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The Tile-map Based Vulnerability Assessment Code of a Physical Protection System: SAPE (Systematic Analysis of Protection Effectiveness)

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1. MOTIVATION

Increasing threats on nuclear facilities demands stronger physical protection system (PPS) within the limited budget. For this reason we need an efficient physical protection system and before making an efficient PPS we need to evaluate it. This evaluation process should faithfully reflect real situation, reveal weak points and unnecessary protection elements, and give comparable quantitative values.

Performance based analysis [1] helps to build an efficient physical protection system. Instead of regulating the number of sensors and barriers, the performance based analysis evaluates a PPS fit to the situation of a facility. The analysis assesses delay (sensors) and detection (barriers) of a PPS against an intrusion, and judges whether a response force arrives before intruders complete their job.

Performance based analysis needs complicated calculation and, hence, several assessment codes have been developed. A code called the estimation of adversary sequence interruption (EASI) was developed to analyze vulnerability along a single intrusion path. The systematic analysis of vulnerability to intrusion (SAVI) code investigates multi-paths to a valuable asset in an actual facility. SAVI uses adversary sequence diagram to describe multi-paths.

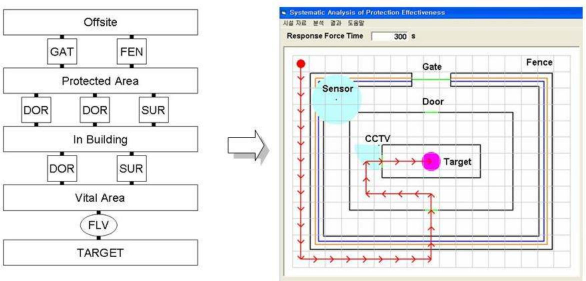

Fig. 1 Adversary sequence diagram (ASD) and the tile-map of a facility

Existing code have limitations in representing the position because they use a simplified model of a PPS – called adversary sequence diagram (ASD) which is displayed in Fig. 1. For example ASD cannot show which position of fence is crossed over.

In the paper, we suggest to use the 2D-map of a facility as a model of a PPS and to analyze a PPS by tile shown the right picture of Fig. 1. Tiles are equal squares which divides the map of a facility. We will call the 2D-map of a facility that is divided by tiles as a *tile-map*. The tile-map has more information, which includes not only accurate distance but also arrangement of a PPS. Accordingly a tile-map is easy to understand and accurately represent a facility.

Also we give a measure of efficient upgrade of PPS. It is the sensitivity analysis to all participating protection elements along a chosen path. The sensitivity to a protection element approximately represents the efficiency of the element for upgrade. Here and further a *protection element* means equipment or system that detect and/or delays intruders, such as a sensor, a fence, a wall, and a lock.

2. PHYSICAL PROTECTION SYSTEM

For neutralizing theft or sabotage attempts, a physical protection system should detect and announce the intrusion, and delay it until response force arrives and interrupt it. A PPS is consisted of intrusion detection, entry control, barriers, emergency communication, and a response force. These protection elements are categorized as detection, delay and response.

A measure of effectiveness can be obtained from the function of the probability of detection, delay time, and response force arrival time. Whether adversaries are interrupted before their task or not, is analyzed based on the performance of these elements.

The effectiveness of a PPS is measured by the probability of interruption (PI). Concretely, the probability of interruption (P_I) along a path including two protection elements (1 and 2), is as follows.

$$P_I = P(D_1)P(R \mid A_1) + (1 - P(D_1))P(D_2)P(R \mid A_2), \quad (1)$$

where the probability of detecting adversaries at the element 1 is $P(D_1)$, the probability that a response force (R) from the alarm at the element 1, interrupts before the adversaries complete their task (A_1) is $P(R \mid A_1)$, the probability of detecting adversaries at element 2 is $P(D_2)$, and the probability that a response force (R) from the alarm at the element 2, interrupts before the adversaries (A_2) is $P(R \mid A_2)$. The first term of equation (1) $P(D_1)P(R \mid A_1)$ means the probability of interruption protected solely by the element 1, and the second term $(1 - P(D_1))P(D_2)P(R \mid A_2)$ means that the probability of interruption protected by the element 2, when the element 1 fails to detect the adversaries.

3. TILE-MAP REPRESENTATION OF A PPS

A tile-map is a model of a physical protection system based on a tile, where a tile is an equal square that divides the 2D-map of a facility [2]. A tile has the probability of detection and delay time of the locating protection element. The values are used to calculate the probability of interruption of an adversary path, which passes through the tile.

Using a tile-map to represent the PPS of a facility has the following advantages comparative to ASD (Fig. 1);

- It provides an intuitive bird-eye views of a PPS, and
- It realistically represents relative positions between protection elements.

Figure 2 shows the tile-map of a facility, and it is also the capture screen of a code called Systematic Analysis of physical Protection Effectiveness (SAPE). The red arrows are the intrusion path of adversaries, and it clearly shows the position of a fence where the adversaries pass through.

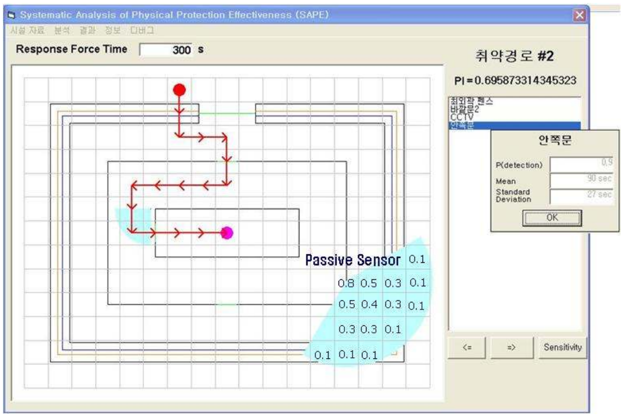

Fig. 2 Systematic Analysis of Physical Protection Effectiveness (SAPE)

4. SEARCH ALGORITHM OF THE MOST VULNERABLE PATH

We measure the effectiveness of a PPS by the PI along the most vulnerable path to a target. Because it is conservatively assumed that adversary knows all the information of a physical protection system. We should evaluate all possible paths to find the most vulnerable one tile by tile.

We use the heuristic search algorithm [3] to find a path which has the lowest probability of interruption. The heuristic search algorithm uses a rough estimation, called *heuristics*, to pick plausible paths.

5. SENSITIVITY

To help upgrading the weakest path, SAPE evaluates the sensitivity to all protection elements which is placed on the path [4]. The sensitivity represents relative upgrade efficiency, and hence higher sensitivity elements should be considered at first in the upgrade of a PPS.

6. RESULTS & DISCUSSION

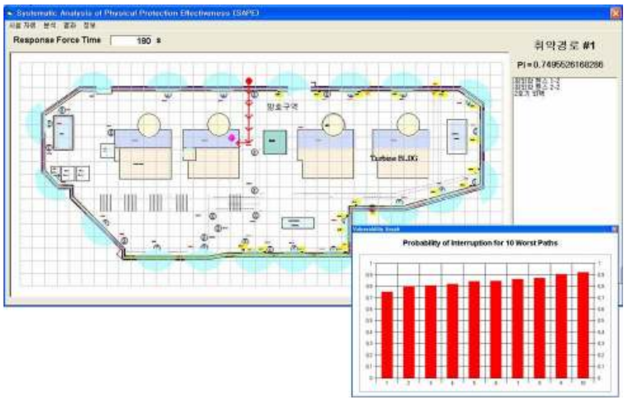

Fig. 4 The most vulnerable path of a virtual facility

SAPE (Systematic Analysis of physical Protection Effectiveness) code is being developed in physical protection team of Korea Institute of Nuclear Nonproliferation and Control. Figure 2-4 shows capture screens of SAPE. SAPE finds ten most vulnerable paths (lower right of Fig. 4), shows the path in the 2D-map (Fig. 2), and analyzes the sensitivity of consisting protection along the path (Fig. 3). Figure 4 shows the analysis result of a model facility. The fan-shape of sky blue color represents areas which are surveyed by CCTV.

Conclusively, we suggest accurate and intuitive vulnerability assessment code based on the tile-map modeling of a PPS. The code will help to assess a PPS and, thus, to build robust protection against terror.

ACKNOWLEDGEMENT

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