MEASURING TRUCK SERVICE TIMES BY GPS

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How well do container terminals support truck operations? This is an important question for logistics hubs such as Panama, with five distinct container ports and a goal of being considered, functionally, a single port-of-call. Achieving this goal requires, among other things, making the movement of containers among ports fast and seamless.

Truck operations are an important part of the land-side activities of any container port. A truck will typically bring a container to the terminal. After it enters the gate, the truck will visit various regions of the terminal ("yards") whose purpose and sequence depend on the type of container delivered. For example, an empty container will typically be dropped off in the appropriate yard depending on whether the container is dry or refrigerated. A full container for export may have to stop at a customs area for inspection and processing before being dropped off at the appropriate yard.

After dropping a container, a truck will typically pick up a container to leave the terminal. The container may be empty or full, dry or refrigerated, and so retrieved from different yards of the terminal. Subsequently, the truck may have to take the container to customs for inspection and processing if it is for import; or it may take the container to another terminal for transshipment. Again, the sequence of services depends on the container type.

Thus each truck will enter by a gate, visit some sequence of locations in the terminal, and finally leave by a gate.

Container terminals typically judge the efficiency of truck operations by the gate-to-gate "turn time". But this is a coarse measurement, as it lumps all the different activities together, including time spent driving, queueing, or receiving service. It is used because it is easy to measure, because terminals typically require entry and exit from controlled gates and so can record arrivals and departures and later match them up. However, this fails to capture times in the various yards. It is technically possible to instrument cranes, etc. to measure service times, but such measurements would fail to capture the experience of the truck and container, which may have had to queue for service. It would also fail to capture times when the truck might have had to stop for traffic or congestion when traveling within the terminal.

We show how to measure — unobtrusively — all these activities within the terminal. Moreover, our method requires no special hardware and imposes no reporting requirements on services within the terminal. And all this is done on data that is already collected.

Most trucks are now equipped with GPS, but this is typically used to monitor for security and compliance. But this data contains much more information than appears on the surface. Each GPS reading contains at least values for latitude, longitude, and time. From this information, it is straightforward to estimate speed and heading (if not provided by the GPS device). Of course none of this is perfectly accurate and so we must algorithmically interpret the readings and relate them to the container terminal under study.

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The challenge is to interpret a stream of GPS readings in the context of container terminal operations (Figure 1). The basic steps of this interpretation are.

1. Draw geofences around key yards of the terminal (wherever trucks may stop). List the 20—40 typical sequences in which services would be obtained.
2. From GPS readings, identify stops (consecutive readings with very low speed and heading of null).
3. Partition the sequence of GPS stops by arrival at or departure from an entry gate to a port. Retain the sequence of stops within a port and call it a “trip”.
4. For each trip, identify the sequence of services that is the best match to locations and durations of stop.
5. For each trip classify the best match as plausible or not.

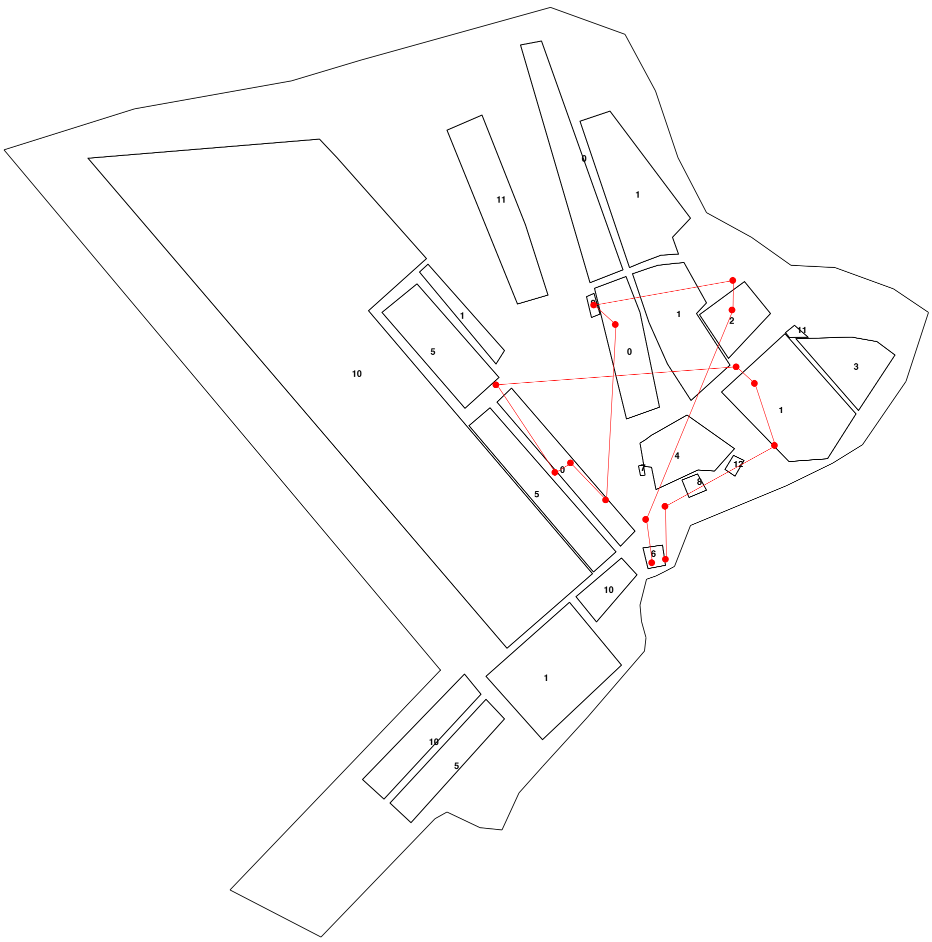

FIGURE 1: HOW TO INTERPRET A SEQUENCE OF STOPS?

FIND THE SEQUENCE OF SERVICES THAT BEST MATCHES THE GPS

Step 2 is the heart of the process. It is a challenge because GPS is not perfectly accurate. Under ideal conditions, 50% of the readings may be farther than 3 meters from the actual position — but a container yard is far from ideal. The stacks of metal containers attenuate and deflect the signal from GPS satellites, which degrades the accuracy of the readings. As a result, a GPS stop may appear 20 meters or more away from where the vehicle actually stopped. This inaccuracy is enough to make the vehicle appear to be across the street and in another yard, which defeats naive interpretation. However, we do not expect the GPS to be “too far” wrong and this enables determination of the "most likely path".

The key idea is to make use of the information inherent in the sequence of expected services. The likelihood that a particular sequence of GPS stops matches a particular sequence of services can be evaluated methodically by dynamic programming. This enables us to efficiently score the likelihood of the match. After we have scored each of the standard sequences of terminal services, we select the one with the best score as the most likely.

IDENTIFY WHICH MATCHES ARE CONVINCING

There remains a final step of judging whether the most likely sequences of terminal services are, in fact, convincing. This is a problem because the truck might have entered the port for reasons other than to drop off or pick up containers. If the cost of the best match is unusually high, we are right to doubt that the truck swapped containers; it may have been dispatched on other business altogether. The problem then is to classify each of the matches as plausible or implausible -- in other words, a classic problem of classification, and we treated it as such.

We trained a tree-based classifier on hundreds of trips that had been reviewed by a person who judged the best match as either plausible or implausible. The resulting classification tree clearly indicated a simple, effective test that filtered out more than half of the implausible matches. The remaining identifications seemed to a trained eye at least probably correct and most were convincing.

RESULTS

The analysis described above allows us to report on the truck turn-times; but, in addition, details such as total driving time within the terminal, total stop times within each service area, and total stop time within the terminal but outside service areas. In addition, we can report times to drop off each type of container and times to pick up each type. We can also see how these times vary by time of day or day of the week, or in relation to the ship schedules. This level of detail can enable a port to focus efforts to improve processes where they will do the most good.

More detail on the algorithms involved can be found in Bartholdi et al. (2017).

REFERENCES

Bartholdi, J. J. III, Lasso, A., Ratliff, H. D., Oliver, Y. (2017). "Measuring port productivity by GPS", _Maritime Economics and Logistics_, https://doi.org/10.1057/s41278-017-0097-1