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MASTER

A MONTE-CARLO APPROACH TO THE GENERATION OF ADVERSARY PATHS

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The purpose of a safeguards system at a nuclear facility is to protect against the theft or dispersal of special nuclear material. In order to learn how effective a safeguards system is at stopping threats, it is necessary to define the threats with which we are concerned. The threat definition can be as general as the number of adversaries against which the safeguards system must defend or as specific as the sequence of events that might lead to adversary success. The focus of this paper is on the latter definition.

To facilitate a description of adversary paths, the nuclear facility is characterized as a weighted, labeled, directed graph[3]. The characterization is illustrated in Figure 1. In the example, the adversary begins outside the facility, passes through some sequence of nodes (1, 2, and 3), then into the material access area where he achieves his objective (node 4). The arc weights, w_{ij}, represent a measure associated with traversing the space between facility entities (nodes) i and j. Two measures that have been employed are the traversal times and the detection probabilities associated with traversing the spaces.

The graph-theoretic structure for characterizing facilities was provided by Hulme[4,5]. The methodology developed by Hulme can be used to generate critical adversary paths based on minimum traversal times, detection probabilities, or a combination of these two measures. The essential difference between the graphs used in Hulme's technique and those employed in the model that is the subject of this paper lies with the arc weights. That is, the weights in the former are deterministic whereas the weights used in the latter are random variables with arbitrary probability distributions.

The output from the model consists of two sets of statistics. One set is related to the adversary paths that are generated and the other to the adversary activities (arcs) which comprise the paths. More specifically, an estimate is obtained for the probability that a particular path is the most critical in comparison to the other paths that are possible. In addition, for each arc in the graph, an estimate is made for the probability that the arc is on the critical path. This measure is potentially useful for resource allocation. That is, the greatest improvement in safeguards system effectiveness might be realized by allocating resources to high probability arcs first.

Table I depicts a portion of the output from the model. Note that the path consisting of nodes (1,3,4) is the most critical since it has the highest probability (criticality index) of being the critical path. Path (1,2,4) is a close second and path (1,2,3,4) is the worst choice for the adversary fo the measure considered. The activity criticality indices are also shown in Table I. Note that activities numbered 1 and 5 have the highest probability of being on the critical path.

The model itself is a discrete-event, Monte-Carl simulation and is programmed in the GASP IV simulation language[6]. The modeling philosophy is not unlike that of Van Slyke[7] who applied an analogous technique to analyzing PERT networks. The model relies on a number of replications of Dijkstra[1,2] searches. The search provides the "optimal" path on a per run basis. For each replication, random draws are made for the arc weights and the search is repeated. Statistics are collected over all replications and estimates are made for the probability measures mentioned above.

The model has been tested for hypothetical facilities and the results are promising. Although the current versions of the model address only detection probabilities and transit times individually and independently, the structure of the model is sufficiently flexible to allow for combinations of these measures and the inclusion of other measures. Future embellishments of the model will include some of these considerations.

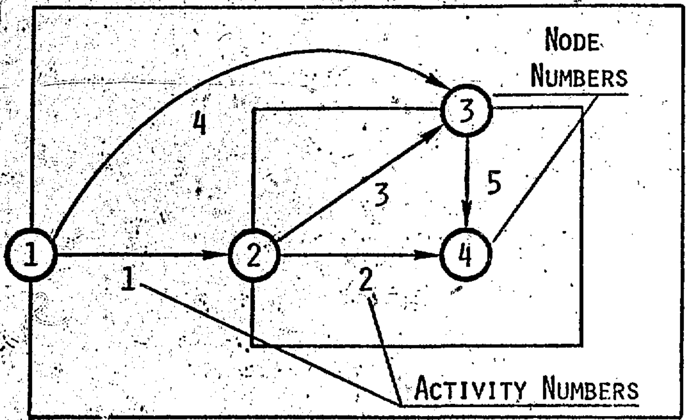

Figure 1: A Facility Characterization

TABLE 1

Path and Activity Criticality Indices

Path Description	Criticality Index
(1,3,4)	0.3898
(1,2,4)	0.3895
(1,2,3,4)	0.2207

Activity Number	Criticality Index
1	0.6102
2	0.3895
3	0.2207
4	0.3898
5	0.6105

References

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