

The Windmill Method for Setting up Support for Resolving Sparse Incidents in Communication Networks¹

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1 Introduction

In domains such as security and surveillance, traffic and transport, medical care and the military, hundreds of professionals are spread over a network consisting of various groups across different organizations to perform various standard tasks at different places and move from one location to another over time. Such tasks are by nature urgent, local, incident prone and require the deployment of resources in terms of personnel, materials, and infrastructure. These tasks often interfere with and depend on each other, as performing these tasks typically involves the activities and knowledge of other people at other locations. For ease of reference we will call such a setting a *Professional Task Setting with Incidents* (PTSI).

PTSI is not the same as general crisis/incident management. PTSI concerns frequent disruptions of routine tasks by relatively small incidents, whereas crisis management and incident management during crises deals with large and disastrous events. However, organizations specializing in PTSI are typically called in to help in crisis management situations.

Situation assessment, coordination and task assignment to members of different organizations are vital to satisfy the intra- and inter-organizational goals given those interdependencies. Especially, when individuals are not co-located, information and communication technology should be called upon to coordinate the actions aimed at handling incidents.

In PTSI handling incidents is difficult due to the time-critical nature of the incidents, limited situation awareness of dispatch operators, the risk of a single point of failure (i.e., formation of bottlenecks, see Figure 1), and the spatio-temporal character of incidents and of the organization (e.g., changes in personnel). Opportunities are the latently existing knowledge in databases, and the tacit knowledge distributed over the personnel of the organization.

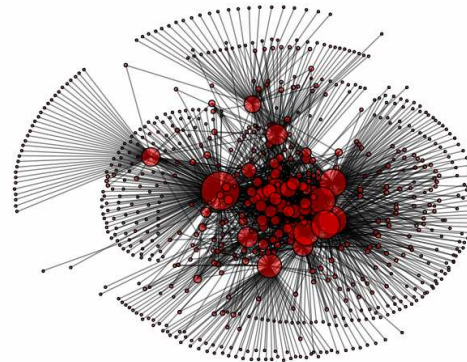


Figure 1. Communication network of actors in MHS security. Larger vertices represent dispatch operators and team leaders. Smaller vertices represent mobile professionals.

2 Windmill Method

We developed the Windmill approach by mapping the difficulties and the opportunities of problems with a time-critical component to a set of aspects (each hierarchically ordered), such that locally available knowledge is applied immediately (being the top ranked knowledge in all aspects).

The Windmill concept is based on the idea that the set of aspects corresponds to the set of blades on a windmill, see Figure 2. Per blade/aspect, the knowledge available is hierarchically ordered according to

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its relevance. The centre of the mill, where all the blades meet at the axis, represents the most relevant instance corresponding to a particular incident, which actually denotes the core of the problem by the most detailed description available. Moving up the blades, to the outside, the position on the blades corresponds to knowledge that is decreasingly relevant to the specific instance and can be considered to be more general. The fantail of the windmill (that which keeps it directed to the wind) represents the defined performance criteria set for estimating and evaluating the performance of potential communication. The milling itself stands for the performance of these potential communication connections; the faster the milling, the better the performance. The adaptability with respect to different time-scales and generality of information is represented in the blades of the windmill.

3 Windmill for Communication Support

Using the Windmill approach requires logged data for analysis and bootstrapping purposes. These logged data should include the performance of past solutions to incident and task handling, each associated with

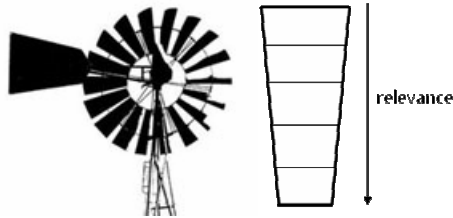


Figure 2. Windmill & a Blade in more detail

the communication session instigating the solution, the nature of the incident itself and the spatio-temporal context in which the solution was achieved. We define such collections of logged data by a set L consisting of a finite number of events. Each event e is represented by a tuple (a, g, τ, c, t) where the components, $a \in A$, $g \in G$, $\tau \in \mathcal{T}$, $c \in C$ and $t \in T$, denote the following: A is a set of actors in charge of a task, G is a set of groups (of actors) having participated in incident related communication, strictly $G=2^A$, \mathcal{T} is a set

of tasks including incidents in set I , C is a power set of context elements, and T is a set of time points.

The goal of communication support is to find a suitable group g for a specific actor a , that is working on a task τ , such as an incident $i \in I$, while taking into account the context c and the time t at which this takes place.

For estimating the performance of potential solutions, and as such constructing recommendation schemes that fit new incidents occurring, the Windmill approach allows comparing new events to past events. This is achieved by an estimation function for v that weights past solutions by their relevance using a relevance metric δ and aggregates the associated performances according to its weights:

$$\hat{v}(e, \sigma^n) = \frac{\sum_{e' \in L} v(e') \times \delta(e, e', \sigma^n)}{\sum_{e' \in L} |\delta(e, e', \sigma^n)|}, \quad (1)$$

where each e and e' is an event and σ^n is a set of n scale parameters to allow non-linear weighing of the relevance metrics. Here, n corresponds to the amount of elements in the tuple $e = (a, g, \tau, c, t)$, which is 4 plus the amount of exact contextual elements.

Although such context-sensitive incident information can be used to select the right recommendation schemes, these incidents may be sparsely distributed over time and space making those schemes become unreliable, i.e., the recommendations schemes will be based on too few cases to guarantee certain accuracy. Furthermore, changes over time t will make those solutions obsolete. The Windmill method therefore specifically addresses the issues of sparseness and spatio-temporal dynamics:

1. By allowing each aspect to contribute to the estimation of the candidate solution's performance independently of the exact composition of elements, also events that have never occurred in reality can be assigned an expected performance based on strong correlations between the different observables.
2. To enhance the estimation of the performance of incident solutions under the temporal dynamics and changes in other aspects, we propose an activation spreading approach with respect to the relevance measure between new and past events. The spreading of the performance data across potential regions of (a, g, τ, c, t) space has to be corroborated by grounded similarity measures between the individual elements or classes of that space.