The University of Hong Kong

SCNC 1111

Tutorial Group X

Optimization of water dispensers’ distribution at HKU

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& Further analysis
& Summary</td><td>Sum up conclusion;
Summarize the Scientific modeling;
Proofread the PowerPoint slides</td><td rowspan="5">Fit the campus map into corresponding grids;
Calculate Ni for every grids;
Collect information of tutorial hours in each classrooms</td><td rowspan="5">Each 20%</td></tr>
<tr><td>Student</td><td>303xx xxxxx</td><td>Data analysis
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Design the excel formula to calculate I from N</td></tr>
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1. Introduction

Inconvenience is often encountered when HKU students try to collect water during class breaks. Our project aims at optimizing the distribution of water dispensers on HKU main campus by eventually suggesting addition and removal based on existing ones. This essay starts with overall assumptions, followed by proposing the ideal locations of water dispensers by mathematical modelling. Finally, we will provide corresponding evaluations and reflections with the help of regression analysis and Scientific Method guideline.

2. Assumptions

The major assumption of our project is that there is a positive correlation between usage rate of water dispensers and number of students taking classes nearby. This enables us to only focus on the number of students and distance factor instead of time-consumingly sampling people's visits to each dispenser.

For simplicity, we have following other assumptions:

1. We did not take canteens and libraries into consideration where students cannot reach between class breaks.
2. A constant and identical attendance rate was assumed for all classes, because the absolute number does not affect the conclusion.
3. Total tutorial hours on Monday could represent the average level of tutorials during weekdays.
4. Classes that did not have official records (e.g. makeup lectures, Cedars activities, tests etc.) had limited effects on nearby water demand.
5. Undergraduate students were the primary source of water demand on campus.
6. The number of students in each classroom was directly proportional to the classroom capacity.
7. Students would collect water from the nearest water dispensers.

3. Procedure

3.1 Data collection

1.Collect data on classroom capacity, denoted by C.

2.Collect data on time and locations of following items:

(i). Lectures from 9:30 to 18:20 on weekdays, which can be found on HKU official website. Time of lectures is denoted by t.

(ii). Tutorials from 9:30 to 18:20 on one Monday. We estimated the total period of time of each classroom by going to each classroom on that morning and collecting data from the LED screens. Time of tutorials on Monday is denoted by t', hence time of tutorials per week is $5t'$.

3.2 Mathematical modelling

Firstly, in order to find out the optimized floor plan for water dispensers, we partitioned the whole campus map into 77x35 grids with around 100m^2 per grid and built a cartesian coordinate, subsequently projecting classrooms on different floors to the xy-plane created.

Secondly, we found the total period of time of all lectures and tutorials in each classroom per week, denoted by T, then $T = \sum(t + 5t')$.

Thirdly, we found the total period of time of undergraduate students all over HKU staying in a grid (x, y)per week, denoted by $N(x, y)$, which is the sum of total time of the corresponding classrooms, then $N(x, y) = \sum C_i \times T_i$.

Fourthly, we defined the distance factor between two grids (x, y) and (x_i, y_j): $D(x_i, y_j) = (|x_i - x| + |y_j - y| + 1)^2$ when $|x_i - x| \leq 10$ and $|y_j - y| \leq 10$; $D(x_i, y_j) = \infty$ when $|x_i - x| > 10$ or $|y_j - y| > 10$.

Lastly, we defined a proper index I that could be used to compare the relative frequency of students passing by each grid per week, denoted by $I(x, y)$:

$$I(x, y) = \frac{\sum C_i \times T_i}{\sum_{i=1,j=1}^{i=77,j=35}(|x_i - x| + |y_j - y| + 1)^2}$$

Since students may fetch water from nearby water dispensers, the actual possibility students may appear in each grid is a weighted number considering both the number of students in the nearby grids and the distance factor. Further the distance, lower the index. Therefore, the index I is inversely proportional to d. Since the decreasing rate of the possibility is quite fast, we will not describe the distance with a linear function. Instead, a quadratic function was used. There are two special situations worth noticing. One is that when two grids are far enough, the possibility students may fetch water from one to another was regarded as zero, consequently the distance defined to be infinity. The other is that the distance of a grid to itself was defined to be 1, giving itself the greatest weight. The final result is shown in the Figure 1.

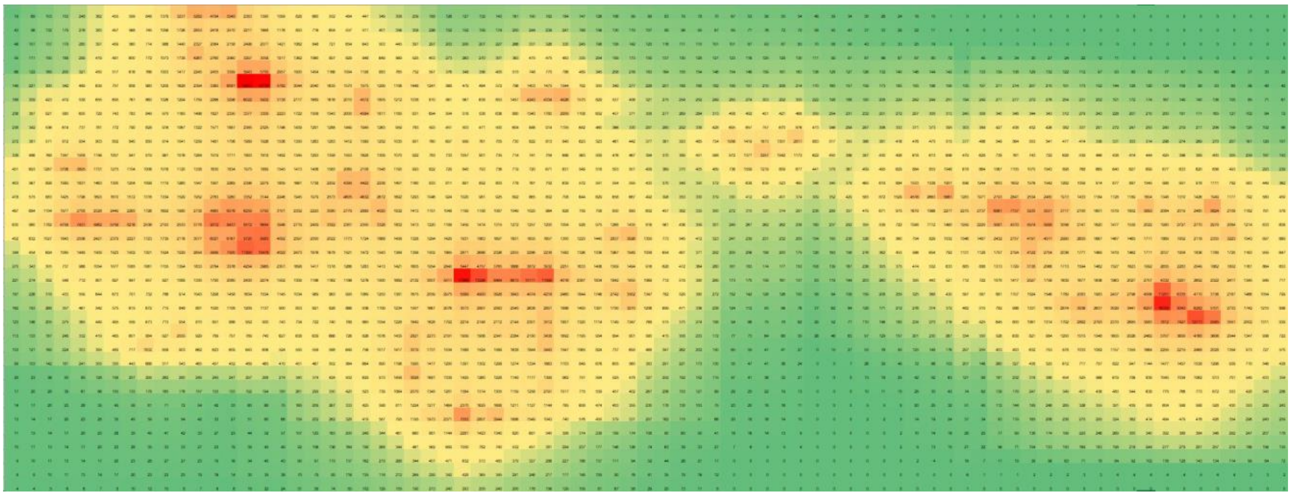

Figure 1 (Heat map with index in each grid)

3.3 Data Analysis

Admittedly, question about why 77x35 partitioning was chosen might arise. To tackle it, we created a method called “Surrounding Elimination”: pick one grid with the highest index I as a place of ideal water dispenser and reset all those grids surrounding that grid to zero in a square fashion.

Use 3x3 surrounding elimination to exemplify: Firstly, we chose the grid with highest index among the 2695 indexes as the first water dispenser’s location which is (15,30). Then, we reset the indexes of the eight grids surrounding the grid (15,30) to zero, as shown in Figure 2, meaning that we would not consider these grids as potential water dispenser’s locations in the following procedure. Next, we chose the grid (28,16) with the highest index among the remaining 2686 indexes as the second water dispenser’s location and similarly reset the indexes of its surrounding eight grids to zero. We repeated the process 20 times, getting a possible distribution map.

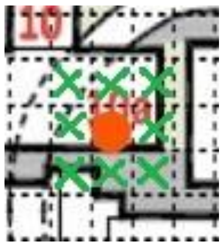

Figure 2 (Eliminating surrounding grids)

We conducted the foregoing method five times with different scales of elimination from 3x3 to 11x11 and finally obtained five possible maps of idealized water dispensers’ distribution, as shown in Figure 3-7.

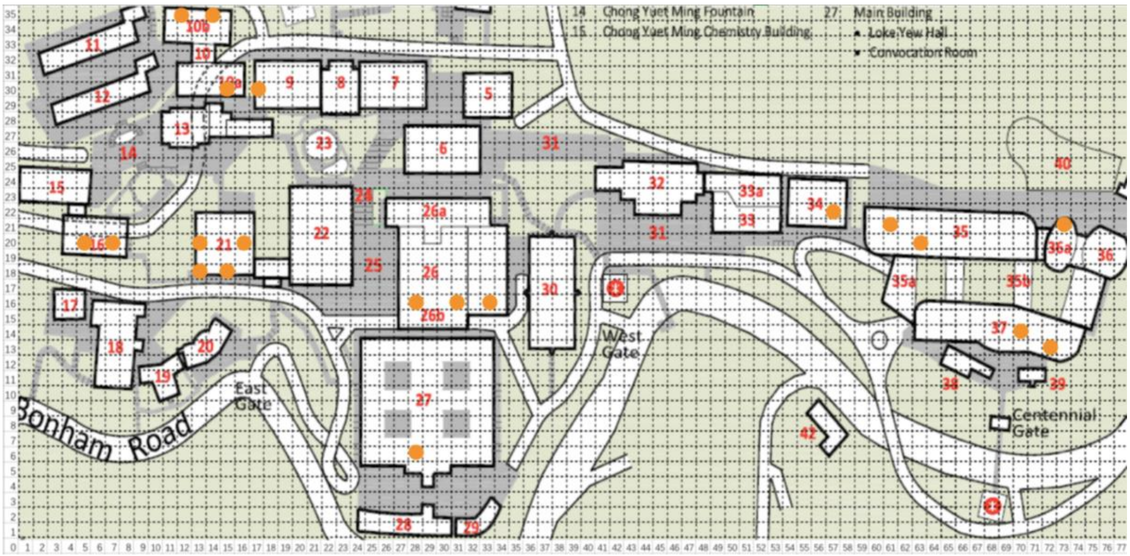

Figure 3 (3x3 Elimination map)

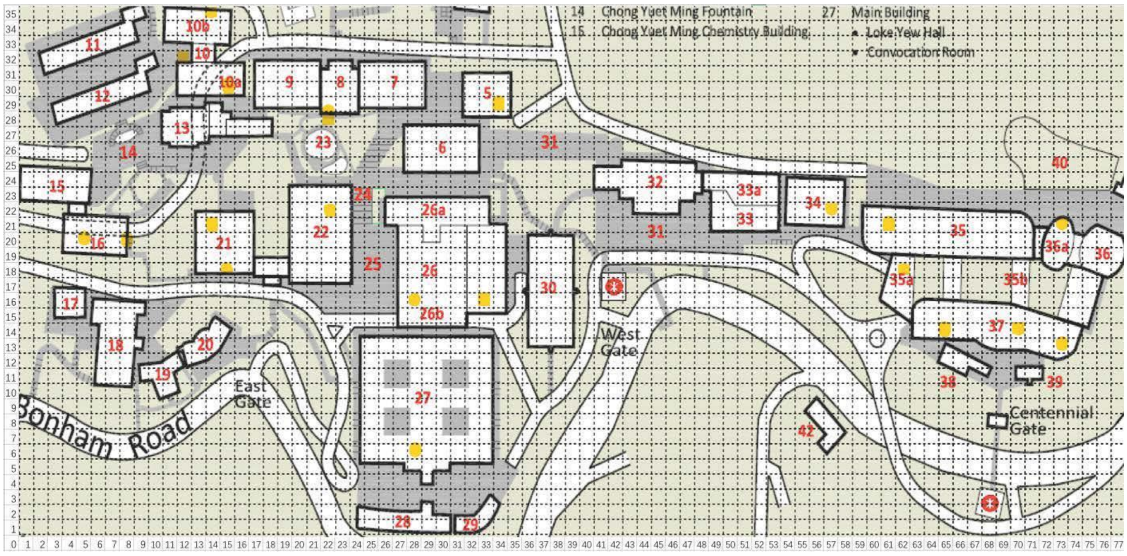

Figure 4 (5x5 Elimination map)

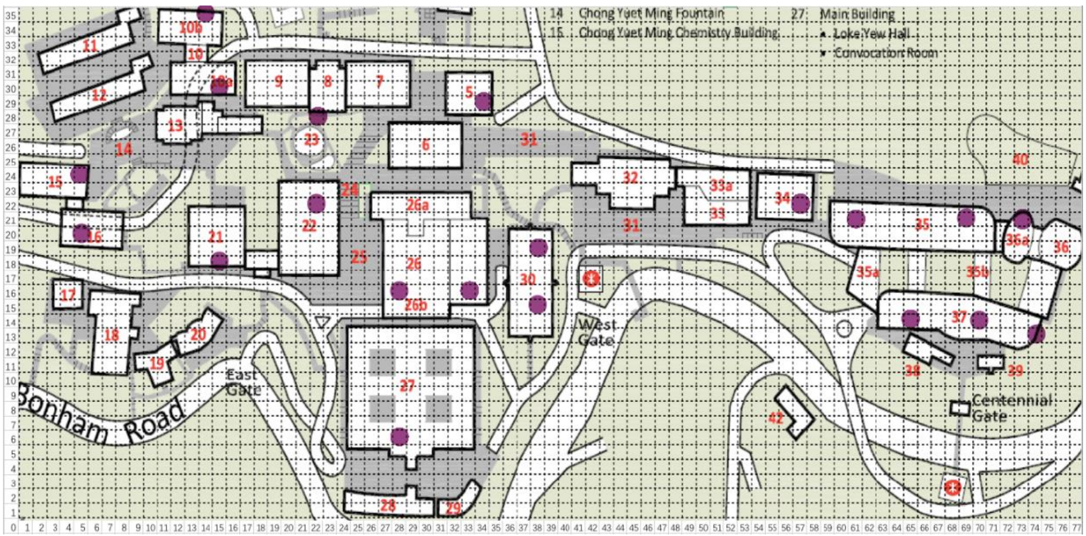

Figure 5 (7x7 Elimination map)

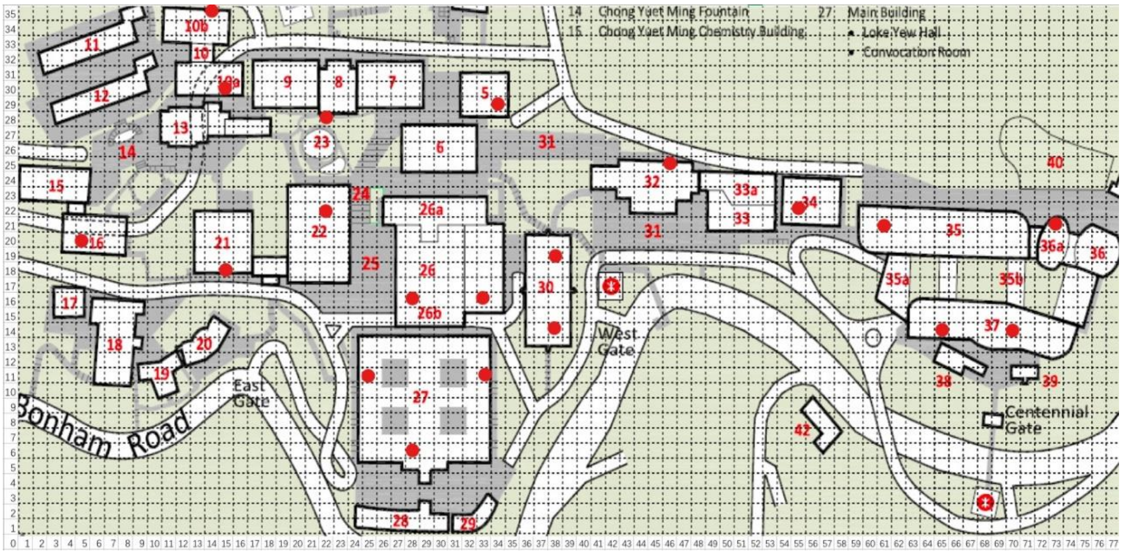

Figure 6 (9x9 Elimination map)

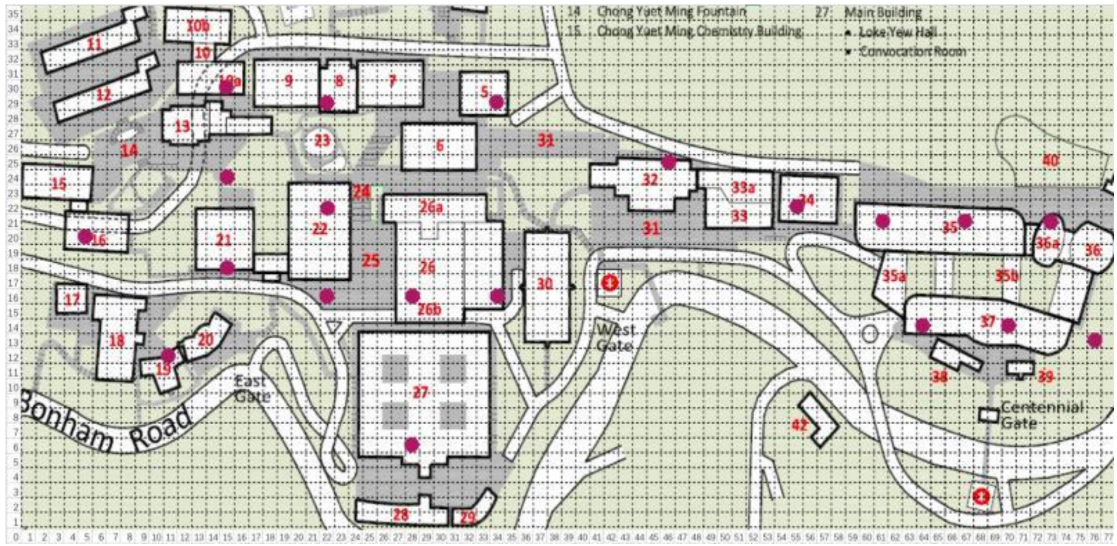

Figure 7 (11x11 Elimination map)

4. Results

4.1 Comparison of different scaling methods

The approximate length of each grid is around 10 meters, hence the possibly smallest distance between two points finally chosen on a 3x3 elimination map is calculated as 20m. Two dispensers would be set too close in this way. The same reason applies to 5x5 and 7x7 map. By contrast, the 9x9 map, with 50m as the minimum distance between two dispensers, is a better option.

Analysis can also be made by relating each building's position in reality. Selected points tend to cluster together while omitting other plausible points with small scaling method, indicating its infeasibility. For 3x3, there are four points in Knowles Building and three in Meng Wah Complex, leaving few points in other areas. Conversely, there are no points falling into Kadoorie Biological Sciences Building for both 3x3 and 5x5. As for the 11x11 map, points fall outside campus, contradicting to reality.

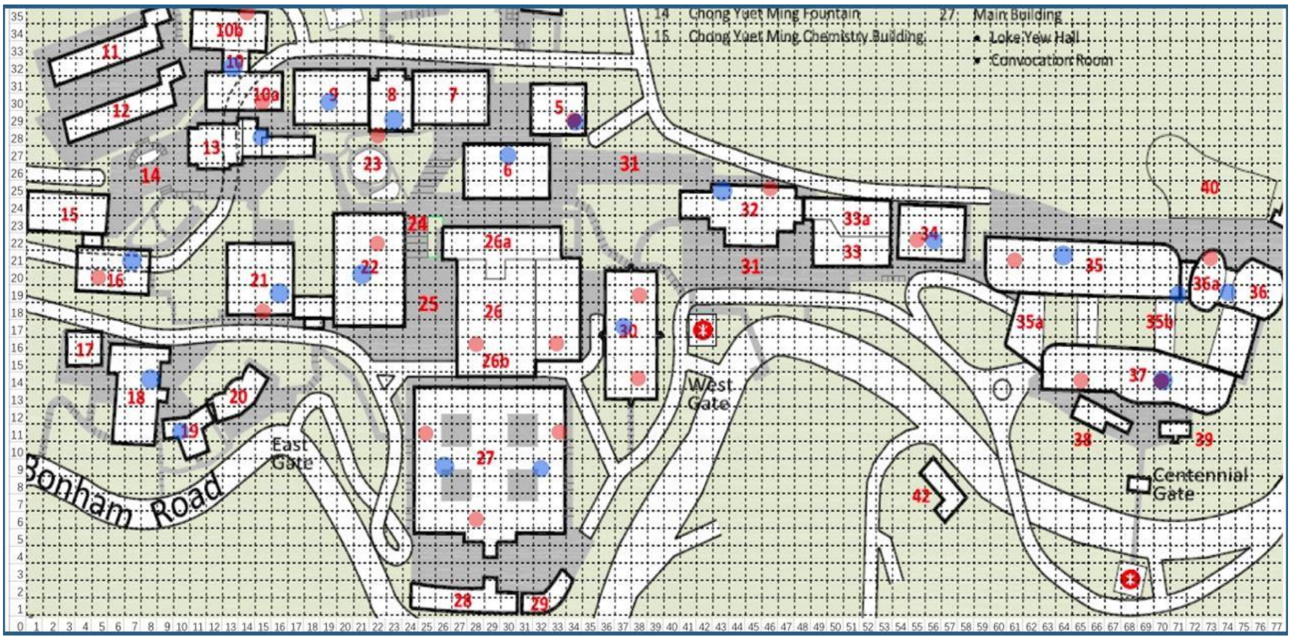

Figure 8 (Comparison between 9x9 Elimination map and distribution in reality)

4.2 Suggestions on addition or removal

We proposed plausible addition and removal of the existing water dispensers based on the 9×9 graph. As shown in Figure 8, noticed that there are approximately overlapped blue dots and orange dots in James Hsioung Lee Science Building and Run Run Shaw Tower, which demonstrates a match between the existing distribution and our prediction. However, other dots failed to behave satisfactorily. Isolated orange dots suggest the need for addition especially around Main Library Extension. Similarly, by looking at the independent blue dots we determined to suggest removing dispensers in Swire Building, Hui Oi Chow Science Building and Runme Shaw Building, whereas T.T. Tsui Building should be retained because 3×3, 5×5, 7×7 graphs do not indicate a demand there in spite of the opposite in 9×9, 11×11 graphs. Moreover, the predicted points in 9×9 graph were plotted in a 3D graph (Figure 9) using MATLAB to provide an intuitive sense: points selected turned out to be situated quite evenly in each peak rather than centralized in a few particularly high peaks.

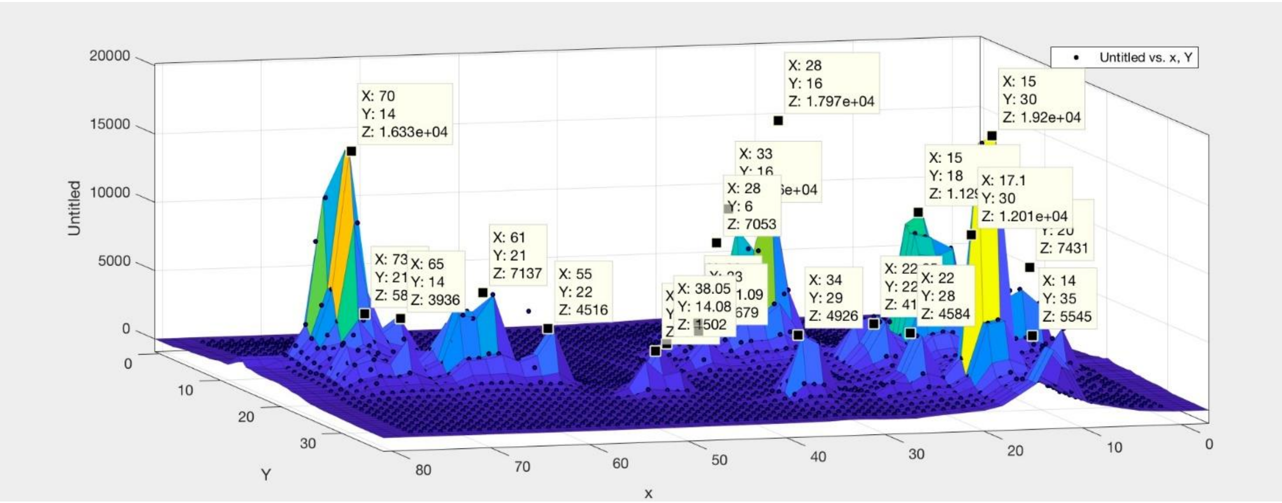

Figure 9 (3D graph)

5.Evaluation

5.1 Regression Analysis

To make our scientific research more precise, we did evaluations of our procedures and mathematical modelling. Firstly, it might be doubtful that the correlation between the index and the usage rate of water dispensers is positively linearly correlated in reality. We conducted a regression analysis to test our major assumption. We made a sample survey on the usage rate of ten major water dispensers. We separated the usage rate into 5 degrees with 5 for daily usage and 1 for seldom usage. After collecting data, we got average values of the degree for each water dispensers and ranked them in descending order. Then we found all corresponding index I for each water dispenser selected and also listed them in descending order. Since these two variables are non-factor variables, we chose Spearman correlation to do regression analysis, as shown in Figure 10. The product moment correlation coefficient is 0.782, which is close to 1, showing that the relation between the results of our mathematical model and the sample is solid. This proves the major assumption trustworthy.

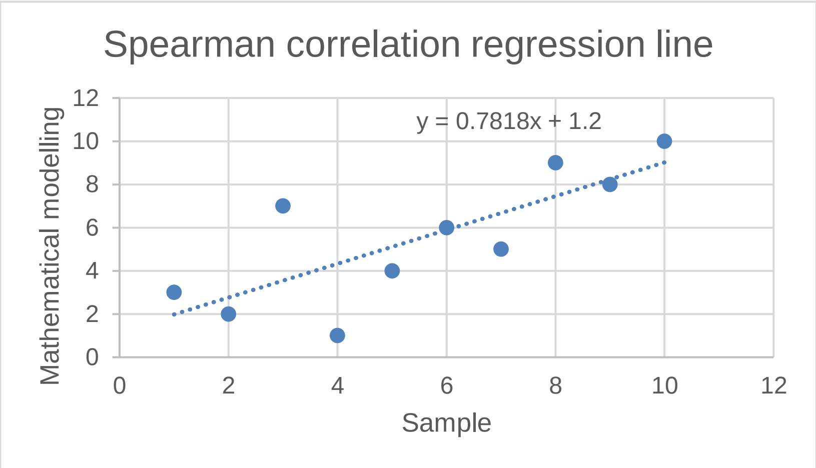

Figure 10 (Regression line)

5.2 Other Evaluations

Apart from the above regression analysis, there is some further evaluation worth discussing.

Firstly, only undergraduates were taken into consideration, which seems to make the outcomes less reliable. Nonetheless, the importance of preliminary reasoning and mathematical model outweighs the mechanical data inclusion. In other words, this method could be applied to more groups of people given required information and modification.

Secondly, we used capacity of each classroom to represent the actual number of students attending classes and that was why we assumed the attendance rate to be constant and identical in the first place. Admittedly, some counterexamples could be found, for instance, KKLG 109, a large-size classroom, is currently used for small-sized tutorials. One way to be more precise is to sample and model the relationship between classroom capacities and attendance rates, subsequently adding it to the model. But apparently it would cost much time and energy and was thus simplified here.

Thirdly, there is no denying that data collection on tutorials is not completely in line with reality because weekly data are obtained by multiplying Monday's data by five. Yet, this issue could be solved if a timetable of tutorials similar to the lecture one is accessible. Although we tried to contact Exam Unit and Cedars, no helpful information was received. Hence, we had to use estimation due to resource insufficiency and time constraints.

Lastly, a fire evacuation picture shown in Figure 11 was used to partition classrooms into grids. It is an example of classrooms that might occupy more than one grid given our partitioning, roughly divided into fractions accordingly. Intuitively we suggested the accuracy for specific locations could be improved if we partitioned the map into smaller grids.

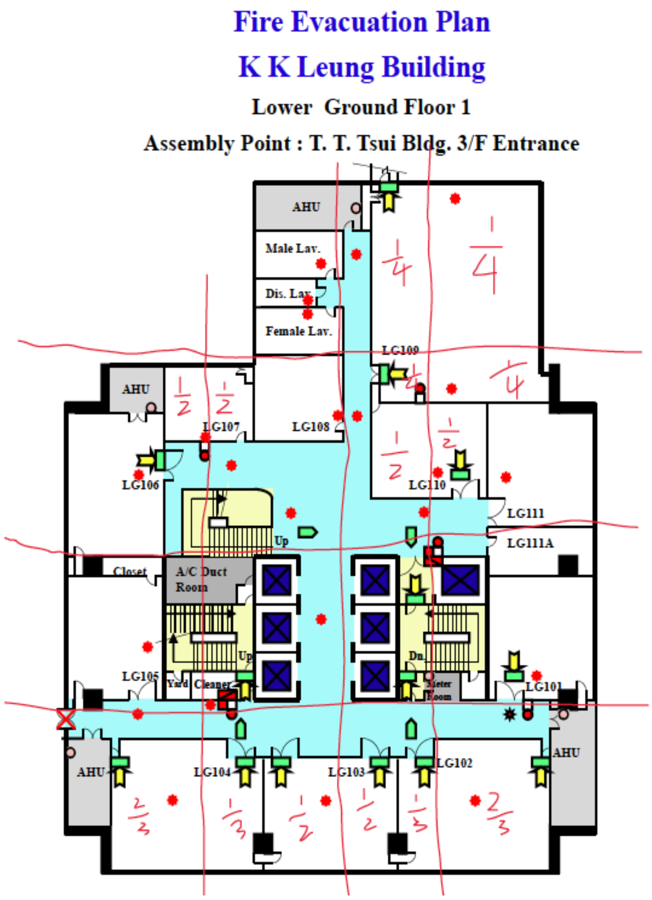

Figure 11 (Partition of KKL map)

6. Summary of Scientific Method

Eventually, the guiding scientific method could be manifested via our project. First and foremost, we observed that the more students passing by a water dispenser, the higher the usage rate. Then we hypothesized that the foregoing two have a positive correlation. Moreover, we conducted the mathematical modelling, obtaining the 3D graphs and the 9×9 graph as our prediction. In addition, we designed the survey and carried out regression analysis, which served as an experiment step. Finally, we confirmed our hypothesis and further proposed plausible modification.

7. Conclusion

All in all, to find the optimized distribution of water dispensers at HKU, we used mathematical modelling and “Surrounding Elimination” to analyze the collected data and obtained a few potential floor maps. After comparing maps with different scaling methods, suggestions were given on the addition and removal of existing water dispenser distributions. Moreover, we conducted a survey and regression analysis to test the validity of our assumptions. Throughout the whole process, we thrived to apply scientific knowledge, enhancing our analytic skills. Although this project may be of limited practical meanings to the real-life problem, reflections and inspirations we gained outweigh the result itself.

8. References

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