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A Multi-area Model of a Physical Protection System for a Vulnerability Assessment

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1. Introduction

A physical protection system (PPS) [1] integrates people, procedures and equipments for the protection of assets or facilities against theft, sabotage or other malevolent human attacks. Among critical facilities, nuclear facilities and nuclear weapon sites require the highest level of PPS. After the September 11, 2001 terrorist attacks, international communities, including the IAEA, have made substantial efforts to protect nuclear material and nuclear facilities. These efforts include the Nuclear Security Fund established by the IAEA in 2002 and the Global Initiative to Combat Nuclear Terrorism which is launched by the USA and Russia in 2006.

Without a regular assessment, the PPS might waste valuable resources on unnecessary protection or, worse yet, fail to provide adequate protection at critical points of a facility. Due to the complexity of protection systems, the assessment usually requires computer modeling techniques. Several Codes [1-3] were developed to model and analyze a PPS. We also devised and implemented new analysis method and named it as Systematic Analysis of physical Protection Effectiveness (SAPE) [4].

A SAPE code consumes much time to analyze a PPS over a large area in detail. It is because SAPE uses meshes of an equal size for the analysis of a 2D map. The analysis is more accurate when the meshes of a smaller size are used. However, the analysis time is roughly proportional to the exponential of the number of meshes. Thus, the speed and accuracy is in a trade-off relation.

In the paper, we suggest a multi-area model of a PPS for a vulnerability assessment to solve this problem. Using multi areas with different scales, we can accurately analyze a PPS near a target and can analyze it over a large area rather roughly.

2. Methods

Multi-areas are connected by some connection points between multi-areas. Figure 1 shows the concept of multi-areas. The three large rectangles represent areas. Violet squares are entrance points and Light green squares are exit points. The entrances and exits either can be the same coordinate or different coordinates of the corresponding area. The former is used for representing a multi-floor building. In this case, the connection points might be stairway or elevator. The latter is used for magnifying a small area. In Fig. 1 the third area from the bottom is the enlarged area of the rectangle in the second area. This magnifying feature enables two-scale analysis of a PPS.

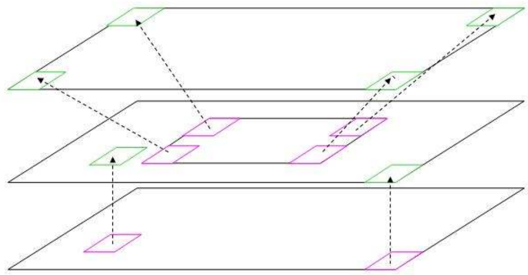

Fig. 1 Connection points and multi-areas

For convention, we give a constraint that every connection must be directed to a higher area where an area having a target is the highest area. That means an area with a target has no connection to other area and every area is ordered.

The analysis algorithm needs not to be changed by the multi-area feature. SAPE uses the best-first search algorithm to find the most vulnerable path [4]. This algorithm is basically a graph search algorithm and the connected area in Fig. 1 can be represented by a graph.

The best-first search algorithm is a breadth-first search using heuristics [5]. The breadth-first search algorithm begins at the root node and explores all the neighboring nodes. Then for each of those nearest nodes, it explores their unexplored neighbor nodes, and so on, until it finds the goal. In exploring neighbors, the best-first search algorithm searches, firstly, the path that appears to have the smallest cost. This estimated cost is the sum of the cost from the starting point to a current position and the estimated cost (heuristics) from a current position to the goal.

However, the estimated cost (heuristics) should be considered further because of connections. The heuristics including connections is as follows. First, as previous one, the delay time passing the straight line from a current position to a target is used as the estimation. Second, two connected meshes has the same estimated. These two rules and the above constraints enable us to calculate heuristics at whole areas. For an area having a target, the cost to a target is the estimation. For an area having no target, the sum of the cost to a connection and the connection value is the estimation. Since there are many connections, the value with the connection giving the smallest sum is chosen as the estimation.

3. Application

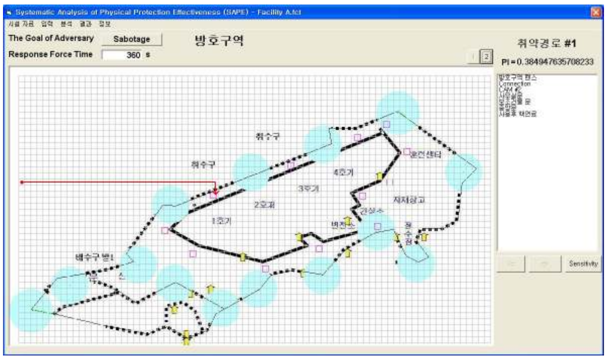

Fig. 2 An outer area of a model facility

Fig. 3 An inner area of a model facility

Figure 2 and 3 display the capture screen of SAPE analyzing a model facility. These figures show two different views of the same facility and they represent a multi-area model. The large area is Fig. 2 and the small area is Fig. 3. The small area is surrounded by an inner fence in Fig. 2, which is represented by a thick black line. The outer area (Fig. 2) is divided by coarser meshes than the area near target. We use two areas to represent a nuclear power plant because there are two distinct areas in the plant. Two areas are connected at specific meshes in the area. These connection points are located right outside of an inner fence and are represented by violet squares in Fig. 2. When an adversary enters the connection point then it immediately transferred to related points in Fig. 3. The red arrows in the figures display the most vulnerable path. The path is also connected at a connection points. We apply it to various facilities and we, however, cannot show the results because of a secret issue.

4. Conclusions

In conclusion, we suggest a multi-area model of a PPS for a vulnerability assessment. These areas are connected by connection points. We modified the algorithm for a multi-area model and we apply it to a model facility. Using multi areas with different scales, we can accurately analyze a PPS in a small area near a target while covering a large area.

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