From MRP Nervousness to Shop Floor Schedule Nervousness in the Industry 4.0 Era

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Abstract.
In the context of Industry 4.0 (I4.0), manufacturing systems are shifting from nonflexible to dynamic, self-aware and self-adaptable ones. Thus, scheduling systems, as a core of production functionality, are turning online, context-aware and responsive. Nevertheless, even when immediate responsive actions are performed when facing disruptions, aimed at getting a new feasible and/or good quality solution, this adaptation-to-change response mechanism might not be well accepted on the shop floor. This is mainly because, repeated changes could lead to a continuous rearrange of predefined manufacturing plans, through different levels, from MRP to the control systems. Traditionally, this behavior is known as schedule nervousness, which triggers unnecessary material movements, delays, reassignments, customers' dissatisfaction, etc. There are many contributions about nervousness at the different planning levels, as well as recent advances seizing that issue at control level. Yet, further specification of the nervousness happening at the shop-floor level (Shop-Floor Schedule Nervousness, SFSN), where a short-term on-going schedule drives the production, is actually required. In this work, the schedule nervousness notion is introduced briefly from a historical perspective, also, a description in relation to the I4.0 context, and a novel notion of the SFSN, are shortly introduced.

Keywords: Scheduling Nervousness; Industry 4.0; Online Scheduling.

1 Introduction

The schedule nervousness (SN) has been used, historically, to identify the impact of frequent changes over a production plan. Firsts authors tackling the issue [1-3] stablish the first notion of SN as a phenomenon associated with the revision of a defined plan, which could have a negative impact on, or the disruption of, the production system. They address the propagation of changes through MPS and MRP systems.

Years after, the SN was analyzed as a propagation of frequent changes that impacts at lower levels, where it causes instability in the parts and components requirements [4, 5]. Because of this, usually, the SN has been studied by quantifying changes between consecutive planning periods, but ignoring the changes that occur within a given planning period.

The terms SN and stability/instability has been used for planning levels, but also for other lower levels. Some contributions cope with schedule instability in relation with reactive or rescheduling activities where the SN is extended in order to describe its relationship with instability at the operational level [6-8]. In these contributions, the goal is the minimization of the instability.

Also, the production control systems community has been tackling the SN to some extent. In [9], authors defined SN as the degree to which elements in the multiagent manufacturing control system react on internal and external stimuli. They conclude that increasing system nervousness leads to a more responsive behavior of the system, but also to a less predictable, and eventually chaotic, one. An architecture that avoids nervous behavior must balance the tradeoff between performing sufficient changes for reacting and enhancing the system's performance and, at the same time, maintaining a stable and safe evolution [10]. Distributed control architectures suffer of myopic when it comes to decision making, which leads to system nervousness [11]. This work is an extended abstract that brief main aspects proposed by the authors in [12].

2 Schedule nervousness in the I4.0 context

From a literature review, it has been seen that the SN is present at various planning hierarchy levels, having a different scope and meaning in each of them (see Table 1).

Table 1. Scope and goals of SN at different planning levels.

	SN in planning	SN in rescheduling	SN in control
Scope	SN explores the problem at an MPS/MRP planning level.	SN is not directly tackled, but it is inferred that it has to do with successive changes in an ongoing agenda.	The system nervousness is addressed at a lower control level.
Aim	Minimize changes in produced quantity among sequential cycles within a given planning horizon.	Minimizing instability leads to less nervous agenda: changes in the tasks' agenda and assignments, each time a reactive action is carried out, is minimized.	Manage the complex fluctuations of signals coming from shop equipment.

Despite the planning level, there is an opportunity to study how new technologies that the I4.0 era brings, will affect the SN as well as how they will expand the scope of the traditional scheduling and planning systems. In this way, it can be observed from literature that authors agree that planning systems facing I4.0 need to address, at least:

- A holistic perspective: self-synchronizing, self-optimized, self-learning processes
- Decentralized, automated, and real-time decision-making processes, at different levels
- Data analysis and intelligence from internal and external sources, in real-time, at different levels
- Dynamic planning and scheduling, with capabilities to address constant changes in complex environments
- Data-driven optimization and simulation
- Predictability, based on real time gathered data and simulated data
- Autonomous and decentralized production control frameworks, with interoperability capabilities
- Digitalization of all the planning processes

The knowledge that this context gives to the planning and scheduling systems facilitates the efficient adaptation and continuous improvement of the plans, but, at the same time, also potentially increases the intrinsic nervousness of the system. Thus, exists a direct relation between I4.0 intrinsic capabilities and the planning systems' nervousness. This is an emerging field that needs to be further studied.

3 A shop-floor schedule nervousness scope proposal

The shop-floor schedule nervousness (SFSN):

- is identified as a state of the shop schedule,
- which establishes that future changes are expected (that produce inefficient behaviors),
- and represents a continuous and cumulative tension on the performance of the ongoing agenda
- that exists at every time point along the scheduling horizon,
- while the shop is executing operations over production orders or jobs,
- and is a result of: (i) what has already happened in the recent past, during the already executed portion of the on-going schedule, (ii) what has occurred in past executed agendas and represented by historical data, and (iii) what has not happened yet, but either it is planned and/or can be expected based on analytics.

The acknowledgment, measurement and management of the SFSN enable to:
(i) Keep track of the past changes on the agenda. This feature is useful to know the deterioration of the agenda along the scheduling horizon, caused by modifications to it.
(ii) Know how stable the ongoing schedule is. Here, the stability level refers to the chance of receiving disruptions or requirements to be modified.
(iii) Be prepared to control changes when a rescheduling action or an agenda adaptation is addressed, in order to control the nervousness level, i.e., to know how the ongoing schedule adaptations have to be done in order to cope with a required nervousness level target.
(iv) Know a nervousness future trend of the agenda, as well as for each individual domain entity that is considered as nervousness relevant.

Conclusions

This short paper summarizes some findings from a literature review of SN at planning, scheduling and control levels; results of an analyses of the role of I4.0 regarding SN; and a proposal of a shop-floor schedule nervousness scope definition. The SFSN is identified as an evolving state associated with an on-going schedule domain. The work places a conceptual ground for future developments regarding this issue, over which diverse frameworks, approaches, models, and metrics can be developed and tested.

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