ISDN 3002

TrolFree Proposal

Group CS

Star, Cecil

THE HONG KONG UNIVERSITY OF SCIENCE AND TECHNOLOGY

Table of Content

Situation

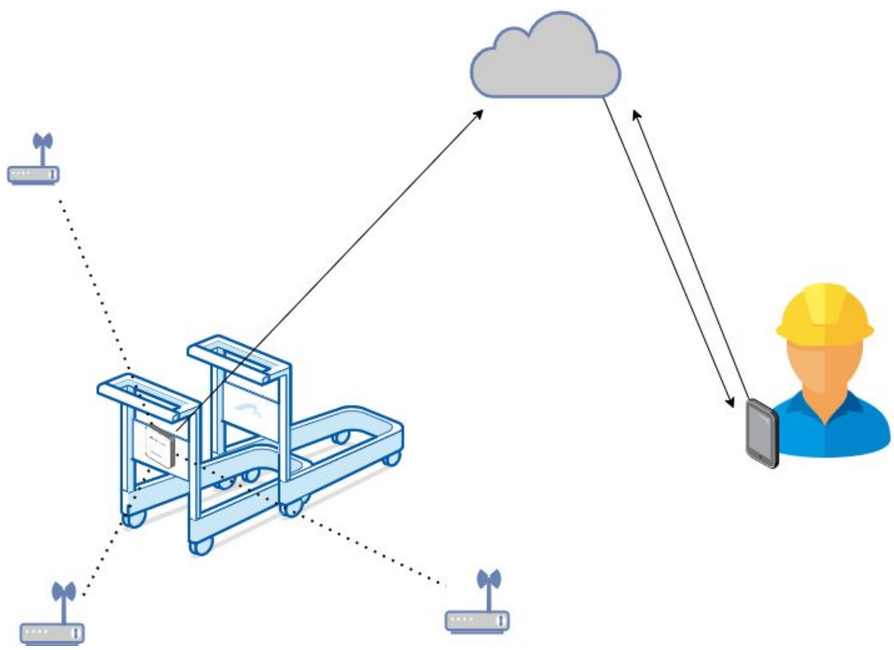
After our literature review and investigation, we found out that simply implementing the locating system could not provide enough benefits or return of money to the airport. Therefore, we need to add more functions on top of the locating system, to fully utilize the feature. Hence, we slightly changed the problem statement given by the airport to make a locating system of trolleys that can also plan the route for the workers to improve efficiency and safety.

Proposed Solution

According to our desk research, although the BLE is currently the most widely used solution, we reckon that its certain disadvantages are critical to its application in the airport scenario. For example, to achieve low power, the beacons could only be sensed within a short-range. Besides, replacing batteries for beacons also requires a lot of manpower and money. Most importantly, if we use BLE, only the chip knows its location, and it still needs to connect to Wi-Fi to send its location to the collector somehow.

Therefore, we proposed to use the existing Wi-Fi network in the airport, which could save a lot of expenditure on infrastructure in first hand. Secondly, because each Wi-Fi router is connected to a power source already, it could transmit more power than BLE to establish the connection at a further distance. Lastly, by using Wi-Fi only, we could save money on the modules installed on each trolley. We proposed to let the chip connect to the Wi-Fi network all the time as long as it is moving, to achieve real-time monitoring. As a result, the location of the trolleys could be calculated on the cloud as long as it is connected to Wi-Fi and no additional power consumption on the chip besides maintaining connection. A big advantage of this solution is that the Wi-Fi coverage in the airport is already very wide, including passengers and staff areas. Even outdoor areas like parking lots or bus stations are also covered. Using this solution, we could achieve at most 2m of accuracy according to the research.

Besides, we would like to include a power generation mechanism on the trolley along with the chip and battery, to achieve no replacement of the battery. At the same time, this system could also tell whether or not the trolley is moving.



Simulation

To quickly quantify and verify cost savings and efficiency boost, a simulator is proposed to provide a comprehensive evaluation of different task assignment strategies. The simulator will be decoupled into two parts:

1. Backend: Mathematical Model describing the interaction between passengers, workers, and trolleys.

2. Frontend: Visualization: Visualize what is going on based on the output of the model

The simulation will evaluate the performance based on the criteria listed below.

Miss rate	Energy spent	Average time for workers to return trolleys
How many times passengers want to use trolleys but cannot find one	Defined to be the root mean square(RMS) of total distance traveled by workers	Average time for workers to return trolleys

Because passengers will come in random time and trolleys will also scatter randomly after being used, the Monte Carlo method will be used to calculate the minimum labor required and minimum trolley required up to a certain probability.

Steps Involved

1. Test out the accuracy and power consumption of BLE and Wi-Fi location systems.
2. Build up a testing field with a floor plan and access point location.
3. Decide objective criteria quantifying the energy spent or time taken by each worker to reach and collect a pre-allocated trolley.
4. Build up a simulator to simulate the minimal labor needed, minimal trolley needed, and cost savings compared to the system without a task assignment system.
5. Choose and verify different strategies we use for the task assignment system.
6. Implement the whole system in the production environment

Benefits

TrolFree will provide an accurate, efficient, and one-stop solution for trolley tracking and task assignment. It is an integrated system leveraging the massive data available on the cloud to boost up the efficiency of every part of the system. In terms of labor savings, by using TrolFree, every worker will follow a predefined strategy and the minimal labor needed can be calculated or estimated in a probabilistic manner (The relative distance between trolleys and workers is random and it cannot be guaranteed that a fixed number of workers will always be enough for any situation). In terms of cost savings, TrolFree can significantly reduce the total trolleys deployed for normal operation by recycling and reused more efficiently, and in turn, the operational cost and maintenance cost or even replacement cost will be reduced dramatically.

Potential Obstacles

The accuracy may be affected by many factors. So even if our testing result is good in our test field, it may not work well in the airport. The power efficiency of the generator is unknown right now, so the trolley may not achieve power balance. The task assignment problem is inherently NP-hard and there is no absolute optimal solution currently. The scheduling suffers from high uncertainty, we don't know when passengers will come, where trolleys will be after being used and what the best probabilistic distributions are that can best describe those random events. It is theoretically possible to approximate those distributions by keeping monitoring the behavior of passengers and location of used trolleys for a long enough time, but it is not feasible in terms of conducting those monitoring in the airport. We have to use gaussian distribution to model the possible location of the trolley and Poisson distribution to model the behavior of passengers, and the result will more or less deviate from the real situation.

Conclusion

Overall, although there are some uncertainties at this stage, our solution is still very plausible to achieve all the tasks we designed. The price of modification and infrastructure is also very low for actual deployment. The central system also has great capability in the future for further development.

Q&A

- **Q: What is the modification cost of the power generated trolley?**

A: According to the preliminary research, the cost could be controlled within 70 HKD. This includes an ESP8266 chip, two power generator, and a battery.

- **Q: If the trolley does not move or no power, no signal will be sent back to the backend server? How can the trolley be monitored?**

A: If the trolley does not move for a very long time, the chip will go into hibernate mode. However, the system would know that it is in hibernation, and it will record its last location and also notify the trolley collectors. If the trolley is out of power, it will be appeared to be offline suddenly. Because the system knows its last location, it will alert the collectors to go there immediately. Because the chip connects to Wi-Fi at least in usage, the time of operation and the length of its travel will be recorded. A heat map could also be generated by the system.

- **Q: Is the location identification only based on WIFI location identifying function? How accurate to identify them? What is the frequency of location update?**

A: Yes, our solution is only based on Wi-Fi. As our desk research, the accuracy could be around 2m. Because the chip will maintain the connection of Wi-Fi, the frequency could be nearly real time.

- **Q: How to monitor the trolley tracker at outdoor area?**

A: We will also use Wi-Fi in the outdoor area because it is also covered by Wi-Fi.

- **Q: How many trolley workers are required in your proposal to collect the scattered trolleys?**

A: We might not be able to provide specific statistics at this time, since it also depends on the number of trolleys, passengers, and space. But we will try to answer this question once we have the simulator and run our solution in it.

Development Budget Proposal

Hardware:

Name	Quantity	Price
Wi-Fi routers	25	200
ESP32	30	30
iBeacon	25	100
Batteries	25	50
Power generator	20	10

Software:

Server	1	5000
Jlink	2	500

Total: 16,000 HKD