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Centralized Optimisation Still Cannot Avoid Coordinative Artifacts and Their Pitfalls

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Abstract. This position paper reports on a "Industry 4.0" project supported by the government through a public investment bank in France. This project was launched by a major industrial actor in the gas domain and aims at equipping its factories with digital technologies, and at connecting all these factories (of the future) through a centralized supervision center, named Operational and Optimization Remote Center (OORC). Based on our observation in 6 plants and the OORC, we present the necessary interaction that still needs to take place, and how it is materially supported. We focus on a digital technology that was introduced to be the only interaction support, and that failed to do so. We analyze this failure using the Boundary Negotiating Artefact framework (Lee, 2007).

Introduction

"Factory of the Future" (FoF) represents an integration of all the systems (from product development to production, logistics, and business) which allows changing a parameter and simulating the impact of this change, and by then managing the entire process in real time (Boyer, Ward, & Leong, 1996; Bullinger & Warnecke, 1985; Chase, 1991; Meredith, 1987). We report here on our inclusion in an "Industry 4.0" project supported by the government through a public investment bank in France. This project was launched by a major industrial actor in the gas domain and aims at equipping its factories with digital technologies, and at connecting all these factories (of the future) through a centralized supervision center, named Operational and Optimization Remote

Center (OORC). Before the start of the project, each of the twenty factories were working in the following way: they buy energy to a provider, which they use to extract air products from ambient air. They then send their production to clients (mainly metallurgy, and food and drinks industries), via pipes for gas products or via land transport for liquefied gas products. The objective of the OORC is to control the production in all the sites in order to ensure a flexible and adaptable production. The goal is to optimize production and logistics at a national level (it was done for each plant before) to decrease the use of energy during the production. This centralized supervision goes with an evolution of the work practices in the plants, from production to maintenance and from shift work to call-on demand. The factories are then responsible of ensuring the functioning according to the centralized decisions made in the OORC. To support this evolution of production processes, some collection of data and information has been put in place, together with coordinative artifacts (Schmidt, 2008).

In this paper, we report on one year of observation in the OORC and some of the plants, and we focus on one of the coordinative artifacts that has been put in place to support the cooperation between each plant and the OORC. We show that even if the design of this tool involved all the stakeholders, the digital tool is not appropriated. We are claiming that concepts from CSCW can help us understanding the failure and help the new cooperative practices to take place.

Data Collection

40 days of observations have been conducted so far during which we conducted and recorded interviews and meetings or took notes about the production and maintenance practices in the OORC and factories (Table I. Comparative table of observations on ORCC and Factories.).

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OORC	6 SITES
23 days of observation	17 days of observation
Shadowing of 4 pilots and 3 analysts	Shadowing of 4 pilots and operators
Recording and transcription of 74 min of meetings between OORC and plants	

About the New Practices

In the ORCC, we can find two roles: analysts and pilots. Each week, the analysts collect all the data about the current situation (energy cost, production capacity, stock capacity, supply chain) and the client's needs, for the whole country. They aggregate all these information, and run some optimization algorithms to define the production that should be launched, and in which plants it should be launched. The pilots then interact with the plants to launch this production. For so doing, they use supervision interfaces to remote control the factories. Interfaces have been developed with the pilots according to their visualization needs. These interfaces aggregate data coming from sensors put on production machine from the twenty factories. This data concerns the physical position of the controller and the levels of product coming out of the controller. The pilots then know if it is possible to execute the production that was defined by the analysts. If sounds possible, then they launch the production in the different plants and inform the plants.

Despite this aim to totally supervise the plants and to optimize the production at a national level to consume less energy, in reality, our first observations of the practices that take place in the supervision center and in some plants show that some coordinative practices are taking place between the plants and the supervision center.

In fact, some data that is needed to check if the production can be launched does not come from the existing sensors, and some information is impossible to be sent automatically. This information can be perceived and analyzed only by an operator on site: indeed, for now, the fact that a machine cannot produce at its maximum capacity can be analyzed only by an operator that is hearing a strong noise, seeing some unusual temperature, some parts that are not functioning well … In the same way, only the local operators have the necessary expertise to analyze the impact of the weather on the production capacity of the plant.

Facing this need of coordination between the OORC and the plants, we have observed that several coordinative practices and artifacts have been put in place:

- Weekly meeting (each thursday) between the OORC and each plant, lasting from 5 minutes to 1 hour depending on the complexity of the situation and the size of the plants: The pilot from the OORC calls the pilots on site to discuss if the production order that has been defined by the analysts is feasible.
- Ad-hoc phone calls from the OORC to a site in 2 situations: when the production order has to change during the week, or to understand something that is going on in the plant and that they have seen on their supervision interfaces; pilots in the OORC need to interact with the pilots in the plant to be able to interpret this data.
- A digital tool called ELogBook (Figure 1. ELogBook.) has been developed in order to trace this interaction between the sites and the OORC. The OORC completes the production launches (using a laptop). The sites use the system (via a tablet) to report on the way they manage the machines to face the production orders: which valve has been closed or opened, which cooler or which pump has been stopped or started, which incidents arose, and depending on the moment of the incident, which calls have been done to operators, which maintenance operation has been done, ...

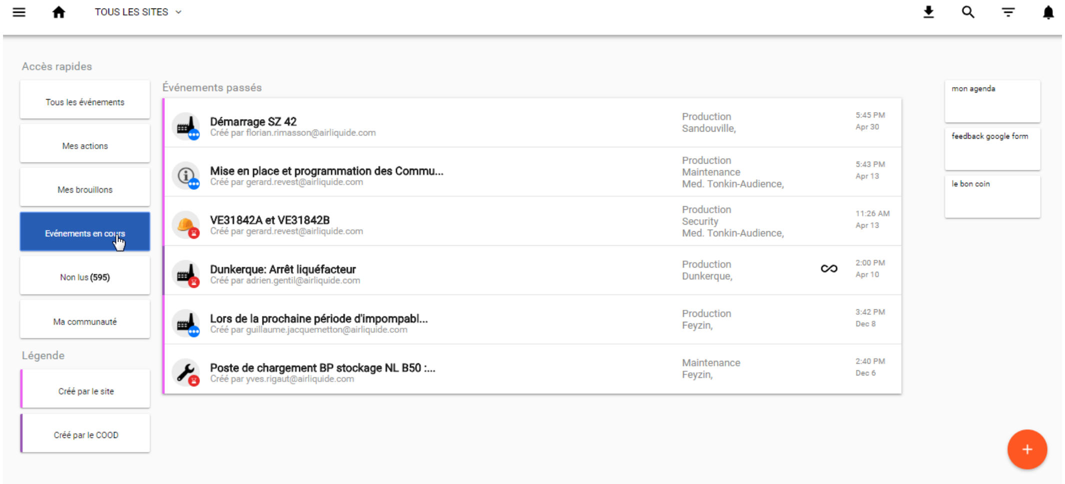

Figure 1. ELogBook.

Before the project started, all these information were collected by the sites on a paper-based notebook (Figure 2. Paper-based Notebook.).

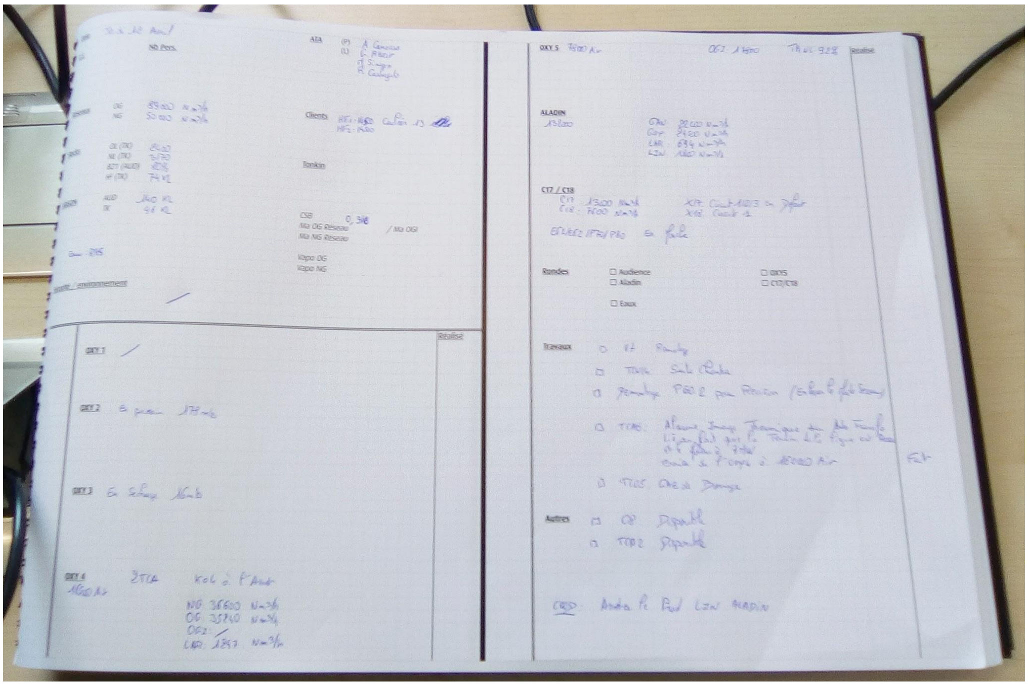

Figure 2. Paper-based Notebook.

The ELogBook has been designed by the gas company, with the help of a start-up specialized in UX Design, and its design process was agile and involved workers from the factory, during design workshops. Some training workshops were also conducted in the different plants by the project manager. But even if the plants started to use the tool, after one or two weeks, the managers on site noticed a dropped down of the amount of information put in the ELogBook. One site even decided to keep the paper-based notebook in addition to the use of the digital tool.

The fact that less information is put in the ELogBook implies that the OORC can collect less information about what is going on in the sites, and is less able to remote control it, and will still need to call the sites and schedule meetings, which is time-consuming and does not allow a good traceability of the negotiations and decision-making processes.

We then tried to understand why, even if the coordination and traceability are needed, and even following an agile and participatory design process, the digital tool is not appropriated.

Analysis of a Failure

The first issue that we have identified is that the design process of the ELogBook was focused on the type of information to the tool will have to collect and in which form, rather than on how this information will support the coordination between the OORC and the sites, and moreover, how the shift from a paper-based notebook to a digital tool will still support the management of a site.

One of the directors of a site, and all the operators we met told us that their major issue with the ELogBook is that it does not allow to get an overview of what has been done in the plant for the last weeks, months or even years. They used to look for events in the paper-based notebook to identify what has been done in a similar situation, or to identify patterns; in other words, they were looking for the *story* of the plants. For the moment, the story is obviously not there because the plants have just started to use the system, but more importantly, its users have identified that their way of recording the events (to build a story) conflicts with what the OORC is waiting for in terms of traceability.

More precisely, the notion of *event* seems to be conflicting: for the pilots in the OORC, an event that should be entered in the ELogBook by the plant is what has been done by the operators to launch the machines. They want to know if the production instructions have been executed, to know the status of the plant. Whereas for the plant, an event is more fine-grained, and represents everything that happens on site. For instance, any part of the machine (valve, pump, …) that has to be repaired, who has fixed, it and how it was fixed, should be recorded.

Moreover, the operators used to write down on the paper-based notebook all the events at the same time (at the end of the day), indicating at which moment each event took place. With the ELogBook, this practice is no longer possible, because the events are traced by the date of their creation on the ELogBook, without any possibility to edit this date.

So, even if the initial goal was to provide an artefact supporting coordination between the OORC and plant, and tracing all the events that can influence production instructions, the introduction of the ELogBook clearly conflicts with the exploitation and maintenance practices of the plants; Our observation highlights that the OORC and the plants do not have the same definition of what to trace and when or how to trace it.

The conflicting definition of an event, and the following failure of the ElogBook remind us about the discussion opened by Charlotte Lee (2007) about boundary objects: We are facing collaborators from different communities of practice (pilots in plants vs in OORC) who are using material artifacts to collaborate. We have identified in particular two boundaries negotiating artifacts[1]: the paper-based notebook and the ELogBook. But while the paper-based notebook supported the collaboration in one place (the plant), the ELogBook aims at supporting the collaboration between two places, the plant and the OORC. The project then replaced a boundary negotiating artifact by another one, but what was overlooked is the fact that the boundary was not the same. To go further, if we follow the categorization of Charlotte Lee, the ELogBook is a *compilation artifact*, supporting an alignment process between two or more communities of practice in order for them to "develop a shared and mutual understanding of a problem and to pass crucial information from one community of practice to another." (Lee, 2007, p. 323). But, exactly as Lee noticed in her case study, "the practices surrounding compilation artifacts were not well-developed and required the development of new practices. This resulted in confusion and conflict." (p. 333).

This preliminary analysis leads us to the conclusion that what is missing is a socially negotiated processes that gives the ELogBook a meaning that the participatory and design process did not allow to achieve.

Conclusion

In this position paper, we introduce the case of a huge Industry 4.0 project supported by public funding from the French government. What interested us is that despite the willingness of the project managers (engineers) to automate the collection of data from the plants, to program algorithms to optimize the production of gas at a national level and to remote control the 20 plants of the country, coordination is still needed between the plants and the supervision center. Moreover, we focused on the digital tool (ELogBook) that was designed to support this coordination, and observed that despite a participatory and agile

[1] "Boundary negotiating artifacts are used to: record, organize, explore and share ideas; introduce concepts and techniques; create alliances; create a venue for the exchange of information; augment brokering activities; and create shared understanding about specific design problems." (Lee, 2007, p. 333).

design process, this tool is not appropriated. The boundary negotiating artifact framework helped us to describe the ELogBook as a compilation artifact that was put in place instead of another compilation artifact that was not supporting the negotiation of the same boundary. This clearly shows that concepts from CSCW could help Industry 4.0 to not overlook to socially negotiate the new processes that are put in place.

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