can trigger the start of a new intermediate rescheduling process.

4. Rescheduling strategies

The *rescheduling strategy* & the re*scheduling techniques* represent the answer to the question of *how* to respond to real-time events. The *rescheduling strategy* is concerned about the mass of the changes to be made, while the *rescheduling technique* is concerned about the method or the approach to be followed to revise the schedule. Two main strategies were presented in this context *(Sabuncuoglu and Bayiz, 2000; Cowling and Johansson, 2002; Vieira et al, 2003)*:

- *Schedule repair:* The schedule repair is the process of mitigating the real-time event through minimum adjustments to the schedule portion related to the event. The major benefit of this strategy is the saving of computational burden.

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- *Complete rescheduling:* Is the process of regenerating the project schedule from scratch. This strategy is practically not preferred due to the required computational time and effort, despite of the fact that it helps in maintaining the near-optimum solution.

5. Rescheduling techniques

The rescheduling technique represents the methodology or algorithm which a computerized system will use to repair/reschedule the project plan. The following techniques were presented in the context of dynamic scheduling:

- *Heuristic techniques:* A heuristic is a technique that seeks good solutions at a reasonable computational cost without being able to guarantee either feasibility or optimality, or even in many cases to state how close to optimality a particular feasible solution is *[Reeves, 1995]*. The most common, but not efficient, schedule repair method is the *Right-shift schedule repair*, where the process of updating the status of progressed activities, and shifting the remaining works forward in time based on their schedule logic. This is the regular update process used in construction, and almost all software packages available in the market use this repair method as a part of the CPM concepts. Other heuristic methods includes: *Match-up schedule repair* (a recovery schedule is prepared in order to match original at some point in time)*, Partial schedule repair* (only the impacted schedule portion is rescheduled), and *Dispatching rules* (decisions are made locally at the resource level without working with a main schedule).

- *Meta-heuristic techniques:* These are high level heuristics which guide local search heuristics to escape from local optima. Meta-heuristics commonly used in schedule repair/rescheduling are: *tabu search (Mehta and Uzsoy, 1999), simulated annealing (Zweben and Fox, 1994), genetic algorithms (Rossi and Dini, 2000; Chryssolouris and Subramaniam, 2001)*, and *Ant Colony (Xianga and Lee, 2008)*.

- *Other Artificial Intelligence Techniques:* DS is an ideal problem for studies in the AI field. Various researches adopted the problem and presented different AI approaches for its solution; these studies used *Knowledge Based Systems (Fox, 1994; Park et al, 1996; Le Pape, 1994; Henning & Cerda, 2000), Case-based Reasoning (Miyashita & Sycara, 1995), Neural Networks (Suresh & Chaudhuri, 1993; Meziane et al, 2000), Fuzzy Logic (Schmidt, 1994; Petrovic & Duenas, 2006)*, and hybrid systems between different AI techniques *(Jahangirian & Conroy, 2000; Li et al, 2000)*.

6. Dynamic scheduling architectures

a) Single-agent Dynamic Scheduling

In most common planning and scheduling systems, the analysis process is done via centralized agent (central computer or database server), in order to ensure consistency of data and results. The centralized approach of the single-agent dynamic scheduling architecture can be claimed to create bottle-necks in the system work flow, and it consists of a single point of decision making which, if failed, causes the failure of the whole system.

b) Multi-agent Dynamic Scheduling

The multi-agent based technique proposes the introduction of several local decision points (or schedule analysis points) within the functional/supervision level, in order to deal with the analysis of local real-time events and perform local schedule repairs.

Two main architectures were presented for multi-agent based system: Autonomous architecture (Figure 4) and Mediator architecture (Figure 5). *Parunak [1987]* presented the concept of autonomous architecture, where local agents are completely responsible for generating and maintenance of their own schedules, and they cooperate directly with each other to generate optimal overall schedule for the entity (or project). This architecture is very effective in optimizing the analysis and decision time; however, it has one main drawback in the relative failure of local agents to produce near optimal solution for the entity. This drawback was addressed in mediator architecture (originally proposed by *Ramos [1994]*), where a mediator agent is introduced to

Figure 4: Autonomous Dynamic Scheduling Architecture
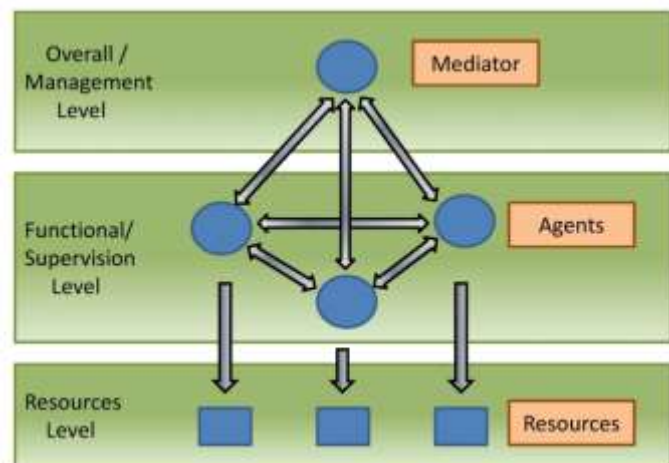
Figure 5: Mediator Dynamic Scheduling Architecture

support in the communication process between local agents for improving the efficiency of the overall schedule, which will also show further improvement with the increase in the application size.
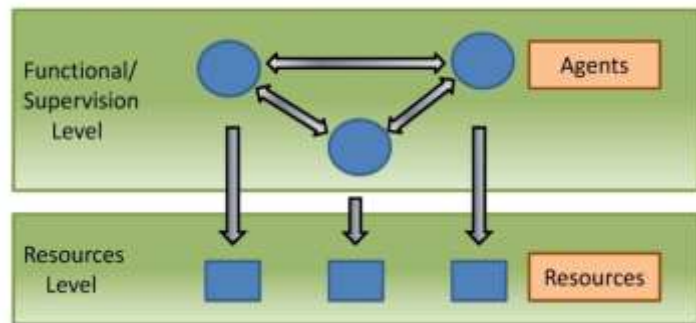
In manufacturing/other industries, which adopted dynamic scheduling in their applications (as shown in next section), *Mediator/Agents/Resources* are all computer based entities, where conditions are analysed and decisions are made automatically.

7. Dynamic scheduling applications

The DS concepts are widely used worldwide in various non-construction industries. The followings are selected examples of dynamic scheduling applications in several non-construction industries: *Lagodimos et al [2004]* in manufacturing industry, *Webster and Azizoglu [2001]* in computer engineering, *Liang [2009]* in logistics industry, *Warburg et al [2008]* in aviation industry, and *Aissani et al [2009]* in petroleum industry. Despite of the wide practical applications of dynamic scheduling in many industries, the review performed was not able to locate automated dynamic scheduling applications within the construction industry, only few researches were found presenting frameworks for Dynamic Planning (such as *Lee et al, 2006*), and few resource allocation field practices especially in the maintenance and service based

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companies. And accordingly this study will review the suitability of dynamic scheduling to the nature of construction industry.

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Tarek has been involved in over 17 EU funded projects as Coordinator or partner under the ICT and NMP (Nano technologies, materials and production) programmes of FP4, FP5, FP6 and FP7. He's got a wide network of European and International partners including Universities, ICT companies, construction organisations, research institutes, consultants, municipalities, etc. He raised research funding of 7 Million Euros and participated in projects of total value of 40 Million Euros. Tarek is engaged in several activities with the EC (European Commission) as an expert evaluator of proposals, expert reviewer of running projects and advising the EC on projects' performance and strategic research agendas for future calls. He is a member of the ECTP (European Construction Technology Platform), with focus area on processes and ICT. He serves on various international panels for evaluation of proposals including the Academy of Finland and the National Research Foundation of Singapore, funding agents of Poland and Russia. He has been an invited key note speaker to several international conferences and sits on the editorial board of international journals.

Tarek's research breadth focused mainly advanced ICT to improve energy efficiency in buildings, and with considerable influence on the EC research agenda in identifying research priorities; in addition to researching into dynamic scheduling in construction, engineering higher education and gender aspects within engineering. Tarek's research output has been reported in high quality journals, conferences and books chapters with a total of over 150 publications. Website: http://www.lboro.ac.uk/departments/civil-building/staff/hassantarek, e-mail: T.Hassan@lboro.ac.uk.

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