A Robust Coalition Formation Framework for Mobile Surveillance Incident Management

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ABSTRACT

Given unexpected incidents on routes of guards that check security objects, like banks, one of the most challenging problems is still how to support improvisation by security personnel in taking decisions to prevent or resolve such incidents. Another as important associated problem is how a security company can naturally take advantage of its existing and novel knowledge about its organizational and ICT infrastructures, and the introduction of a decision support system to help leverage of improvisation by humans. To tackle all this, on the one hand we present a dynamic coalition formation framework that allows the (re)configurations of agents that are associated with joint tasks in situational contexts to be evaluated by appropriate value functions. On the other hand, we present a dynamic scale-space paradigm that allows a security company to distill ranked lists of robust context-dependent reconfigurations at critical scales. We highlight the merits of ASK-ASSIST as a solution to the problem of supporting human improvisation.

Keywords

Coalition formation, Coordination, Robustness, Mobile Surveillance, Incident Management, Reconfiguration, Scale-Space

INTRODUCTION

Organizations physically located in urban areas and isolated industrial zones hire private security companies to guard their property from theft and vandalism. There are many ways in which security at such locations can be realized. For example, security personnel may be stationed at the different sites of the organization. This is a standard way of monitoring (unauthorized) entrance to a site during daytime. In addition or alternatively, patrol guards are sent by car to watch multiple client premises during nighttime or week-ends. In this paper, we focus on the latter case of mobile surveillance of security objects and in particular the management of incidents like alarm by offering the guards on patrol support for improvisation.

Handling incidents is commonly achieved following documented security protocols and procedures. Due to lack of transparency and the low quality of those (paper-based) protocols, such procedures are hardly internalized in the organization and offer little help (Abbink, Dijk, Dobos, Hoogendoorn, Jonker, Konur, Maanen, Popova, Sharpanskykh, van Tooren, Treur, Valk, Xu and Yolum, 2004) when faced with unexpected events or even not anticipated incidents members in the private security organization are compelled to improvise. In such cases, mobile security personnel, after assessing the situation in-situ, by default contact team leaders or a responder at the dispatch center for assistance. As a consequence, the physical and cognitive work load of all security personnel increases. We develop a mobile surveillance coalition formation support system, ASK-ASSIST, that facilitates improvisation by security personnel themselves in case of incidents or emergencies by improving the efficiency of communication amongst them. It has been suggested that decision support systems are helpful in handling incidents (Burghardt, 2004; Johnson, 2003). Hybrid human-agent systems enabling such support require particular groupings of e.g. guards and systems.

The problem of grouping together individuals in an effective way has been studied in a variety of different settings (Knuth, 1997). For example, matchmaking tries to bring individuals together into couples (Gale and Shapley, 1962; Roth and Sotomayor, 1990). Many situations occur in everyday life where one group of entities must be mapped on another (e.g., employees/jobs, patients/doctors, consumers/products). At a first glance, it also seems logical to model the formation of these simple coalitions using bipartite graphs. However, a security guard, for example, needs to contact another security guard via a responder of the dispatch center and, possibly, a team leader for a particular reason (e.g., certain expertise about a security object is required). Those extra organizational roles and context should be taken into account in the formation process, as the qualities of the coalitions heavily depend on them.

Coalition formation was originally studied in game theory. Recently, bounded rationality, incomplete information, or communication overhead in large coalitions of agents were put forward as reasons against forming (too) large coalitions (i.e., against the super-additive property of agent networks). Robust matchmaking or coalition formation appears rather to occur at critical agent network scales. For example, in pair partnership matching an agent is satisfied with a coalition of itself and only one other agent as soon as a specific threshold of a value function is met or passed at a critical scale. Here the value function reflects e.g. an agent preference scheme and a critical scale the maximal possible or tolerable level of communication intensity between two agents given their limited storage, communication and processing resources (Sarne and Kraus, 2004). Similar critical context-dependent temporal dynamic scales can be identified for larger coalitions needed to resolve more complex incidents. In earlier work, a framework was suggested that (i) generalizes existing conceptual or formal matchmaking and coalition formation models and (ii) is used for the implementation of a matchmaking system (Valk and Ferro, 2006). The effectiveness and efficiency of such groupings and in particular the value functions have to be accounted for and empirically modeled.

Such accounts, and accounts for coalition formation, may come about after collaborative filtering the logged agent network history of coalition formation patterns at critical scales. Coalition formation given incidents can be modeled by means of content-based, collaborative - either memory-based or model-based - or collaborative content-based filtering (Basilico and Hofmann, 2004).

The kernels induce incident-specific coalition formation support models for improvisation by humans. Robust models can be distilled upon learning the performance - effectiveness and efficiency - of situational context-specific coordination schemes of dynamic multi-agent systems (MAS), including artificial and human agents, viz. (Buşoniu, De Schutter and Babuška, 2005). Learning by MAS in turn can be corroborated by complying to an appropriate scale-space paradigm (Salden, Ter Haar Romeny and Viergever, 2001) that captures adequately system dynamics and evolution and self-organization at critical scales.

For reasons of lack of space we refrain ourselves from in-depth expositions on our coalition formation framework and collaborative filtering. Instead we apply them to a emerging mobile surveillance scenario (see section EMERGING MOBILE SURVEILLANCE SCENARIO) given a specific incident on a route of security guards, to find a suitable group of agents and tasks this group has to perform when additional (artificial) agents and agent functionality come available (in this case a coalition formation support system). Next, in section MODELING MOBILE SURVEILLANCE DOMAIN, we use our framework to create a model of this dynamic mobile surveillance domain. In this section, we start by presenting a formal description of the domain entities in a coalition formation environment. Second, we will describe the configurations of coalitions and the evolution of these configurations. Finally, we sketch how to retain robust context-specific (including potential incidents) ranked coalition formation models by collaborative filtering actual, historic and potential context data corresponding to that mobile surveillance domain.

EMERGING MOBILE SURVEILLANCE SCENARIO

In the sequel we sketch a mobile surveillance scenario in which the need for coalition formation support is compelling.

Scene : Bob Is Transferred Automatically to Carol

A sudden sequence of incidents may lead to an increase in the workload of dispatch center employees and team leaders to undesirable levels. The assignment of alarms to guards is a much recurring process. Such processes deplete the physical and cognitive resources of those involved (Boy, 1998). It requires new planning activities, which may obstruct operational processes and even aggravate current security alarms. Team leaders manage dynamic mobile surveillance (also in case of incidents). They malfunction and underperform as they are subject to communication overload. It is not surprising, that there is an interest in automating (irrelevant) delegation and escalation processes from security guards towards dispatch center employees or team leaders as soon as their threatened by physical or cognitive overload. Another reason for automation is to more rapidly resolve incidents and needless to say to prevent disasters. Before we discuss into more detail how automation could be attained, let us briefly illustrate this automated process:

A Saturday at noon, Bob arrives at a department store. He updates his PDA and he enters the building. He notices that the alarm has been shut off. Since this is not what Bob expected, he likes to sort this out. Instead of calling the dispatch center or team leader - which is still possible -, he calls a support system, ASK-ASSIST. An IVR menu is presented and Bob chooses option 4: ***last security guard at the current location****. ASK-ASSIST uses operational data as context (e.g., Bob's location, choice he made in the IVR menu, history of earlier logged data) to determine the right person to help him in case of this incident. ASK-ASSIST calls out to Carol (a suitable match) and when she answers, Bob and she can speak to each other.*

Security guards are confronted with many more contingencies that make it difficult for them to perform their tasks as planned. For example, a guard may also be in need of certain keys of or expertise about a particular security object. The idea is that in such cases ASK-ASSIST uses information about the actual and historic states and contexts of the relevant entities (e.g., keys, vehicles, guards) to determine the right coalition of (human) agents and assigned tasks in order to resolve the incident or at least to provide that information crucial to solve the problem by human improvisation. Thereto, we propose ASK-ASSIST to recommend given situational contexts ranked lists of potential current or future agent coalitions for either retrieving the requested information or setting up communication or audio phone conference amongst security personnel. Such recommendations by ASK-ASSIST are established after properly grounding the mobile surveillance entities involved and empirically modeling their actual and historic situational contexts.

MODELING MOBILE SURVEILLANCE DOMAIN

In this section, we use our framework to model the dynamic mobile surveillance domain as illustrated in the previous section.

Coalition Formation Environment

For any particular coalition formation problem, we say that the coalition formation elements belong to a coalition formation environment associated with the problem domain. In earlier work we have given a formal definition of the concept of a coalition formation environment (Valk and Ferro, 2006).

In a coalition formation environment we make a distinction between two types of elements. The first type of elements we call active elements A, (e.g. a buyer, a provider, a patient or an employee). Active elements are capable of exerting particular preferences to when and which groups are (potentially) formed. The second type concerns elements B that are passive (e.g. tasks or real-estate objects). Passive elements are indifferent to what group they belong. Typically, past, current and future contexts are considered passive elements. In many applications, matchmaking or coalition formation aligns and groups individuals (e.g., users) and items (e.g., access code information) such that their configurations meet the preferences and requirements of all the separate entities, being perhaps all possible individuals or any subgroup thereof. The general idea is that active elements, in contrast to passive elements, have and impose preferences and requirements during the coalition formation process. In the domain of mobile security, for example, coalition formation could concern a security guard requesting expertise about a security object, preferably, by the most experienced security guard available. In figure 1, we illustrate such a grouping and alignment. Clearly, this process depends on the contexts, i.e., aspects of the collective of passive elements involved.

Now, if we look into more detail to the scenario of the previous section, we identify the following active elements (roles) in this security domain:

- Mobile surveillance security guards in $MS=\{MS_i\}$, and
- Team-leaders, $TL=\{TL_j\}$, and
- Dispatch center responders, $DPC=\{DPC_k\}$, and
- Private alarm centers, $PAC=\{PAC_l\}$, and

- Coalition formation support system, ASK-ASSIST, $ASK=\{ASK_m\}$.

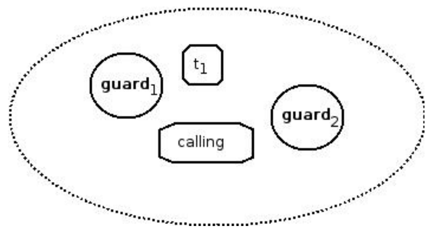

Figure 1: A group of two guards calling at t_1

Active elements represent the roles that agents $\mathcal{A}$ in a domain can fulfill. One can imagine that individual agents fulfill different roles over time. Furthermore, that new active and passive elements are introduced in the domain. Last but not least, relations between agents $\mathcal{A}$ and active elements A can be spelled out (see (Valk and Ferro, 2006) and figure 2).

As mentioned earlier not all elements in the environment need to be active. In our mobile security scenario, there are several entities that have no notion of preferences and requirements, namely:

- The set of all tasks $\mathcal{T}=\{\tau_i\}$,
- The set of all security objects by $Obj=\{obj_j\}$,
- The set of patrol vehicles $V=\{v_k\}$,
- The set of keys for accessing or locking security objects $K=\{k_l\}$,
- The set of security object specific alarms $S=\{s_m\}$,
- The set of routes $R=\{r_o\}$, and
- The set of discrete times $t=\{t_p\}$.

Note, the set of task also includes interactive tasks, such as communication. In the scenario of the previous section, for example, communication is set up by ASK-ASSIST between two security guards. This means that in reality this communication task is connotated with the relevant member of the set of active elements A. These sorts of relations could, for example, also be relevant to the set of security alarm, because of their object specificity. In this work, we do not explicitly model these connotations.

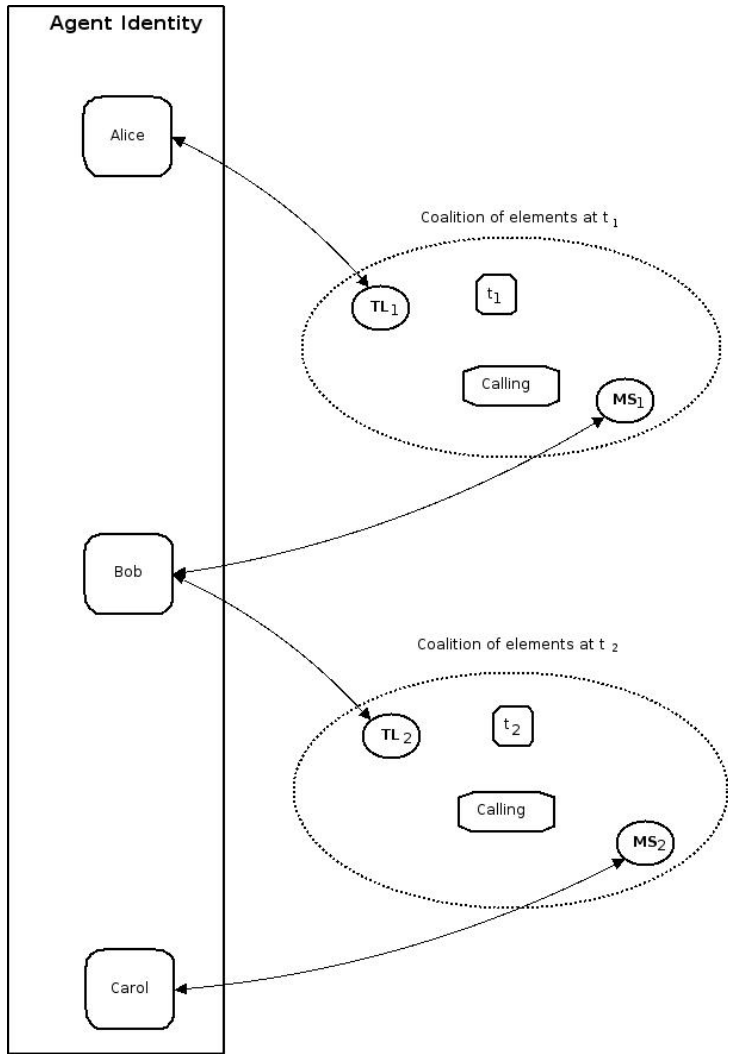

Figure 2: Agent Bob takes two roles over time: He is first security guard and subsequently team leader.

Evolution of a Configuration of Coalitions

Having a coalition formation environment M at its disposal, the goal is not only to generate a configuration of elements, so-called coalitions, that can handle common mobile surveillance circumstances, e.g. a daily patrol, but also that can handle unexpected security incidents by providing improvisation support to humans with the advent of newly added elements, e.g. ASK-ASSIST, $ASK=\{ASK_m\}$ in the scenario of the previous section..

Our research interest lies in showing how the introduction of ASK-ASSIST taking advantage of a domain-specific collaborative filtering paradigm facilitates run-time reconfiguration either to tackle security incidents directly or to enable improvisation by humans. The latter ASK-ASSIST can accomplish for example by recommending to place the right security personnel in a conference call or to provide the most appropriate security context information or support systems. Before we discuss this paradigm, let us make the concept of a configuration explicit in terms of our coalition formation environment and additional structures.

To structure a configuration we distinguish role groups. A group role is a subset of A that performs a collection of tasks, i.e., subset of $\mathcal{T}$, in a specific group context, i.e., a subset of B. This implies that an agent coalition having a certain group role in a given group context is assigned to a corresponding collection of tasks. We represent this assignment in terms of a function $\gamma:2^A\times 2^B\rightarrow 2^{\mathcal{T}}$. Thus a coalition of agents A_i in context B_i at discrete time t_i perform a collection of tasks $\gamma_{t_i}^{A_i,B_i}$. Here the time-points corresponds the procedural time indications of the schedules, i.e., the time at which, ultimately, the tasks have to be completed.

For our mobile surveillance domain we formally denote a configuration as:

Definition 1 (Configuration) *Given a coalition formation environment M with agents in $\mathcal{A}$, the roles agents can fulfill A and passive elements B, a configuration is defined by a collection of coalitions, in which each coalition is represented by the time-ordered composite task assignment to roles in a context, labeled by a route number, as $\gamma^{r\in R}=\gamma_{t_n}^{A_n,B_n}\circ \ldots \circ\gamma_{t_0}^{A_0,B_0}|_r$. Here $\circ$ is a composition rule consistent with an in general noncommutative operator or task algebra.*

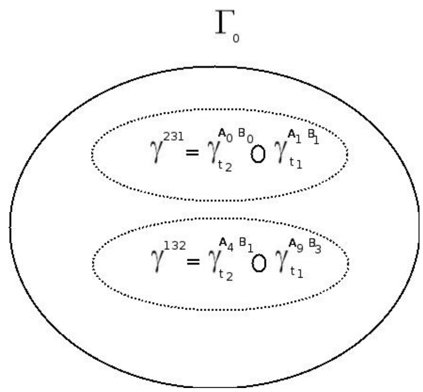

Figure 3: A configuration of agent coalitions visualized as time-ordered composite task assignments to group roles in group contexts.

Particular configurations may not be effective or possible at all. Different types of constraints, i.e., those spelled out by the task algebra, limit the set of all possible combinations of coalitions. The collection of possible combinations of coalitions for a specific route in the environment we coin the skilled set of configurations Γ in the environment. For the routes $r\in R$ a configuration $\gamma^{r_0}\cup\ldots\cup\gamma^{r_n}$ is a member of the skilled set, i.e. $\Gamma_0\in\Gamma$ (see figure 3).

Furthermore, not all configurations of the skill set perform well enough in terms of (emerging) security requirement levels. In general, there may be various security performance measures associated to a configuration. In order formalize let us for each coalition in a configuration consider a so-called *M*-value:

Definition 2 (*M*-value) *Let M be an environment. An M-value is a pair $(\mathcal{V},v)$ where $\mathcal{V}\subseteq\Gamma$ and a value function $v:\mathcal{V}\rightarrow R$.*

Now, to identify the different value schemes that indivual agents may apply to coalitions, we define an *M*-evaluation as a family of *M*-values where the index set, represented by the set of agents, of the family is used to identify the different schemes

Definition 3 (*M*-Evaluation) *Let M be a coalition formation environment. An M-evaluation is a finite family $V=\{(\mathcal{V}_a,v_a)\}_{a\in\mathcal{A}}$ of M-values.*

Analogously, we have to perform an *M*-Evaluation of the possible reconfiguration functions ***f***: $\Gamma\times t\rightarrow\Gamma$, when security incidents, like alarms, occur at a certain point in time (see figure 4) that require assistance and gathering of security guards active on other routes, or that require a coalition formation support system, like ASK-ASSIST is introduced.

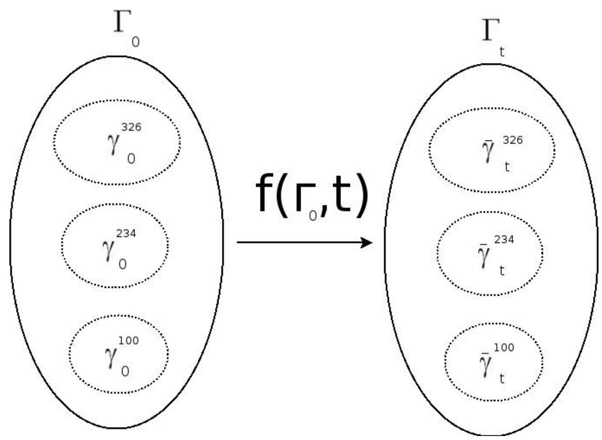

Figure 4: A transition of one configuration to another

This ranking feature of an *M*-Evaluation operator with respect to context-dependent reconfiguration functions provides the desired means to recommend the right coalition formation support for improvisation by humans. In this case the *M*-Evaluation may also cover the actual and plausible future operational contexts (including evaluations, e.g. involved costs) of more than one coalition. For example, whenever a security guard is instructed to leave his or her route to assist a colleague on another, the required time needed for providing assistance and the delay caused by traveling forth and back may hamper his or her overall route performance more than that of another guard just in close vicinity of the guard in need. *M*-Evaluation will shed a light on various types of differences as well as on communication delay reduction and other operational performance advantages of adopting ASK-ASSIST. This ranking can be formally captured by inducing context-dependent hierarchies of reconfigurations following similar ideas presented in the literature (Widya, van Beijnum, Salden, 2006) for quality of context-based optimization of end-to-end mobile-health data delivery services:

Definition 4 (Context-dependent M-Evaluation Hierarchy on a Reconfiguration Function *f*) *Let M be a coalition formation environment and* $V=\{(\mathcal{V}_a, v_a)\}_{a \in \mathcal{A}}$ *an M-evaluation in terms of M-value pairs* $(\mathcal{V}, v)$ *where* $\mathcal{V} \subseteq \Gamma$ *and generalized value function* $v: \mathcal{V} \times \ldots \times \mathcal{V} \rightarrow R$ *describing the value for consecutive reconfigurations coinciding with (unexpected) context changes over time. Assuming that reconfigurations occur at* $t_0, \ldots, t_n$ *, corresponding to time-points at which incidents occur, a CMH of reconfiguration function f is defined by:*

$$CMH(f) = \left\{ (\Gamma_q^{opt}(t_0^r), \ldots, \Gamma_q^{opt}(t_n^r)) \,|q, n, r \in \mathbb{N}| \right\}$$

where $\Gamma_q^{opt}(t_i^r)$ *is valid from* t_i *to* t_{i+1} *and where r is denotes the route number and q denotes the index set of the ordering on the set of possible (re)configurations. Note that the time points carry route-specific annotations. Labeling* Γ *by opt expresses the optimality of the (re)configuration in terms of the M-evaluation associated with it, such that the following holds:*

$$(\Gamma_q^{opt}(t_0), \ldots, \Gamma_q^{opt}(t_n)) = arg_{(\Gamma, \ldots, \Gamma)/(\Gamma_{q-1}^{opt}(t_0), \ldots, \Gamma_{q-1}^{opt}(t_n))} \left[ext\ v(\Gamma(t_0), \ldots, \Gamma(t_n)) \right]$$

where ext $v(\Gamma^n)$ *denotes an extreme value configurations, this could be either a maximum(for profits) or a minimum(for costs) depending on the type of value function used.*

Herewith our conceptual model of our mobile surveillance domain is complete but not yet readily made operational. Grounding or empirical modeling of context-dependent *CMH*-hierarchies of reconfiguration function *f* and ASK-ASSIST functionalities are needed in order to really support improvisation by humans in setting up communications or taking decisions. Methods are needed that are capable to propagate information or knowledge about surveillance operations throughout the evolving security network of multi-agent systems. For example, when introducing ASK-ASSIST for aligning systems and security personnel in case of an incident, we would like to take advantage of the already stored and accessible historic contexts to do so. Thereto, the network should self-organize this given the potential reduction of communication chains and delays provided by ASK-ASSIST compared to standard way of working, and the observed and processed historic contexts of e.g. who wants to contact whom when such an incident happens. This self-organization of the evolving security network culminates in a prediction model for reconfiguration given unexpected events or the introduction of novel coalition formation support systems.

Robust Reconfigurations

Collaborative content-based filtering (Basilico and Hofmann, 2004) can readily be applied to incident-specific coalition formation problems in the security domain. Joint kernels weighing past reconfigurations (explicitly by measuring feedback or implicitly by measuring occurrence) can be used to predict and recommend ranked lists of reconfigurations, i.e. context-dependent *CMH*-hierarchies on the reconfiguration function, given not anticipated incidents or the introduction of ASK-ASSIST. The context values, e.g., locations of security guards and road traffic states, can only be known up to a certain level of resolution. Furthermore, specific types of *M*-evaluations, such as surveillance expertise needed in case of alarms, require exploring and analysis of the exhibited skills and knowledge level of security personnel at typical context-dependent critical temporal scales. Thus to find a lost key it makes sense to ask the most experienced only when there is evidence that the last guard who visited the security object claims or has deposited the key where it should.

In order to arrive at robust grounded coalition formation alternatives we elaborate on how to apply our dynamic scale-space paradigm (Salden et al., 2001). Thereto, it is necessary first to define notions of reconfiguration image, gauge and dynamic scale-space of reconfiguration image.

Definition 5 (Reconfiguration Image) *A reconfiguration image $I:M\rightarrow N$ is a representation of the external vector-valued energy-density field M of an actual reconfiguration as a vector-valued density field of the induced one N.*

Note that the vector-valued density field of the induced reconfiguration is a member of all potential and existing context-dependent reconfigurations that can be made operational or are stored in a database, e.g. ASK-ASSIST solutions for putting the right security people in a mobile conference call when an alarm occurs.

To properly analyze such an image in terms of a complete and irreducible set of equivalences, it is mandatory to know how the reconfiguration image changes whenever they are subjected to a particular class of so-called gauge groups:

Definition 6 (Gauge) *A gauge group G consistent with reconfiguration image (Definition 5) is a group or set of transformations leaving (Definition 5) some of its properties invariant.*

Such gauge groups could cover spatio-temporal deformations and even morphological transformations including spatio-temporal reordering, cutting, pasting, insertion and deletion of reconfiguration (image) objects. For example, introducing ASK-ASSIST in security company next to the standard way of working causes non-trivial image reconfigurations in case of unexpected alarms and given incentive to reduce the workload or to increase operational performance.

A set of equivalences *F* of a reconfiguration image (Definition 5) comes about after setting up a (co)-frame field, metric and/or connection invariant under a particular class of gauge group (Definition 6), see (Salden et al., 2001). As alluded some of the gauge groups can generate active transformations, such as introducing ASK-ASSIST. However, these transformations can be undone by means of similarity operations inducing robust deliberation schemes on the reconfiguration image. Thus a categorization problem with respect to reconfiguration images involves besides the problem of invariance under gauge groups also the problem of robustness under similarity operations. For example, a reconfiguration image - due to a sudden alarm - need not cause a dramatic drop in the security level compared to the daily patrol shifts executed.

In order to ensure robust reconfiguration a gauge group consistent dynamic scale-space of reconfiguration images must be generated (Salden et al., 2001). Such a dynamic scale-space is obtained by a gauge group consistent context dependent coarse graining of reconfiguration images. Such a coarse-graining or self-similarity operation removes microscopic aspects of the images and yields similar images properties above critical context-dependent length scales, but with possibly different (renormalized) values of the parameters.

Definition 7 (Dynamic Scale-Space) A dynamic scale space of the context-dependent free energy F of a reconfiguration images, that is invariant under gauge group G, is governed by

$$\delta_\tau F = -j^F,$$

where

$$j^F = -\frac{\nabla^{\Pi}_{v_s} F}{\kappa^2(\sqrt{g(\nabla^{\Pi}_{v_s} F, \nabla^{\Pi}_{v_s} F)})}$$

with

$$Z = \exp\left[-F\left[V_i(x)\right]\right]$$

and with

$$F\left[V_i(x)\right] = \sum_{i,k,p} dv^p \left(\tilde{V}_{i;\pi_k(g_1 \dots g_k)}(x, \tau_{i;\pi_k(g_1 \dots g_k)})\right)$$

with κ a monotonic increasing function, (g,Γ) a metric and connection, suitable initial-boundary conditions, v_s connecting free equivalence states $F(p_i)$ and $F(p_j)$, and free energy F is related to statistical partition function Z. Here x labels any context complex, π_k a permutation of a sequence of $k \geq 0$ integers $(g_1 \dots g_k)$ with k=0 for labeling frame vector fields v_{g_k} and τ's for dynamic scales consistent with the gauge group G and equivalences $\wp_{i;\pi_k(g_1 \dots g_k)}$.

Note that the evolution of contexts, agents and associated joint tasks, and thus reconfiguration images are captured by the dynamic scale-space. Robust prediction models for recommendations of context-dependent reconfigurations naturally emerge over time: evolutionary symmetry breaking is covered by dynamic scale-space of the reconfiguration images, as the renormalization-group coarse-graining is intrinsically coupled to them; a necessary prerequisite for self-organization. This does not mean that the introduction of ASK-ASSIST may have such an impact. It merely causes a renormalization of the performance of the security organization even if security objects and procedures become more complex: normally humans would solve incidents for example in an awkward way with many people involved. Adding ASK-ASSIST removes unnecessary overhead from the required new configurations, but does not reduce the level complexity of the security problem introduced by an incident - law of conservation of complexity or rather free energy *F* prevails.

Critical solutions manifest themselves on context-specific temporal scales, for example, finding a suitable guard with expertise about a security object. This can be determined taking into account the right time scale. The time scale of determining the most *recent* possessor of a particular set of keys and the time scale of determining some guard's expertise (*longer period*) are different. In fact, recommendation in the case of incidents entails scrutinizing contextual segments of a security guard that has found itself in a related context. To determine the different types of time scales, greedy methods could e.g. be iteratively applied to the run-length encoding of the primal context data stored and acquired till corresponding query-specific thresholds are surpassed. These thresholds are manifest in the time-periods that appeared statistically to be predominant and lead to incident resolution. Note that for finding keys or the person that latest visited a security object corresponding to those keys might be the same and implies to use another contextual scale instead of the temporal one. For analyses of the computational complexity related to the problem we presented in this paper, we like to refer the reader to related work on the complexity of contextual reasoning in multi-context systems (Roelofsen and Serafini, 2004) and work on the complexity of evolving interactive system (Verbaan, 2006).

CONCLUSION

We proposed a dynamic coalition formation framework for the mobile security domain that enables communication decision support to security personnel when faced with unexpected incidents or confronted with the introduction of ASK-ASSIST. The framework is based on a sophisticated multi-agent modeling paradigm, in which for various situational contexts the roles, actors and systems are associated with active and passive elements, agents are assigned tasks, and the (re)configurations of joint tasks are evaluated by appropriate value functions. The framework also provides a mathematical physical paradigm to recommend ranked lists of robust context-dependent reconfigurations (with their implications) at appropriate critical scales: this way improvisation by humans in case of uncertain and unexpected incidents can be facilitated. An aspect of our model that is particularly interesting for further research concerns the computational complexity of determining the context-dependent *CMH*-hierarchies of the reconfiguration function.

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