Airport security checkpoints: an empirically-grounded ontological model for supporting collaborative work practices in safety critical environments

Chiara Bassetti
Institute for Cognitive Sciences and Technologies – CNR - Italy
chiara.bassetti@loa.istc.cnr.it

Department of Sociology and Social Research
University of Trento
Italy
chiara.bassetti@unitn.it

Roberta Ferrario
Institute for Cognitive Sciences and Technologies – CNR - Italy
roberta.ferrario@loa.istc.cnr.it

Maria Luiza M. Campos
Post-graduate Program on Informatics –
UFRJ - Brazil
mluiza@ufrj.br

ABSTRACT

Resulting from an interdisciplinary endeavor, the paper proposes an ontological model for supporting collaborative work practices in critical settings, and shows its application to a specific domain. The model is empirically-grounded, as based on ethnographic research carried out at an international airport –clearly an example of safety-critical environment, where emergency prevention and preparedness are crucial. On the other hand, the model leverages on previous ontological work on collaboration and observation in emergency response, and revises it when necessary, thus contributing to its development. Taking hand-baggage screening as an example, the paper shows how the model can be applied, and how it could be used to run model-based simulation in order to better understand collaborative work practices and analyze the impact of different techno-organizational changes on such practices and their effectiveness. This could result in suggesting guidelines for enhancing workflow, security policies and, more generally, time- and safety-critical situations management.

Keywords

Airport security, collaboration model, ethnography, ontology, work practices.

INTRODUCTION

Airports are prototypical examples of safety-critical environments, as they may be affected by many kinds of emergencies endangering the life of a relevant number of people, like acts of terrorism directed towards a specific flight or towards crowded areas of the terminal. They also represent entry points into a State, so they can become the place where criminals or illegal goods gain access to the country. For these reasons the emergency prevention and preparedness phases are particularly important and, as a consequence, taken care of in airports.

VisCoSo[1] is an interdisciplinary project, whose final objective is that of providing an ontological model of a socio-technical system able to (a) describe it in its details, and of (b) showing the mechanisms that are enacted in it in order to prevent, deal with and recover from emergencies/critical situations. The case study of such project is an international airport; one of the activities that have been conducted under the scope of the project is the participant observation of specific areas where emergency concerns are particularly present –namely, security checkpoints, passport controls and surveillance and coordination room. An ethnographer has been conducting 380 hours of participant observation over 13 months, distributed over different seasons, days of the week and time slots, as to guarantee coverage of different periods and moments of the "life" of the airport. The observation has produced more than 1000 pages of field-notes, that can be used as ground material to build accurate descriptive models.

Observing the activities going on at security checkpoints is particularly interesting, as most of the job is constituted by collaborative practices within a work team. Butthere are also cooperative practices between different groups belonging to different organizations active inside the airport. Their activities are always monitored, both for security reasons, and for checking the efficiency of workers, who are subject to time-critical – alongside safety-critical – tasks.

A comprehensive model that takes into consideration all these connected aspects is COM (Collaboration Observation Model), developed in Gentil, Campos and Borges (2014).

The aim of this contribution is that of, first, trying to represent the chosen scenario with COM, revising it where necessary, then to check whether what the model foresees through simulation corresponds with what has in fact been detected and noted during participant observation.

THE COLLABORATION OBSERVATION MODEL (COM)

The Collaboration Observation Model (COM) was proposed to support the systematic observation and capture of elements involved in collaboration. It complements elements of the Collaboration Ontology (CONTO) (Oliveira, Antunes and Guizzardi, 2007), and also uses ontological analysis grounded on basic categories from an upper level ontology. COM is a core ontology, as its concepts may be reused in different situations or application domains where collaboration is the main focus and observation is conducted in order to capture activities and resources of a collaboration process. Analogous to CONTO, COM was developed following the structure of the 3C (cooperation, coordination and communication) Collaboration Model.

Figure 1 presents a partial and modified version of the COM model, more specifically focusing on elements from the collaboration and coordination parts that are relevant to our scenario. A *Collaborative Group* specializes in *Observation Group* and *Operation Group*, where their members (*Agents*) play the roles of *Observer* and *Observed*, correspondingly, with respect to the observation activity. The separation between *Agents* and *Roles* is particularly important because it maintains rigidity criteria for the instances while still giving the flexibility to acquire properties associated with specific assumed roles at different occasions.

[1] http://www.loa.istc.cnr.it/projects/viscoso/

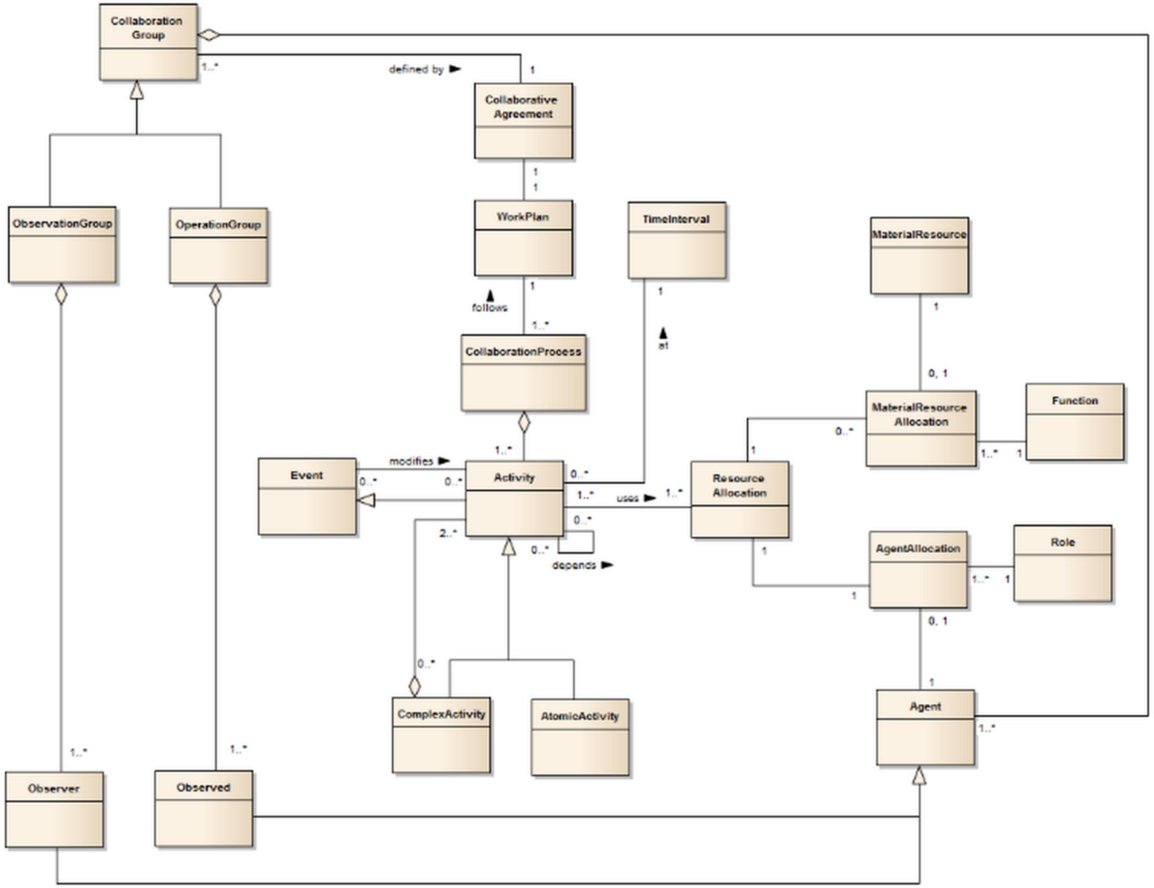

Figure 1 Partial and modified version of COM Model (adapted from Gentil et al., 2014)

Agents are capable of performing actions (activities), and they can be either *Human Agents* or *Artificial Agents.* An *Activity* is part of a *Collaboration Process* and it occurs in a *Time Interval*. It can be a *Complex Activity*, when it is composed of two or more activities, or an *Atomic Activity*, when it cannot be further decomposed. Also, an *Activity* may depend on other activities as well as may be modified by an *Event,* which may even cause the execution of new activities.

The *Operation Process* follows a *Work Plan* derived from a *Collaboration Agreement* (formal or informal) established by the *Collaboration Group*. To be performed, each *Activity* requires a *Resource Allocation*, which involves the allocation of an *Agent* to a *Role* and, possibly, of a *Material Resource* to a *Function*. This part of the model was revised, generalizing Material Resource and Agent allocations as Resource Allocation, and including Function to better characterize Material Resource use.

Both Observation and Operation Groups follow agreements and their associated plans, are involved in processes, and execute activities. Also, these groups contemplate coordination roles and related activities. This is also different from the original COM modeling, as it now reuses elements previously modeled separately, bringing flexibility to the representation, and supporting interactions within and between the different groups.

Necessary skills and behavior can be learned from observation of the teams' interactions at work (Rekabdar, Shadgar and Osareh, 2012; Johnson and Gonzalez, 2014; Luff, Hindmarsh and Heath, 2000), and simulations can complement this information by generating variants of situations that might enrich training activities. Simulations can provide examples of desired behavior or a reference against which to compare team members' behavior. Programming these simulated teams to perform various tasks depends on developing a proper model to acquire and represent the associated knowledge (Law, 2009). Most models of airport security found on the literature (Wilson, Roe and Annie So, 2006; McLay, Lee and Jacobson, 2010) are mainly simulation-based models, but not necessarily empirically-grounded, and do not focus on a high-level conceptual representation. Even though they are very useful in the task of foreseeing possible future scenarios, the absence of a conceptual foundation may hinder their scalability and adaptability to different contexts.

CASE STUDY: AIRPORT SECURITY CHECKPOINT

Security lines represent a dense socio-technical microcosm within the whole airport socio-technical system, and one marking a fundamental boundary. The aim of passengers and hand baggages control is to prevent the uncontrolled access to the sterile area of:

- *unauthorized* persons, that is, basically, people without boarding pass;
- *dangerous* items, such as bombs, guns and weapons in general;
- *prohibited* items, like liquids, aerosols and gels (LAGs) exceeding 100 ml.;
- *to-be-screened-separately* items, such as LAGs under 100 ml.

Security guards work in groups of 4 at each line, or they operate two lines in 7 (the "experimental"); a further guard stays "outside" and checks boarding passes with a scanner. At each line, 3 guards alternate themselves every 20 minutes in different tasks, that can be regarded as situated roles:

- *unpacking* at the beginning of the line: instructing passengers to extract LAGs and electronic devices, to take their shoes or belt off, etc. (G@b, guard at the beginning/belt);
- *screening* at the x-ray machine monitors: visually inspecting images of passengers' belongings (G@m, guard at the monitors);
- *attending* to the metal detector arch, to the screener, and to any other need, such as sniffer controls (G@a, guard at the arch and as attendant).

This is called "the round", and its timing is given by law, following the rule according to which the screener cannot carry out the task for more than 20 minutes. The rationale of the rule rests on a widespread conception of attention dynamics, and on the conviction about screening being the fundamental procedure at the checkpoint. Indeed, it is the screener who must stand up after 20 minutes and reach the colleague to take her/his place, so that the latter can do the same with the third operator.

The fourth guard in each line (or the seventh one in two) is the supervisor: s/he is responsible for the line/s, and basically acts as a G@a though s/he does not take part in the round. The presence of two guards who may attend arch-related procedures is relevant also with respect to the same-gender rule in force for patting. Such a rule affects guards' distribution in the rounds, the assignment of the supervisor role, and the situated coordination of work activities within and beyond each line.

Guards are employees of private security firms that, after specific training, serve as "public officers" in the context of airport security. They work — by law — under the supervision of the Police, which means under the supervision of a police agent who stays nearby the lines (and calls for reinforcement in case of need).

Figure 2: Examples of detected and undetected TIP and non-TIP

Guards have also to deal with Threat Image Projection (TIP), a technology that allows exposing screeners to artificial but realistic x-ray images during the routine baggage control (see e.g., Cutler and Paddock, 2009). Images randomly appear on the monitors, positioned within passengers' belongings, as if part of them (see Figure 2). The screener should recognize the TIP image as such, and push a specific button on the keyboard in the following 15 seconds. When s/he succeeds in doing so, a green-backgrounded message pops up, stating the TIP has been detected and identifying the projected object category (e.g., "knife-4"); simultaneously, a red rectangle appears around its image. When s/he fails to do so, the message is red-backgrounded and states the TIP has not been detected. Finally, when the guard presses the TIP button in absence of a projected image, a yellow-backgrounded message appears, stating there was no fictitious image — this is called "non-TIP".

The TIP library is composed of 6.000 images and it is replaced every 6 months. In autumn 2013, during participant observation, the library update at the considered airport marked an important twist: whereas images were previously representing mostly dangerous items, they now represent also more prohibited and, especially, many more to-be-screened-separately items — and passengers' belongings are actually full of both kinds of objects. We call this "TIP New Order".

MODELING CHECKPOINT ACTIVITIES

In this section, we will try to model our case study, the airport security checkpoint, by using the COM model. In such a scenario, there are two *Collaboration Groups* involved in the checkpoint activities: the security guards and the policemen. With respect to such specific activities, we can see the guards as *Operation Group*, since they directly perform the checking, and the policemen as *Observation Group*[2], as one of their tasks consists in supervising the guards while they accomplish their own task of passenger and baggage control. Concerning the guards' *Operation Group*, many more details can be modeled. First of all, the "round" can be seen as a *Collaboration Process*, composed by different complex activities (unpacking, screening, and attending the arch). Those

[2] We could also decide to assign the class *Observation Group* to the ethnographer who conducted participant observation on the checkpoint. This would have been more adherent to the original COM model, but we believe that, especially in scenarios that are particularly concerned with security and surveillance, often there are workers assigned to tasks of monitoring and supervision. This choice could thus be useful to stress this organizational aspect.

can be further decomposed into atomic activities, like passing the sniffer on a luggage, in case something anomalous is detected during the x-ray screening. Such *Collaboration Process* is institutionally established in the security plan of the airport, which in the model would correspond to a *Work Plan*.

Going further into the analysis, we can see that each *Activity* foresees a *Resource Allocation*, which includes an *Agent Allocation* and possibly also a *Material Resource Allocation*. Each *Agent* (in our scenario we only have *Human Agents*) is allocated to a specific *Role*. Analogously, each *Material Resource* is allocated to a *Function*, that is a behavior of the artifact selected and intended by some agent. In our example, a *Human Agent* in the *Role "*G@b — guard at the belt" is allocated to the unpacking *Activity*, without *Material Resource*. Another *Human Agent* in the *Role "*G@m — guard at the monitor", and the x-ray machine as *Material Resource* with the *Function* of visually inspecting the interior of a luggage are allocated to the screening *Activity*. Finally, a *Human Agent* in the *Role "*G@a — guard at the arch"- and the metal detector arch, the sniffer, and other similar tools as *Material Resources* are allocated to the attending to the arch *Activity*. Furthermore, another *Role* is here at stake, namely that of supervisor (the guard responsible for the activities carried out in one or two lines). This example is particularly interesting, as it depicts very well how the attribution of *Roles* may vary. In this case, there is a general "super-role", the one of security guard, which is more permanent, as it is more linked to the job contract, while there are other roles, like G@b, G@m, and G@a, that are necessarily alternatively attributed to different agents in the course of each shift and in a precise timely manner (20 minutes); every agent who plays the role of security guard, and this is the only requirement, may be assigned to these roles. Conversely, there is another role, that of supervisor, that is fixed throughout a shift, but assigned to different agents across different shifts. The agent must fulfill further requirements in order to be eligible to acquire such a role, and the fact of playing the role of security guard is not enough.

Turning now to events (Figure 1) and how they might influence activities, we will use the case of TIP described above to show how the COM model can be applied. In this case, the appearance (actual or assumed) of a TIP on the screen is an *Event*, which may trigger an *Atomic Activity*, the pressure of the button. This changes the successive activities, as the belt is stopped at the appearance of any TIP-related message (being detected TIP, undetected TIP or non-TIP).

We will focus now on two variants of the same practice, the one in place before the 2013 change and the one that has emerged after the change, i.e., under the TIP New Order. It is worth noticing that both variants are to be considered applications of the same institutionalized procedure, that is "press the button each time you recognize a TIP on the screen". Previously, guards tended to be precise in the task of signaling TIPs, as these were representations of dangerous objects, like weapons, which are obviously not frequently found in passengers' luggage. Since the TIP New Order, screeners enact a practice that we call "pressing-to-be-s(ec)ure". It consists in pushing the TIP button for nearly each container that passes under the x-ray machine, just to be s(ec)ure. This is because luggage often contains many intertwining and overlapping objects, including prohibited and to-be-screened-separately objects, like bottles. The result of this practice, most of the times, is a non-TIP. Such a practice has been often reported by workers themselves during interviews conducted in the scope of the VisCoSo project and, not surprisingly, it has consequences on the workflow of the checkpoint activities, especially on their timing.

The model could thus be used in the future to run simulations over different variants of the TIP technology (number of images in the library and their difficulty, represented objects categories and their relative percentage, etc. - cf. e.g., Cutler and Paddock, 2009; Steiner-Koller, Bolfing and Schwaninger, 2009), in order to explicitly show their impact on the everyday collaborative work practices of the guards and the consequent effects on the passengers' experience. This can be particularly helpful since previous studies have been only experimental (Cutler and Paddock, 2009: 47).

CONCLUSIONS

What this and similar works show is that complex socio-technical systems are defined by a strong intertwinement of the social and technical dimensions, such that emergencies nearly always happen at a systemic level, involving both dimensions. Thus, they can only be detected, dealt with and possibly solved at the same systemic level. Such endeavor is possible only by adopting a strongly interdisciplinary approach, contemplating both empirical analysis and model-based simulations, and where not only each discipline contributes for its part, but it must dialogue with all the others.

In this article we started from an empirical case of techno-organizational change, and the way guards recounted such a change during interviews. What came out is that, for better performing at the secondary task of TIP detection, most of them started enacting a new work practice: pressing-to-be-s(ec)ure. The latter is not only suboptimal for guards' primary task of real threats detection, it has also consequences for the whole collaborative process of security control. Model-based simulation can be very helpful on this regard. First, it allows to predict variations in the collective performance depending on variations in individual conducts. Second, it permits to foresee the effects of diverse small changes (e.g. type, number, and frequency of TIPs) — actual and not — on the whole collaboration activity and its effectiveness. This could result both in a better understanding of the change and in the related suggestion of guidelines for more effective workflow and security policies. We see this as a way to enhance emergency prevention and preparedness, and, therefore, to get ready for the unexpected. On the one hand, the TIP system has been designed as a tool to train the guard to recognize prohibited and unauthorized objects even when they are hidden among the passengers' belongings. In this sense, this can be seen as an emergency prevention measure. On the other hand, with the simulation, we are able to show the consequences on collaboration of the alternative implementations of the TIP system. This should in turn allow to single out and correct those implementations that make the whole collaboration process more cumbersome, thus threatening the guards' preparedness to react.

The Collaboration Observation Model has been adapted and extended to contemplate more general situations, but still aiming at expressiveness and consistency. Current work includes a more detailed representation of (i) coordination roles and their associated rules and constraints; (ii) types of events and their characteristics like frequency and duration, to support simulations parametrization; (iii) work plan elements, at a type level, such as activity types, role types, resource types, as they are different although related to the already represented occurrences describing real world situations.

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