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Digital Twin, support for collaborative practice: application to the railway system

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Abstract. The digital twin is one of the promising technological concepts of the Industry 4.0. However, few research deals with the cooperative use of the digital twin. Through this PhD project, I aim to study how the digital twin of the French railway infrastructure can improve the coordination between the stakeholders of its maintenance . In order to study this, I am conducting a multisited ethnography to identify the coordination mechanisms that are involved in the work scheduling activity. I am planning to study more in depth how the digital twin can support cooperative practices by using technological probes. PhD Research context

This PhD takes place as part of a collaboration between SNCF Réseau and Troyes University of Technology. SNCF Réseau is the French railway infrastructure manager; it manages the maintenance, exploitation, and development of 30 000 km of railway infrastructure. As other infrastructure managers, SNCF Réseau has started to develop a national asset management strategy. This strategy seeks to coordinate the maintenance, exploitation and development of the railway infrastructure at a national scale to meet performance requirements. To do so, one of the pillars of this strategy is the digitalization of work practices.

In this context, SNCF Réseau is developing a technological concept: the railway digital twin. In the literature, the digital twin concept can be summed up as a digital replica of a physical system that is connected to it (Grieves, 2015). It could also be seen as a real-time reflection of the physical asset, that interacts with the physical asset (Tao et al., 2018).

Despite the fact that the digital twin concept has been built in order to offer a real-time, integrated and collaborative representation of the infrastructure (Tao et al., 2018, 2019), few researches address the use of digital twin whether as a means of communication, coordination, or cooperation (Lamb, 2019; Tao et al., 2019)

We envision the digital twin as a new technological opportunity to support coordination practices among railway infrastructure stakeholders. More precisely, we think that the digital twin can help us revisit some issues of the technological support for awareness.

Indeed, awareness has been intensively studied by CSCW scholars (Bentley et al., 1992; Heath & Luff, 1991) and has been characterized by a set of practice that workers have developed in order to coordinate their actions with the actions of others in a seamless way (Schmidt, 2002).
Tenenberg et al. (2016) proposed to revisit the concept of awareness by no longer emphasizing on how an individual perceives the activity of another but rather emphasizing on how an individual in a group perceives something, what they have called “we-awareness”. This work puts forward the shared intentionality and the recursive social inference under awareness practice. Nonetheless, Tenenberg et al. did not answer the question of the technical support of we-awareness.(Greenberg & Gutwin, 2016).

Research questions

In this research context, the PhD is looking at the following questions:

- How can the digital twin support a daily maintenance management practice locally while ensuring a cooperation between SNCF Réseau work entities?
- Which representation of the digital twin can be appropriated by the different actors of the maintenance management?
- How flexible the digital twin should be to be embedded into a local practice and at the same time ensuring cooperation with other units?
- And to which extent the flexibility of the digital twin could support a standardized process?

To study those questions, a preliminary field study has been conducted. Its goal was to identify a work situation in which coordination takes place among SNCF entities. This preliminary study has allowed to identify the work scheduling activity as an interesting field to focus on regarding the research questions.

The case study: The work scheduling activity

Most of works on the railway infrastructure imply traffic interruptions. In order to minimize the impact on train traffic, these interruptions generally take place during the night, for a few hours (approximately 4 to 6 hours). The challenge when scheduling works on the infrastructure resides in maximizing the traffic while ensuring that all the works can be done and also ensuring the safety of people on the work site. For that, no train can cross the work site : elementary protection zones (ZEP in French) are put in place; ZEP are track sections that either divert trains, or turn the signals to red.

The work schedule is co-designed by three SCNF Réseau establishments:

- The infrapole, which is responsible of the maintenance of a railway sector.
- The infralog which is responsible of the renewal or development work.
- The traffic establishment, which is responsible of the traffic management on a sector.

The PhD focuses on the pre-operational work scheduling phase which starts with a coordination meeting six weeks before the works on the infrastructure take place. During this meeting, the requesters (the ones who are requesting some work to be done) (from infrapoles or infralogs) are gathered by a coordinator from a traffic establishment. During the meeting, scheduling “clashes” (e.g. two works planned at the same place at the same moment) are discussed. At the end of the meeting, a first schedule is ready. Then, this scheduling is instantiated on the train timetable in order to produce a daily work notice that is sent to the switchman of the traffic establishment the day before the works should take place. But between the coordination meeting and the daily work notice issue, the schedule may encounter some changes.

Data collection

To study the diversity of practice, we were engaged in a multi-sited ethnography (Marcus, 1995) involving two sectors around Paris. We have combined semi-directive interviews and observations on both sectors. In the sector 1, we interviewed one requester (in infrapole) and the two managers in charge of the

coordination center (in a traffic establishment) and we have observed one coordination meeting. In the second sector, we observed three coordination meetings and interviewed three requesters (in infrapole). These coordination meetings took place during the COVID-19 pandemic, and therefore were conducted online. Interviews and observations were conduct by the PhD student, and discussed with supervisors. The aim of the interviews and observations was to collect the experience of work scheduling stakeholders.

First Findings

In order to describe the coordination practices that underline the work scheduling activity, we have analyzed our data through the coordinative mechanisms concept (Schmidt & Simone, 1996). We have therefore identified the coordinative protocol, and the coordination artifacts which we have described in a manuscript submitted to the CSCW Journal.

Our analysis highlights strong differences between the two sectors. First, stakeholders of the work scheduling activity are different. Then, the schedules between them are different (e.g. in one sector, the coordination meeting deals with works that take place in six weeks, and in the other one, the coordination meeting deals with works that take place in six, three, and the following week). Finally, the artifacts used are either different or are used in a different way.

Despite those differences, we have identified three coordination mechanism that are common to the two sectors:

- The common understanding of the sector (e.g. ZEP name, tracks name …)
- The construction of a common understanding of the work scheduling (what is done, when, where and by who).
- The articulation around scheduling clash that is composed of an identification of clash by the coordinator, followed by a negotiation between requesters and coordinator, that can lead to arbitrage if no arrangement is found.

The digital twin to support cooperation during the work scheduling activity

To study more deeply how the digital twin can support cooperation through an representation of the infrastructure, we are willing to use technology probes (Hutchinson et al., 2003). Through probes, we seek to learn more about how

coordination takes place in the work scheduling activity, and to test different digital twin designs and features, and finally to ground the reflection on the digital twin design and how it could better support the work scheduling process.

Currently, we have designed two probes; the first one aims to plot work sites on a geographical information system and to highlight scheduling clash. The second one aims to provide an awareness of existing requests.

Expected contribution

This PhD seeks to contribute to three research communities. First, we would like to envision how the digital twin technological concept can be a new way to support cooperative practices.

Secondly, in order to address cooperative use, the digital twin concept must be designed in that way. Thus, this research aims to bring attention to cooperative use and practice-centered design to the digital twin community.

Finally, this research takes place at SCNF Réseau. Therefore, we seek to bring to SCNF Réseau a collaborative digital twin basis for the work scheduling activity and methodologies to extend this basis to other activities.

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