Contracts for Resources in Crisis Management

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ABSTRACT

Today, crisis management relies to an extent on the provisioning of required resources from third-party providers. The crisis management capability is thus dependent on the adherence to, and the consistency of, a set of contracts for resource provisions. We aim at formalizing contingency plans as sets of contracts and developing a computational model for assessing whether the contracts for resource provisioning yield an adequate crisis management capability, with respect to resource provisioning. This paper outlines ongoing research on how to enable an analysis of contingency plans with respect to resource provisioning using the contractual formalism under development. We outline the important issues and illustrate with an example how contracts can be used for resource sharing.

Keywords

Resource sharing, Contracts, Contingency planning.

INTRODUCTION

Civil crisis management has to a great extent embraced the principles of service-orientation and net-centric operations. It is thus not a rule that the responsible agencies and organizations own all the equipment or resources required for engaging crises. Instead, there is a reliance on collaborations and on composing task forces on the basis of the crisis at hand and on the current needs. Among the advantages with the shift in paradigms are that it decreases the cost of resource maintenance; it provides for a more efficient crisis management; and that agencies and their operational units may specialize in certain tasks and resources usages (Fredholm and Göransson, 2006). There is nowadays also a greater acceptance toward relying on the private sector for providing resources in crisis management. For example, clearing roads after snow storms may be managed by private companies.

It is essential for crisis management tasks that the right resources are provided at the right time. In net-centric crisis management, the allocation of resources depends to an extent on agreements with third-party resource providers, where third-party resource providers may be other agencies, private companies, or volunteers. The crisis management capability thus depends on agreements with third-party resource providers. It is therefore important that such agreements can be analyzed and evaluated.

In our research, we are addressing the issue of analyzing crisis management capability with respect to resource availability under the assumption that required resources may be provided by third-party actors. There are several important issues to address. First of all, there are several issues regarding resource availability. For example, two responsible crisis managers may have contracted the same resource provider, possibly leading to an impeded crisis management capability when both managers are engaged in the same crisis. A second issue is that of finding a fairly uniform representation scheme for the diverse types of resources used in crisis management. A third issue concerns the patterns of a resource usage, which depend on who is using it and for what the resources are used. We need a flexible formalism for describing resource usage patterns. A last issue we mention is that monitoring of resource usage may be extremely difficult and complex, both technically and computationally. This is due to the inherent uncertainty of crises and crisis communication and to dependencies among resources.

We are addressing these issues by developing a representation scheme for resources general enough for capturing a large number of resources. For usage patterns, we have a model that allows us to normatively describe the usage of

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resources during the performance of a crisis management task. The norms are captured in contracts between operational units and the responsible agencies. We are aiming at modeling all the agreements included in a contingency plan in the contractual formalism under development. Contingency plans are analyzed by assuming that all the contracts are honored. Under this assumption, by analyzing the contracts with respect to the normative resource usages, we can determine whether the resource provisioning is sufficient for a successful crisis management. The analysis of contingency plans can be taken further by varying the assumed adherence to the contracts: e.g., what happens to the crisis management capability when a particular contract is broken? The analysis becomes particularly interesting when several units from different agencies are engaged in a crisis. The agencies may have formed their contingency plans independently, and there is then a risk that two or more contingency plans are incompatible in the sense that they are contracting the same resource provider, possibly leading to resource shortage for one or more units during the crisis engagement. The analysis can be made in advance of a crisis engagement and we aim at being able to detect such incompatibilities or other resource availability issues, which in turn may suggest remedies in terms resource sharing agreements or entry into contracts for backup resources.

The approach with using contracts as a formalism has three additional benefits. First, it alleviates the need for monitoring or estimating resource usage during a crisis. The amount of resources used is inherently uncertain, both before and during the crisis. Second, it is close to the actual agreements between agencies and resource providers. Contracts are common and are analyzable by a large number of practitioners, such as lawyers, mathematicians, and crisis contingency planning staff. Third, contracts allow a degree of flexibility in specifying contingency plans, which is necessary as crises are inherently uncertain both in their extent and development over time.

The approach has limitations, which we need to be clear about and also investigate further. First, contracts for resource provisioning cannot guarantee that the resources actually are allocated during a crisis. Contracts may be broken for several reasons: there may be no resources available; or the unavailability of a resource on which the contracted resource depends (e.g. transportation of a contracted expert); or because the contractor decides to allocate the resource elsewhere. Second, the contracts may have been outlined based on flawed or otherwise imperfect models of the needs, which may lead to failure of an operation or loss of value. Third, contracts may be entered for political or otherwise exogenous reasons and therefore not necessarily be adequate for a particular crisis engagement. Fourth, crises may pose unexpected resource requirements, which cannot be captured in advance by contracts. Fifth, while contracting resources may be feasible, the authority to take tactical decision and improvise during crisis management will remain with the agencies. This may lead to impeding re-negotiations about resource provisioning in time-critical situation. The most significant limitation of the approach is that the proposed analysis gives a measure of the adequacy of contingency plans only with respect to resource availability, whereas the success of a crisis engagement also depends on several other factors, such as communication, trust, leadership, and training.

The first five limitations listed in the previous paragraph point to general problems in crisis management. We are aiming at using the contractual formalism to represent contingency plans as closely as possible. Then, as a tool for analyzing contingency plans, the formalism will be helpful in detecting problems in existing contingency plans. The approach will thus add to crisis management capabilities by high-lighting possible contractual problems which may correspond to problems in existing contingency plans, such as those given by the limitations above. In particular, for the limitation concerning unexpected resource requirement, we foresee that the formalism can be used to incrementally improve the existing resource contracts, by taking into account the experiences from crises with unexpected resource requirements. For the last limitation listed above, we consider our approach a potentially valuable part of improving the overall crisis management capabilities, of which there are several at least equally important aspects and issues which also need to be addressed, but not necessarily by our approach.

The contribution of the paper is the motivation and the outline of a formalization of resource provisioning and contingency plans by contracts. The formalization enables the development of a tool for efficient calibration of contingency plans and evaluation of the adequacy of crisis management capabilities, with respect to resource provisioning. We also give a motivation for resource sharing agreements as a method for improving contingency plans.

RESOURCE SHARING

In this section, we outline our approach to formalizing resource usage and sharing.

Crises and Tasks

We assume that the event of a crisis triggers the assembly and dispatch of a crisis management task force composed of several operational and tactical units from several different agencies. The units have different capabilities and collaborate for achieving a crisis relief. Each unit has its tasks and the tasks may depend on each other (for example, evacuation of a number of citizens from an island may require airlift capabilities, but prior to that, the citizens must have been transported to an air field.) The collaborating units are assumed to perform their tasks according to predefined contingency plans. Since the units are under different commands, we cannot assume that the contingency plans are compatible in the sense that all of them can be performed successfully in parallel (even though they might be in isolation).

Resources and Actors

The resources in crisis management form a diverse collection and we aim at a representation that can capture most of the resources. Therefore, the definition of a resource is in our setting very abstract. A resource is identified by a name and to the name we associate a number of attributes. The attributes correspond to the measures of the resource that are of significance in crisis management. A compound resource is defined as a set of resources, where the set has a name and a number of attributes. The measurement of an attribute of a resource depends both on the attribute and on the particular task in which the resource is used. As a simple example, if all we care about concerning the resource R is whether it is available or not, we may use the attribute *available* with possible values in the set {yes, no}. On many occasions, we may want more elaborate measures; for example the sustainability of a unit, which is measured in hours or days depending on the type of unit and the type of engagement. The measure may be an exact figure, such as 3 hours, or an interval such as 2 to 5 hours. The interval representation can be used to capture the uncertainty of a crisis or possible dependencies on external factors. For this paper, we assume that a resource has only one attribute with values in a set of integers.

Usage of resources is made by actors. Some of the actors provide resources, some use the resources, and some actors are responsible for the performance of the tasks in which the resources are used. In our formalization, these actors play a crucial role as being the parties who enter the contracts that the contingency plans are comprised of.

When an actor uses a resource for accomplishing a task, the values of the attributes of the resource change. (Using fuel for propelling a vehicle decreases the amount of stored fuel in the vehicle.) In formalization of resource usage, the monitoring of resource consumption becomes computationally complex, especially when taking dependencies into account. In practice, monitoring requires reports (from sensors or otherwise) at a certain rate, which may be unreliable and perhaps even infeasible. Instead of relying on resource usage monitoring, we rely on monitoring of *contracts for resource usage*. Monitoring then boils down to the validity of, and adherence to, such contracts. Analysis of contracts for resource usage will play a crucial role for assessing the compatibility of contingency plans, as described in the introduction.

We define a usage model for a resource by annotated state machines. The usage model is flexible and we may define any number of states required for a particular modeling task. In an example further below, we define the states *beginning* and *end* and tell how much of a resource is required in the beginning of the performance of a task, and how much of the resource that will be returned on completion of the task. The usage model for a resource is represented as a *resource usage contract*.

Contracts

In general, a (unilateral) contract is based on an offer by a first party to perform a service on a condition. If and when the offer is accepted by a second party, we may say that the parties have entered a contract. With the acceptance of an offer follows that the first party is obliged to perform the service as soon as the second party (i.e. the holder of the contract) fulfils the condition. In our research we are presently investigating how far the notion of contracts can be used. We are investigating a notion of a *contract for a resource measure*. With this notion, we say that a provider P of a resource R offers a measure of a resource on a condition. The condition may be the transfer of resources (e.g. money) to the offeree, or just (the bringing about of) a state of affairs.

TOWARD A FORMALIZATION

In this section we give a brief sketch of the formalization of resource provisioning and illustrate how to capture some of the notions presented in the previous sections. We are working with a number of different representation schemes, and here we will present the formalization in a way that is influenced by the contract language by Ralph Johan Back with co-workers (Back and von Wright, 2000). Note that our use of Back et al's formalism is quite free, and it does not necessarily conform to their original work. A second formalism we are considering is Service Level Agreements (IBM, 2003).

The crisis management actors are formalized as atoms called *subjects*. The basic notions are those of *resource measures* and *resource allocations*. A *resource measure* is a term of the form (R, A, K) where R identifies a resource, A identifies an attribute of R, and K identifies a constraint on the domain of possible values of A (K could for example denote a subset of the domain of A). A *resource allocation* is a term of the form (S, M) where S is a subject and M is a resource measure. The intended reading of a resource allocation (S, M) is that the subject S is allowed to use the resource to a certain measure, where both the resource and the measure are given by M.

A *resource offer* is a term of the form $\{C\};(S,M)_{S1}$. The notation $\{C\}$ is an assertion that C holds, where C is the condition in the offer. The notation $(S,M)_{S1}$ means that S1 promises to make the resource measure M available to the subject S. The colon in $\{C\};(S,M)_{S1}$ says that C must be brought about before $(S,M)_{S1}$ is executed. An *accepted offer* is a term of the form $\langle S:=S2\rangle_{S1};\{C\}_{S2};(S,M)_{S1}$, where $\{C\}_{S2}$ means that S2 accepts to bring about the condition C and $\langle S:=S2\rangle_{S1}$ means that S1 agrees to assign S2 to the subject S, so that it is S2 that becomes the subject that has the right to use the resource measure M. The angular delimiters indicate that it is an assignment to a variable to be made. Note that $\langle S:=S2\rangle_{S1}$ must be executed before $\{C\}_{S2}$, otherwise S2 may not have an incentive to bring about C, as another subject could then have been assigned to S. A note on the semi-colon notation: in the term $X_{S1}; Y_{S2}$, if S1 fails to bring about or execute X, then S2 is relieved of the contract. If S1 succeeds in X but S2 fails in Y, then S1 may hold S2 responsible and claim compensation.

Accepted offers are the simplest contracts in our formalization. The contractual formalism of Back et al is very expressive and it allows parallel execution, loops, conditional execution, and assumptions. Of course, timing and duration can also be expressed by considering time as a resource. We intend to expand the formalism along these lines and in the end be able to formalize whole contingency plans as (sets of) contracts. For giving some indication of what that means, we give some further examples of formalizations. In the previous section we assumed that the event of a crisis C triggers responsible agencies, say S1, S2, and S3 to dispatch operational and tactical units to perform tasks, say T1, T2, and T3. This can be formalized by the contract

$$[C]_{S1,S2,S3}\ ;\ T1_{S1} + T2_{S2} + T3_{S3}$$

where C is a description of the state of the world where the crisis has occurred. The notation $[C]_S$ denotes that the subject S is only bound by the contract under the assumption that C holds. Thus, if C holds, then S1, S2, and S3 are obliged by the contract to perform the tasks T1, T2, respectively T3. The plus sign means parallel execution. The tasks T1, T2, and T3 may themselves be formalized as contracts. For example, say that T1 can be achieved either by performing subtasks T4 and T5 in parallel or by first performing subtask T6 and then subtask T7. Using Back's notation, we would write that as $T1 = (T4 + T5) \vee (T6 ; T7)$ where each subtask and the choice operator ($\vee$) would be assigned to some responsible subject by subscripting.

The semantics of the contractual formalism is crucial to the development of a tool for analyzing contingency plans. The semantics of a set S of contracts (formalizing a set of contingency plans) has three components: a translation of the contracts into state machines; a record of the resources mentioned in the contracts in S; and a set P of possible runs of the state machines. Each run in P corresponds to a particular order in which the contracts in S are executed. A run is thus a sequence of executed contract terms. At each step in a run, we update the resource records (with respect to the measures of the attributes of the resources) according to the resource usage contracts. If for each run in P, no resource has been depleted (or fallen below some given limit) as given by the resource record, then the set S of contracts is said to yield an adequate crisis management capability with respect to resource provisioning, otherwise we say that S does not yield an adequate crisis management capability with respect to resource provisioning. Note that the choice of the set of runs is crucial, and we foresee that the particular choice has to be influenced by experienced crisis management practitioner.

EXAMPLE OF RESOURCE SHARING AGREEMENTS AND ANALYSIS OF CONTINGENCY PLANS

Assume that two agencies, A1 and A2, have contracted the same provider P of a resource R. Assume that P has 10 units of the resource. Assume that A1 and A2 dispatch the agents U1 respectively U2 for using R for completing tasks T1 respectively T2 in a crisis engagement. Assume that U1 requires 5 units of R and that it returns the units to P after it has completed T1, while U2 requires 7 units of R which it destroys and thus returns nothing to P after completing T2. This setup does not, according to our semantics, yield an adequate crisis management capability since there is a run that renders the available amount of R to 3 before U1 has even begun performing T1 (that is the run where T2 is executed before T1). However, with a sharing agreement between A1 and A2, the combined contingency plan can be rendered adequate. The agreement should say that U1 must have performed T1 before U2 performs T2. In our contractual formalism, this could be written as $(\{T2\}_{U2}; \{T1\}_{U1}; \perp_{U1,U2})$, where $\perp_{U1,U2}$ is a term that signifies that both U1 and U2 are in breach of the contract.

A second example where the approach could be applied is elaborated from an incident in 2005 where a World War I naval mine was detected in a harbor in Gothenburg, at the west coast of Sweden (KBM, 2007). The preparedness for clearing mines was shared between naval bases, and at this occasion it was a base on the east coast (Stockholm) that was in preparedness. A mine clearing team would normally have been transported by helicopter from Stockholm to Gothenburg. Due to bad weather, air force helicopters were not allowed to fly and no police helicopter was available. The team was instead transported by car, resulting in a loss of possibly critical time. With a contractual representation of this setup, we envisage that our approach could have detected the potential loss of time in the crisis engagement. Crucial to the detection would be the contractual representation of the ban of flying on air force helicopters under certain weather conditions. Upon detecting this possible unavailability of resources (helicopters), contingency planners could in advance have entered a backup contract with a local private helicopter rental service.

EVALUATION AND FUTURE WORK

The evaluation of our approach has so far been through discussions with, and demonstrations of initial ideas for, crisis management practitioners. This has given valuable input regarding the relevance of the approach and regarding future extensions and focus. There are still aspects of our approach to be evaluated. We need to see how the approach scales up when considering hundreds of compound resources with several attributes. We also need to assess the computational complexity of monitoring of contracts. A further future direction, suggested by practitioners, is to enable a probabilistic assessment of whether a specific contract will be adhered to.

CONCLUSION

We have outlined a contractual formalism for analyzing aggregated contingency plans with respect to resource provisioning. We have argued that this is important for two reasons: the crisis management capability depends today on agreements with third-party resource providers, and the aggregation of contingency plans may introduce conflicts in resource usage and thus an impeded crisis management capability.

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REFERENCES

1. Back, R J R, Wright J von (2000), Contracts Games and Refinement, *Information and Computation*, 2000.
2. Fredholm, L, Göransson, A (2006), Ledning av räddningsinsatser i det komplexa samhället (in Swedish), Räddningsverket 2006.
3. IBM Research (2003), Web Service Level Agreements, http://www.research.ibm.com/wsla/
4. KBM (2007), Minan i Göteborg den 7-9 december 2005 (in Swedish), Swedish Emergency Management Agency (KBM) 2007