Art Exhibition Security System

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September 2015

Abstract

In this paper, we deal with the task of designing an art exhibit wall arrangement for hanging paintings that would optimize security. We began by defining security in terms of camera viewing time of paintings, such that a painting is secure if the center of the painting is seen by the camera. The centering of the paintings allows us to disregard the dimensions of the paintings, which remain unknown to us and may vary. Next, we defined our two metrics of security as primarily the average viewing time of all fifty paintings measured in seconds, and secondarily the standard deviation of viewing time among all fifty paintings measured in seconds. Therefore the wall arrangement with a maximum average viewing time of paintings and smallest standard deviation is the optimal mathematical solution. In finding an "optimal" solution, however, we also considered and utilized the maneuverability of the portable walls for actual people walking through the museum. A UNITY program was used to determine the individual viewing time of each painting according to the parameters of our decisions, which allowed us to collect security time data across all fifty paintings for any arrangement of paintings. The program and our metrics were initially used to test the two wall arrangements in the problem statement, and we found that the Figure 1 wall arrangement is better with both a higher average painting viewing time and a smaller standard deviation of viewing time than those of Figure 2. After testing many wall arrangements using our program and adjusting arrangements based on observations of our data, the optimal solution was found to be near identical to the wall arrangement in Figure 1, so we chose the optimal solution based on our model to be the arrangement in Figure 1.

Introduction

An art gallery is holding a special exhibition of small water colors. The dimensions of the room that the exhibition is being held in is a rectangle 22 meters long and 20 meters wide with entrance and exit doors 2 meters wide. Two security cameras are fixed in the corners of the room, with resulting footage being watched by an attendant. The security cameras at any instant scan with a beam spanning 30 degrees and rotate to complete an entire cycle in 15 seconds. We were tasked with finding an optimal portable wall arrangement to maximize our definition of security for the art exhibit.

Assumptions

Our first assumption was that the security cameras do not stick out of the corners they reside in because the model considered them as points. We also assumed that we could intuitively determine if a particular wall arrangement was aesthetically appealing and maneuverable by the viewers. The viewers were also not taken into account in the model, and so the people were assumed to be transparent and thus not able to block the camera's view of each painting. The model also took for granted that the portable walls had close to 0m widths and that the paintings stuck out very little from the walls.

Definitions and Justifications

Definitions

We first defined the center of each painting to be at around eye level from the ground. Thus, because the average eye height of adults is about 1.7 meters, we set this as each painting's centered height. Next, we decided that the cameras were 4 meters high (at the top corners of the rooms) and began their cycle facing the adjacent permanent walls. Additionally, the paintings were centered horizontally at the midpoint of their occupied 1 meter space on the permanent and portable walls. Because the exact dimensions of the paintings were unknown and could vary among the fifty paintings, we defined that a painting was secure for every instance when a camera views the center of the painting. Third, because straight lines could not be drawn from the security cameras to the paintings along the walls adjacent to the camera, we defined the paintings on these adjacent walls as not being seen by the camera. This was because a camera elevated 4 meters off the ground could only view the tops of the frames that jutted out from the walls adjacent to the camera, not the center of the painting. These definitions have direct implications on how our program registers the start and stop time for our defined security of the paintings.

In our model, our metric of security is chiefly defined as maximal average viewing time of all fifty paintings, or:

$$M = \frac{1}{50} * \sum_{i=1}^{50} t_i$$

Where t_i is the security time of one of the fifty individual paintings.
Secondly, the wall arrangements with high M values can be compared with standard deviation of camera viewing time, or:

$$\sigma = \sqrt{\frac{1}{50} * \sum_{i=1}^{50} (t_i - M)^2}$$

Obviously, among the wall arrangements with high average security time, the best mathematical solution is to pick the wall arrangement with the lowest standard deviation because optimally all paintings would have a security time similar to the M value. Thus, among the possible wall arrangements with high average camera viewing times and low standard deviation of viewing times, the portable wall arrangement most humanly maneuverable, which is intuitively determined, will be chosen as the optimal solution.

Justification of Definitions

Defining average viewing time as our primary measure of security is justified because the average viewing time exactly reflects the total defined security time across all fifty paintings for a given wall arrangement. To account for variation of security time in individual paintings, we decided to include the standard deviation of viewing time as a secondary metric so we can address the possibility of arrangements with decent average viewing times that hide the problem of paintings with poor security times averaging out with paintings with good security times. To deal with this potential issue that is not reflected in the average security time, we are justified in using the standard deviation as a secondary metric to identify the optimal wall arrangement among arrangements with similar average viewing times.

Current Situation

The two models from previous exhibitions are shown in Figures 1 and 2 below. Using the values from the UNITY simulation, the calculated average secure time of models 1 and 2 was 4.87 seconds and 3.14 seconds, respectively. The standard deviations for the two models are 3.21 seconds and 3.32 seconds, respectively. From our calculated mean and standard deviation of security time for figures 1 and 2, it is clear that Figure 1 is superior in terms of our defined security because Figure 1 comparatively has a much higher average security time and a lower standard deviation of viewing time.

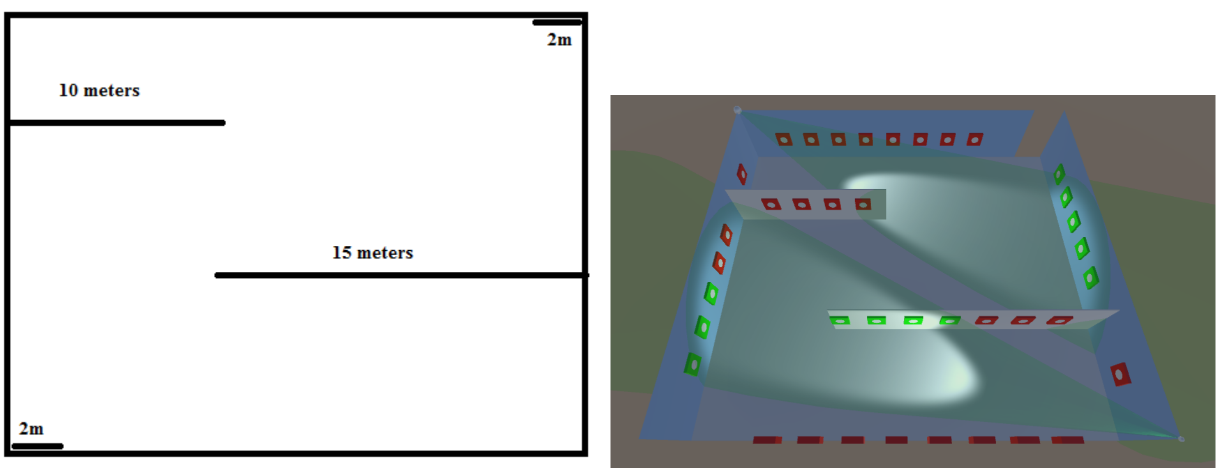
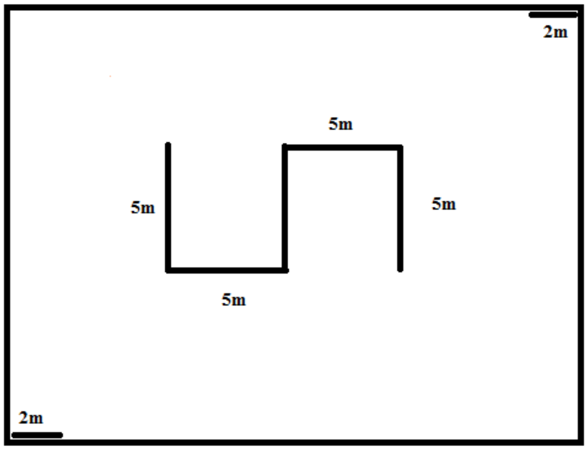


Figure 1: Exhibit Configuration: November 3-25, 2014
Average Time Secure: 4.87 seconds
Standard Deviation: 3.21 seconds



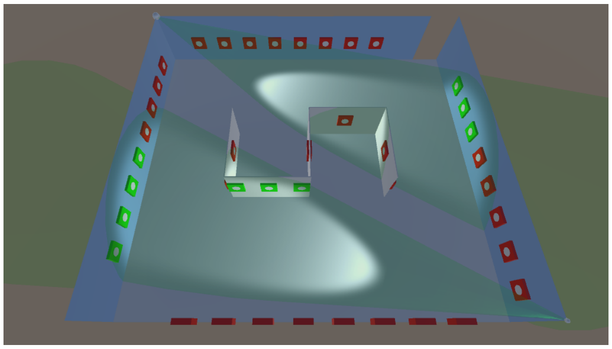


Figure 2: Exhibit Configuration: March 4-29, 2014
Average Time Secure: 3.14 seconds
Standard Deviation: 3.32 seconds

Painting	Times	Painting	Times
1	0.00	26	4.19
2	0.00	27	0.00
3	6.84	28	6.74
4	0.00	29	9.04
5	3.30	30	6.94
6	0.00	31	7.95
7	3.07	32	9.13
8	5.13	33	6.45
9	0.00	34	6.58
10	4.23	35	7.22
11	0.00	36	6.58
12	3.96	37	7.45
13	0.00	38	9.13
14	3.07	39	5.48
15	5.29	40	7.26
16	0.00	41	7.72
17	1.84	42	7.02
18	2.67	43	9.62
19	0.00	44	9.03
20	5.68	45	7.01
21	6.30	46	9.63
22	1.84	47	6.84
23	4.56	48	6.84
24	6.96	49	7.47
25	0.00	50	7.60

Figure 3: Security Times for Figure 1 Arrangement

Painting	Times	Painting	Times
1	0.00	26	0.00
2	0.00	27	0.00
3	0.00	28	0.00
4	0.00	29	0.00
5	2.67	30	4.23
6	0.00	31	0.00
7	3.63	32	5.14
8	0.00	33	0.00
9	3.96	34	6.51
10	4.54	35	0.00
11	0.00	36	0.00
12	0.00	37	7.77
13	3.07	38	7.18
14	0.00	39	8.93
15	1.83	40	8.23
16	0.00	41	8.39
17	5.30	42	6.51
18	2.42	43	8.39
19	4.74	44	8.28
20	5.70	45	6.22
21	0.00	46	8.88
22	0.00	47	7.18
23	0.00	48	0.00
24	3.30	49	7.82
25	0.00	50	6.22

Figure 4: Security Times for Figure 2 Arrangement

Design of Model

We created a program in Unity that replicates a 3D simulation of the parameters in the problem statement, our definition of when a painting is secure, and potential obstructions of camera view due to portable wall placement. Because of these considerations, the program is considered highly comprehensive and accurate for recording security time for all 50 paintings for any wall arrangement. The program accomplishes the task of recording the security times of all fifty paintings in a 15 second cycle for a inputted wall arrangement. Following the execution of the program, we would extract the security times from the program and calculate our two metrics: mean security time and standard deviation of security time. Given that our program can provide security time data to calculate our two metrics for virtually any wall arrangement, we essentially simulated the dimensions of multiple experimental wall arrangements we suspected would produce high mean security time and low deviation of security time. When we constructed test arrangements, we kept in mind the necessity of an aesthetically pleasing and humanly maneuverable arrangement.

In running many test wall arrangements, it became clear that for our definition of painting security, not all paintings can be seen for our tested arrangements of portable walls and permanent walls. Specifically, this led to multiple tests of portable wall arrangements in response to the paintings on the permanent walls receiving 0 security time because of the portable walls blocking the security camera's views. A few test cases we ran in response to paintings along the permanent walls not being seen are shown below:

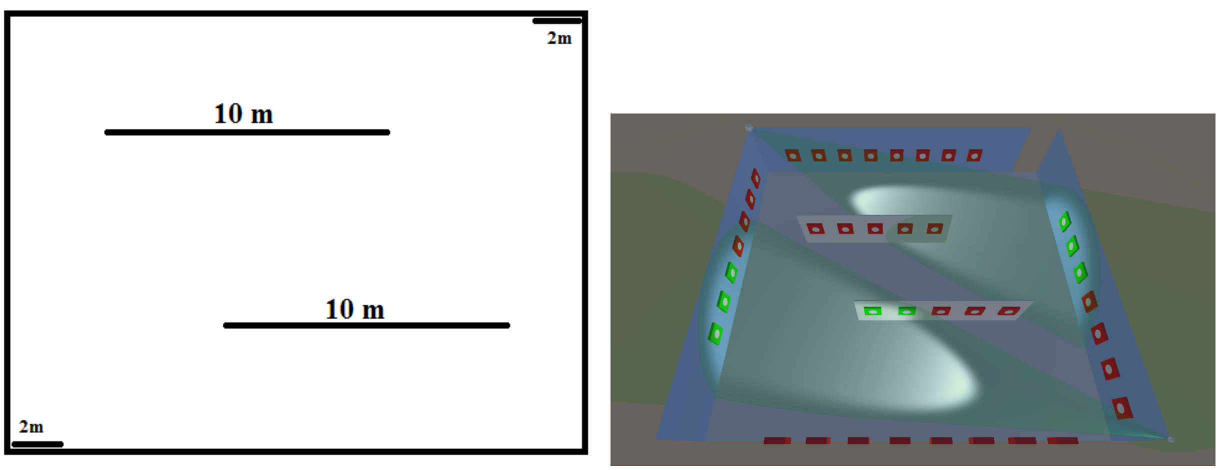


Figure 5: Test 1
Average Time Secure: 3.00 seconds
Standard Deviation: 3.50 seconds

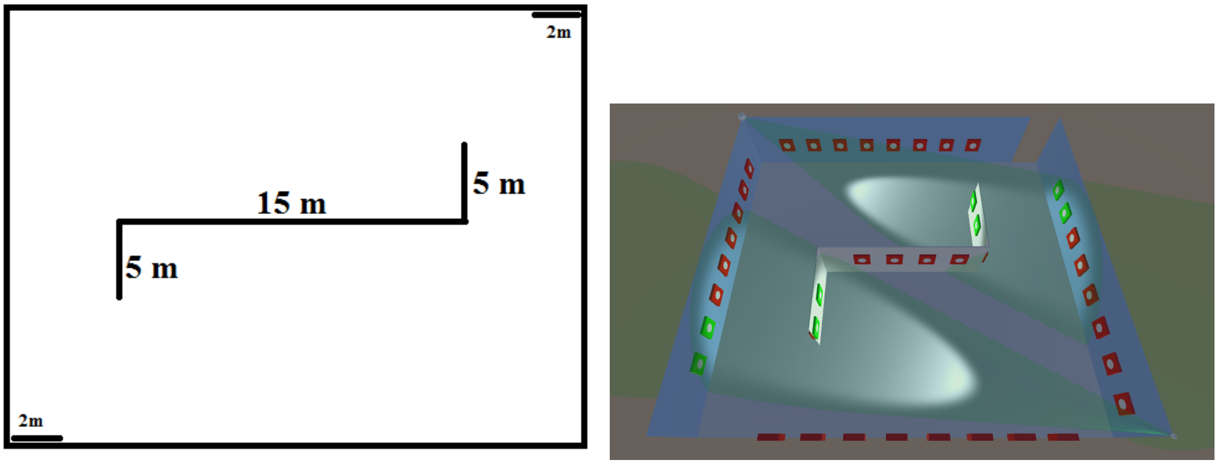


Figure 6: Test 2
Average Time Secure: 3.03 seconds
Standard Deviation: 3.32 seconds

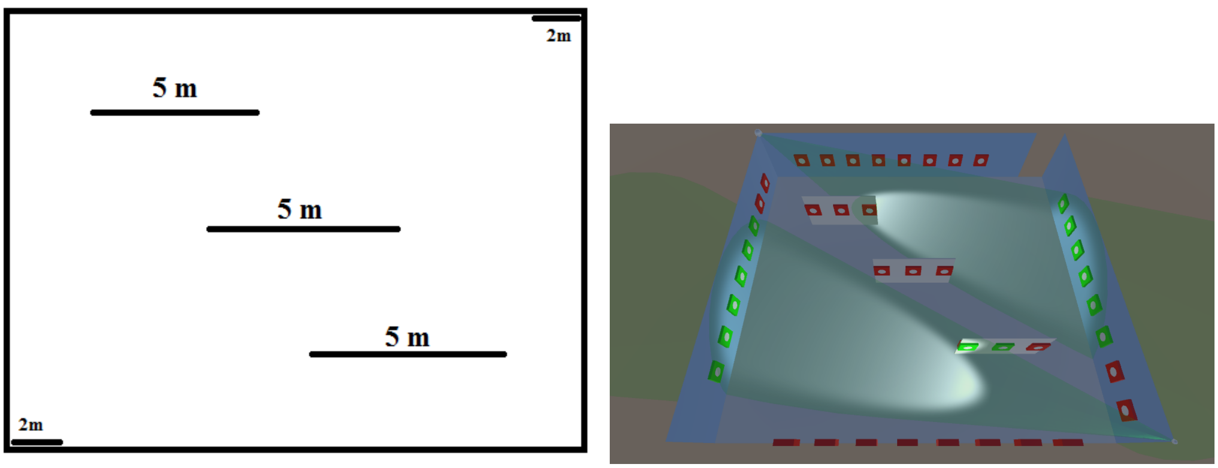


Figure 7: Test 3
Average Time Secure: 3.84 seconds
Standard Deviation: 3.38 seconds

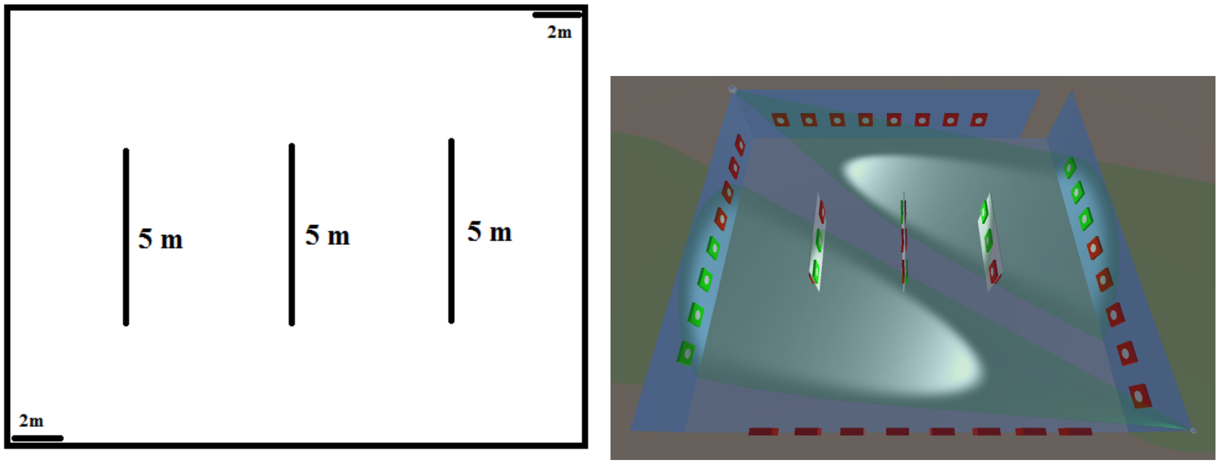


Figure 8: Test 4
Average Time Secure: 4.04 seconds
Standard Deviation: 3.38 seconds

Proposed Solution

Based on the models we created and tested, the configuration with the highest average time watched and lowest standard deviation is solution 1 (Figure 1). This specific arrangement resulted in an average time security of 4.87 seconds with a standard deviation of 3.21 seconds, superior to all of the best test case results we selected to compare against (Tests 1 to 4). Thus the optimal solution we found and are proposing is the wall arrangement found in Figure 1.

Strengths

First of all, our design of the model is quite strong in the sense that we minimized assumptions and made decisions that can easily incorporate more inputs of constants that were not known to us. By defining the location of the center and deciding that it must be seen for a painting to be safe in an instance in time, our model is robust in the sense that paintings may be variable in dimensions. Additionally, the idea of viewing the centers of paintings itself is a strong definition of security because it represents checking the presence of the actual painting, not its frame or general space. Furthermore, the decision to use average security as the main metric and the standard deviation as the secondary metric is highly representative of our defined security because the average reflects the total security time of all fifty paintings for an arrangement, while the standard deviation allows for selection among the best average security times. The strengths of using a comprehensive computer program to find our optimal solution is that the program is very precise and accurate, resulting in extremely low error while completely adhering to our decisions and definitions of security. We ran multiple iterations of the program to determine its accuracy and found that the difference between iterations was minuscule. Finally, the solution we proposed is strong because it the largest average security time and the lowest standard deviation compared to our best proposed test arrangements.

Weaknesses

A primary weakness of our method of determining the optimal model is the unrealistic definition of when a painting is secure. This definition essentially means that our UNITY program only records security time if the center point of the painting is seen, which is not physically accurate and consequently resulted in more paintings with zero security time than a real scenario where the dimensions of the painting are known and would generate non-zero security times for these paintings. However, the flaw of the definition was consistent across all simulations we ran, so we were still able to choose an optimal wall arrangement with confidence. The only error lies in the possibility that when/if actually considering the dimensions of the painting and defining security as seeing any part of the painting, a different, more realistic optimal model may be found. Ultimately, this could not be done for our model because we chose not to limit our model's robustness by making assumptions for the size of the paintings. This results in the data in our solution to be the worst case scenario in all scenarios.

A weakness of our definition of security is rooted in the fact and decision that paintings on permanent walls adjacent to a security camera will not be seen by said camera. However, the camera does still scan the space in front of these paintings, but we cannot quantify that as security simply because of our definition of security. Additionally, the method for finding an optimal solution was essentially case testing based on observations we made on initial passes. Because we were unable to mathematically prove an optimal wall arrangement, the most effective method was for us to generate different configurations through intuitive construction and to test the effectiveness of each configuration, and from those trials, attempt to adjust the portable walls based on the data. In conjunction to this, the number of trials (number of proposed solutions) designed was few in number because although we considered a large number of configurations, many of them were deemed improbable due to the limitations of our model. We selected and tested only the 4 most feasible and most secure models of the 10 or so originally hypothesized.

Team Member Contributions

Every team member worked together step-by-step on the math, logic, and intricacies of the solution.

Sunwoo used his programming expertise to simulate our experimental exhibit configurations as well as the previously designed exhibit configurations. He also contributed to the presentation and edited the paper.

Peter worked out the timing calculations by hand to ensure the accuracy of the computer model, identified key errors and made adjustments to the model, worked on improving assumptions and definitions, and wrote a large portion of the paper.

Jack thought of the definitions and assumptions of the model with the input of the team and focused on contributing to the presentation.

Jessica contributed to the design of the various configurations, writing and editing a large portion of the paper, and creation of the presentation.

Acknowledgements

We would like to thank Dr. Teague for providing guidance through the process. In addition, we would like to thank Ms. Gann for serving as an advisor on the problem and giving assistance when needed.