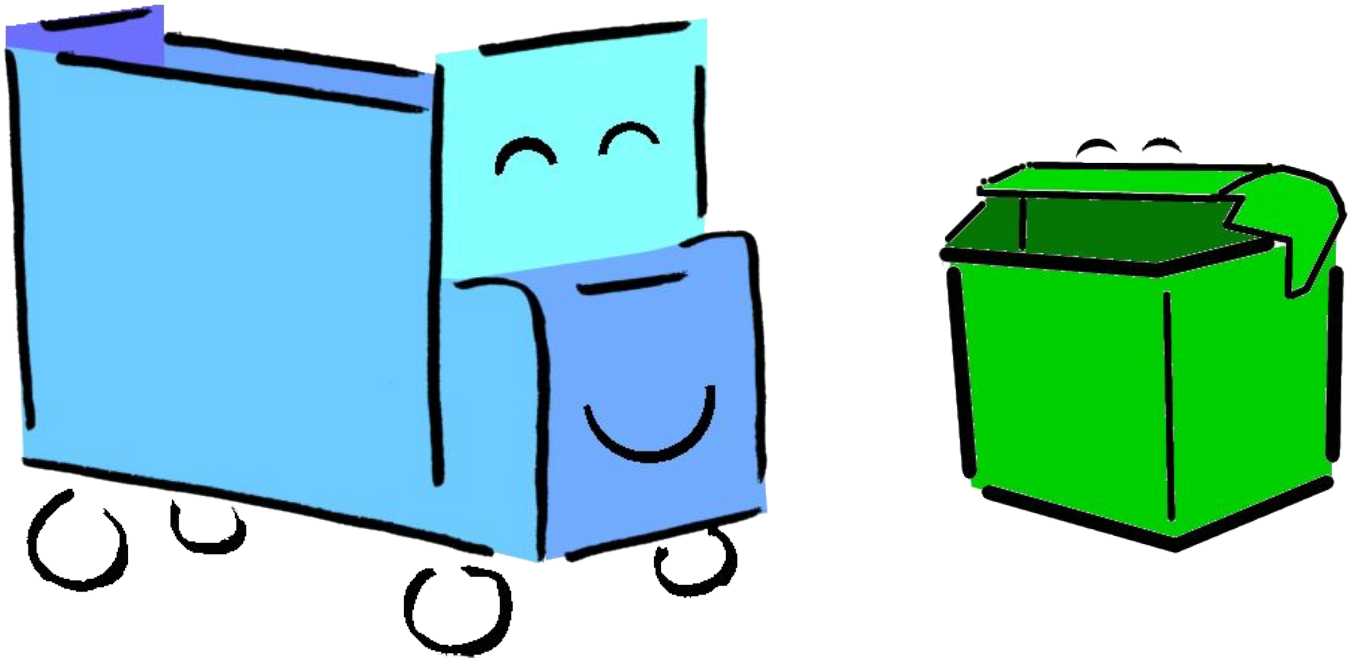


Garbage Collection with FOSS4G

Vicky Vergara / Daniel Kastl

This Old Earth

"This old earth
Needs our help
To stay fresh and clean and green
With a pick it up; pitch it in; and throw it in the can--
This old earth needs a helping hand!"

Celia Virginia Vergara Castillo

- Economist, Computer Scientist
- Work in Georepublic
- pgRouting developer
- Living in Mexico
- Known as Vicky

Please, enjoy FOSS4G Bonn!!!

The Problem

Sustainable City → Waste output → Garbage Collection

Using FOSS4G tools

Montevideo City

Backend Developers

Vicky Vergara

Steve Woodbridge

pgRouting developers

Sustainable City

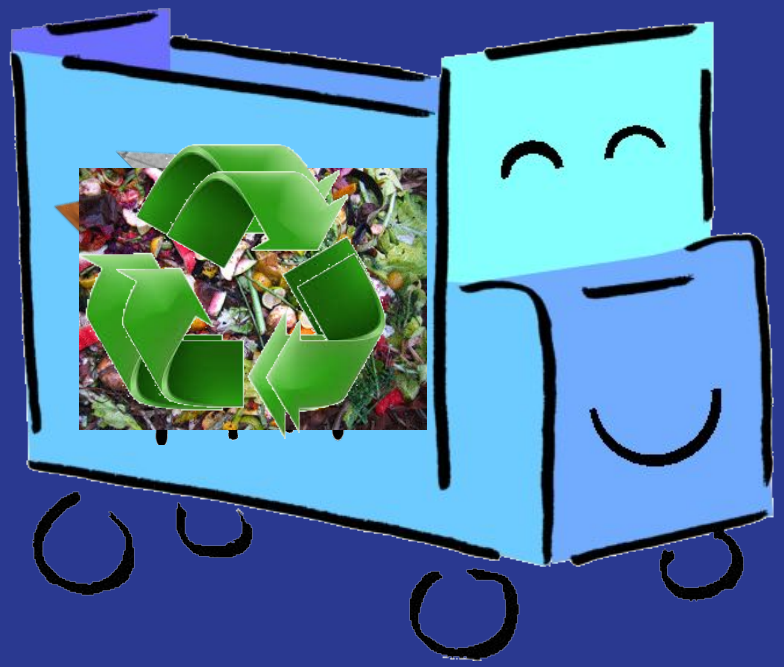
Consideration of environmental impact

Minimization of

- Required inputs of energy
- Waste output
- Pollution

Waste Output

- Household waste
- Industry waste
- Dry waste
- Wet waste (organic)
- Recyclable waste



Garbage Collection

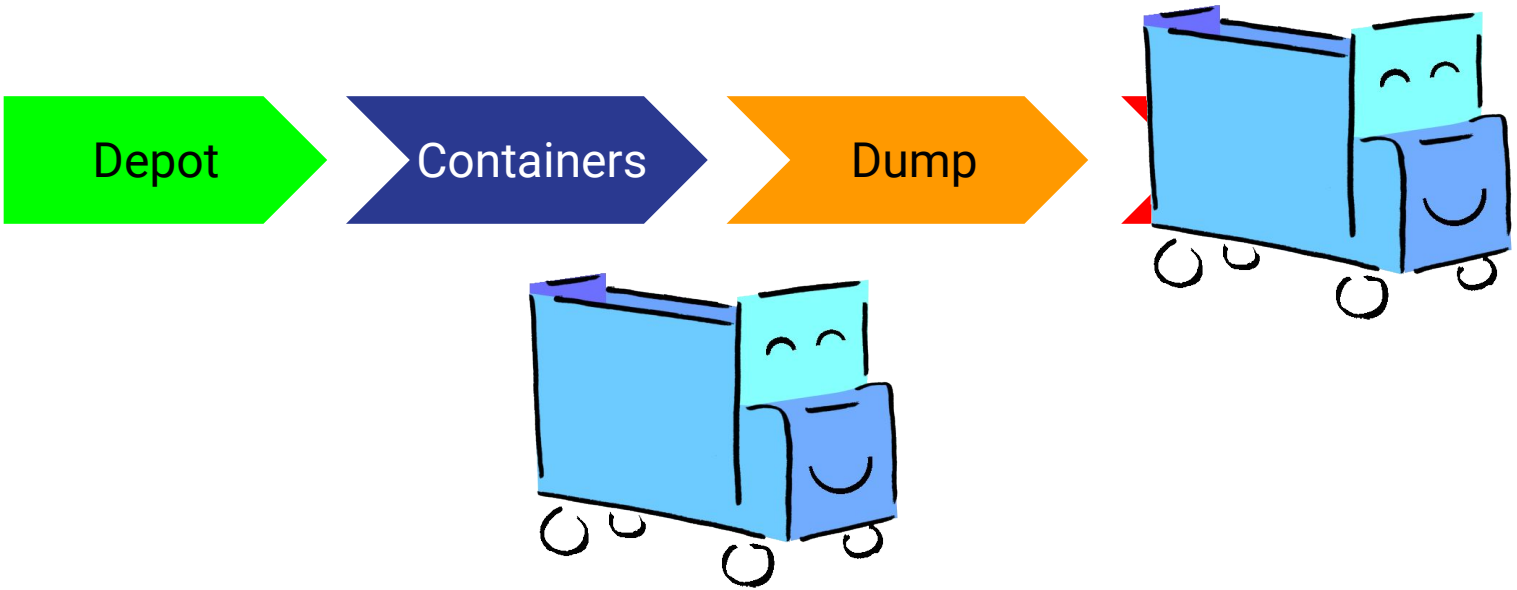
VRP

Vehicle

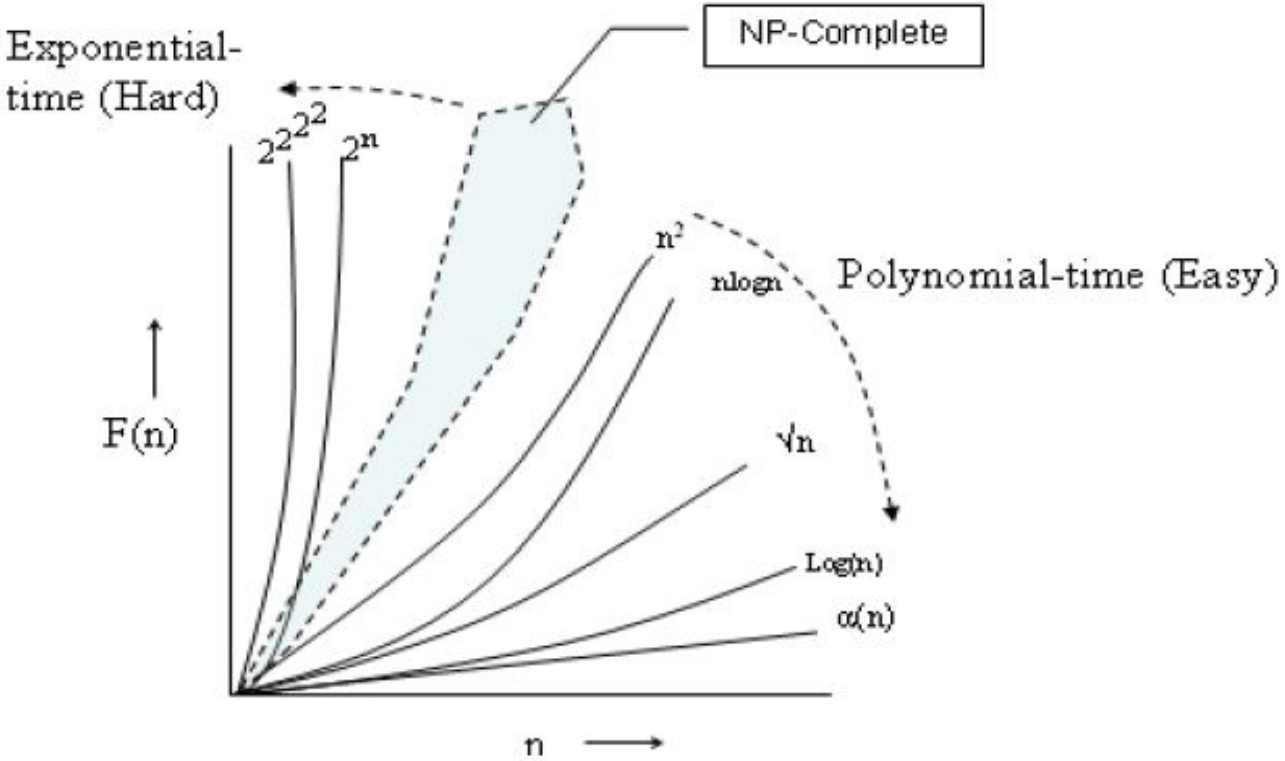
Routing

Problem

VRP simple Truck’s trip



NP Problem:


NP-Complete
Exponential-time (Hard)
$2^{2^{2^2}}$
2^n
n^2
nlogn
Polynomial-time (Easy)
F(n)
√n
Log(n)
α(n)
n

VRP: variants

CVRP

C = capacity

The vehicles have limited carrying capacity.

VRPMT

M = Multiple T = trips

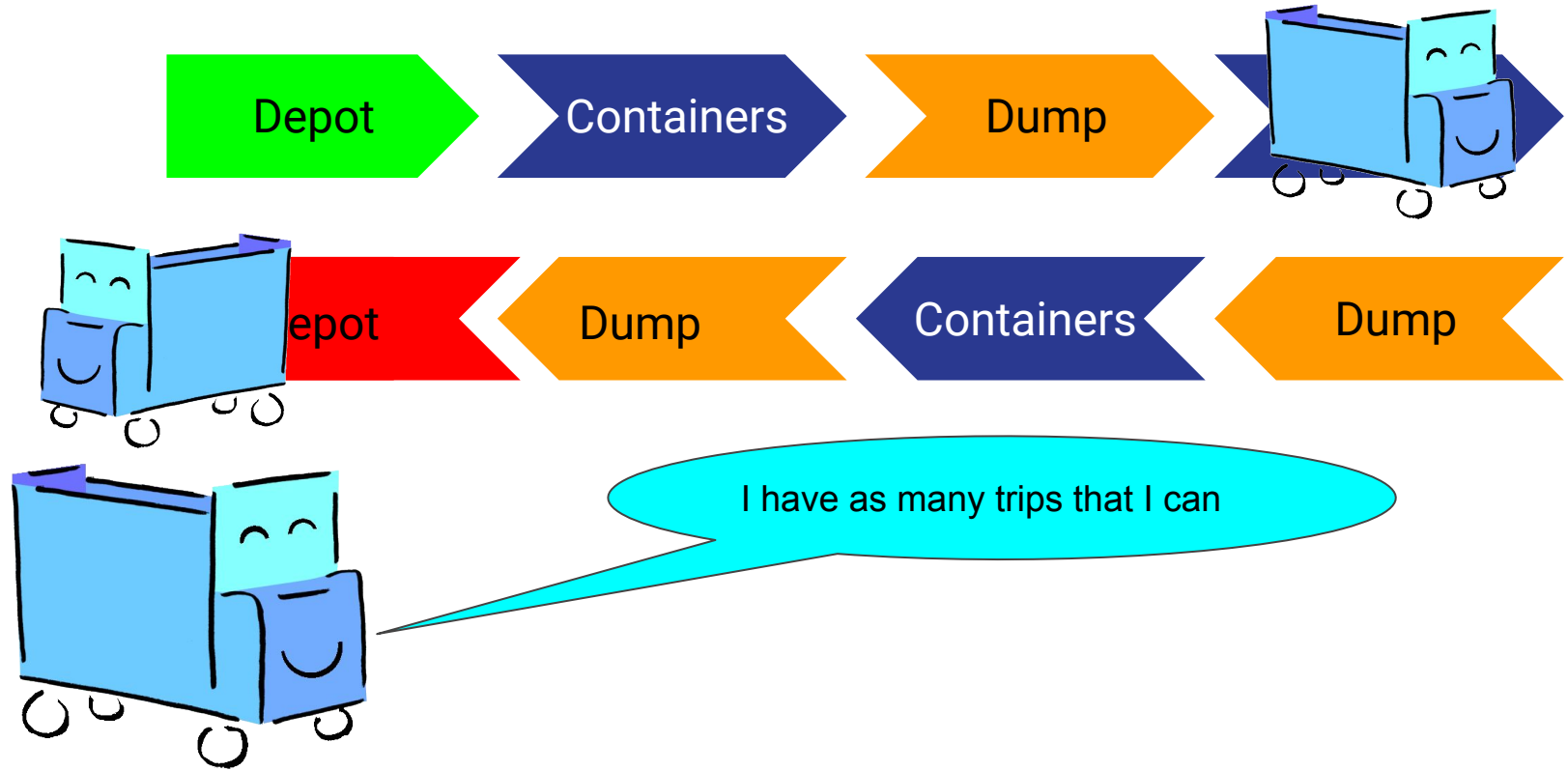
The vehicles can do more than one route.

VRPTW

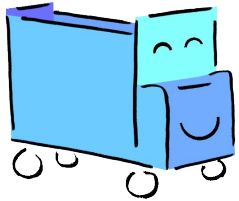
T = time W = windows

The locations have time windows within which visits must be made.

Garbage Collection Truck Trip



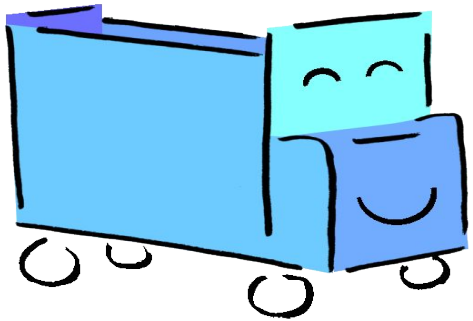
Truck with different capacity



Depot → Containers → Dump

Dump → Containers

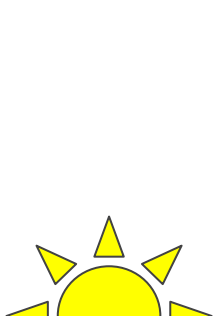
Containers → Dump → Depot

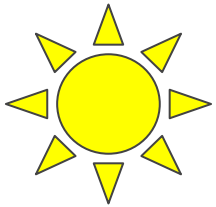


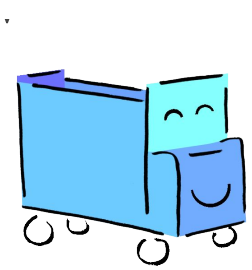
Depot → Containers → Dump

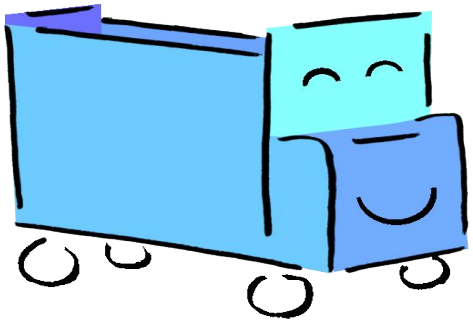
Depot ← Dump ← Containers

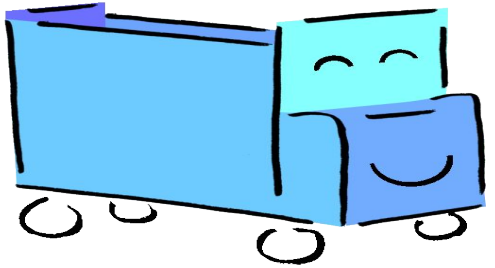
Truck Drivers With Different Schedules











VRP variants on Garbage collection

Is a CVRP ?

YES!!!

The vehicles have limited carrying capacity.

Is a VRPMT?

YES!!!

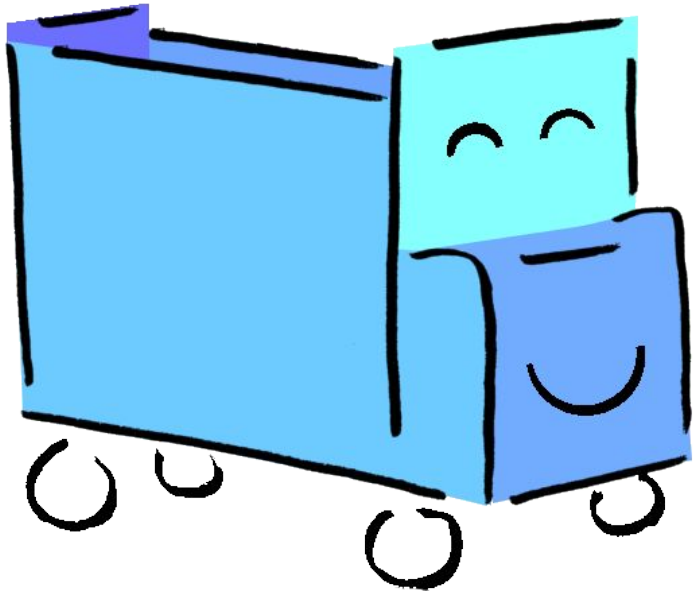
The vehicles can do more than one route.

VRPTW

YES!!!

The locations have time windows within visits must be made.

CVRPTWMT

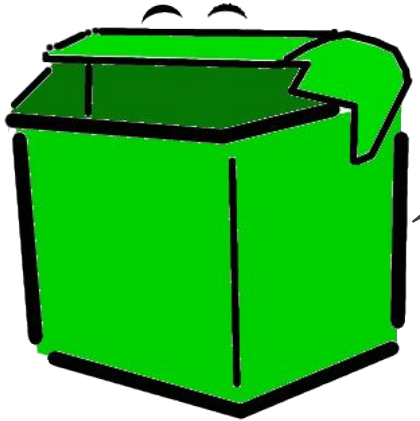


Garbage Collection:

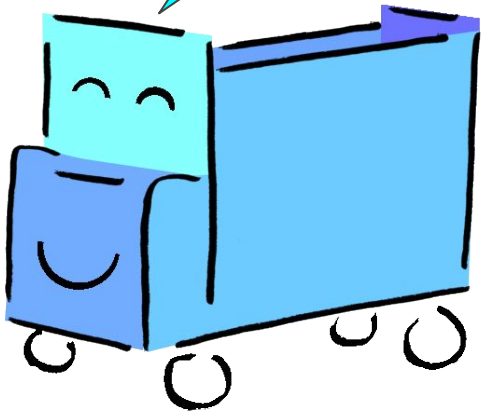
Is a Capacitated Vehicle Routing Problem with Time Windows and Multiple Trips

More Restrictions

I am in a street market



I am on the right side of the street



Can not make U turns

I pick up from the left side.

More Restrictions

Municipalities

A truck that picks from one municipality, can not pick from another. Exception: trucks that pick up hospitals biomedical waste.

Waste - Truck relationship

For some types of waste there are special types of trucks

Container - Truck relationship

For some types of containers there are special types of trucks

More Restrictions

Access Restriction

A truck can not access areas within a certain times.

Speed Limit

The average speed limit can change depending on the time of the day.

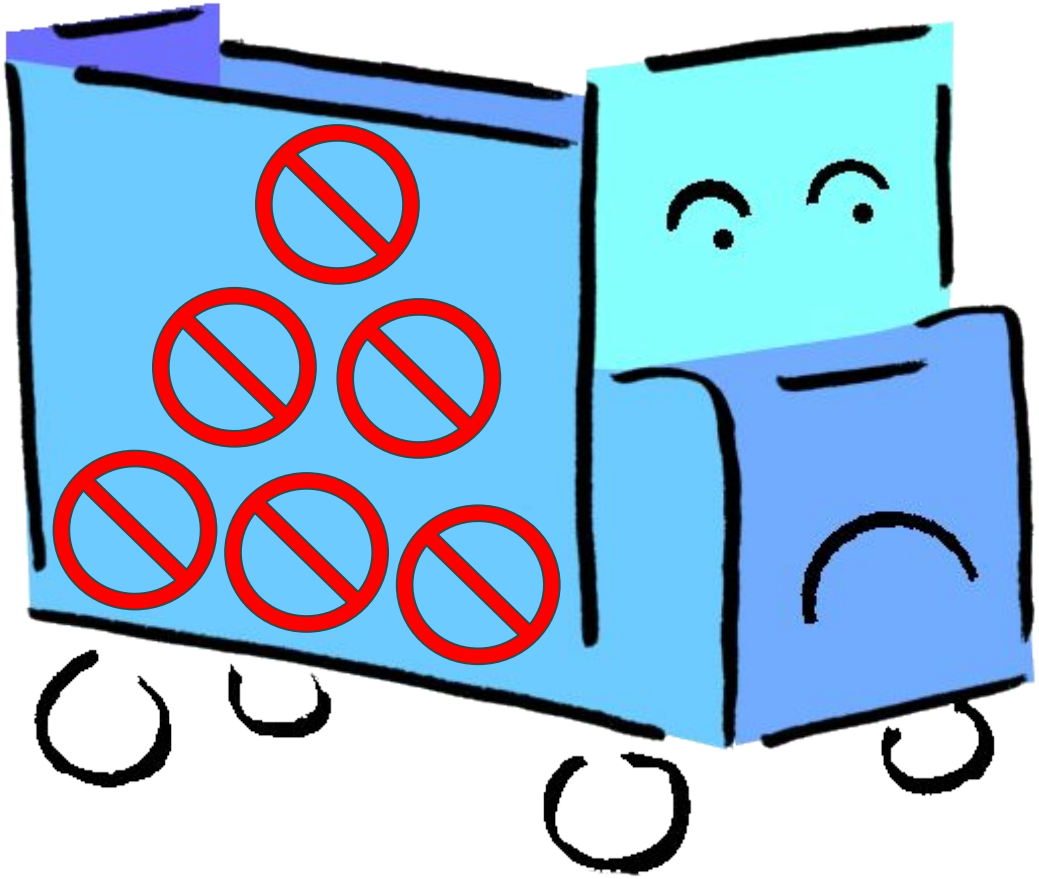
Turns restrictions

A truck can not make a U turn.

Restrictions classification

- Global restrictions:
  - Containers within Municipalities
  - Trucks for Municipalities
  - Containers across Municipalities
    - Medical waste

- Detailed restrictions:
  - Capacity
  - Right/left side pickup
  - Speed



Approach

FRONTEND

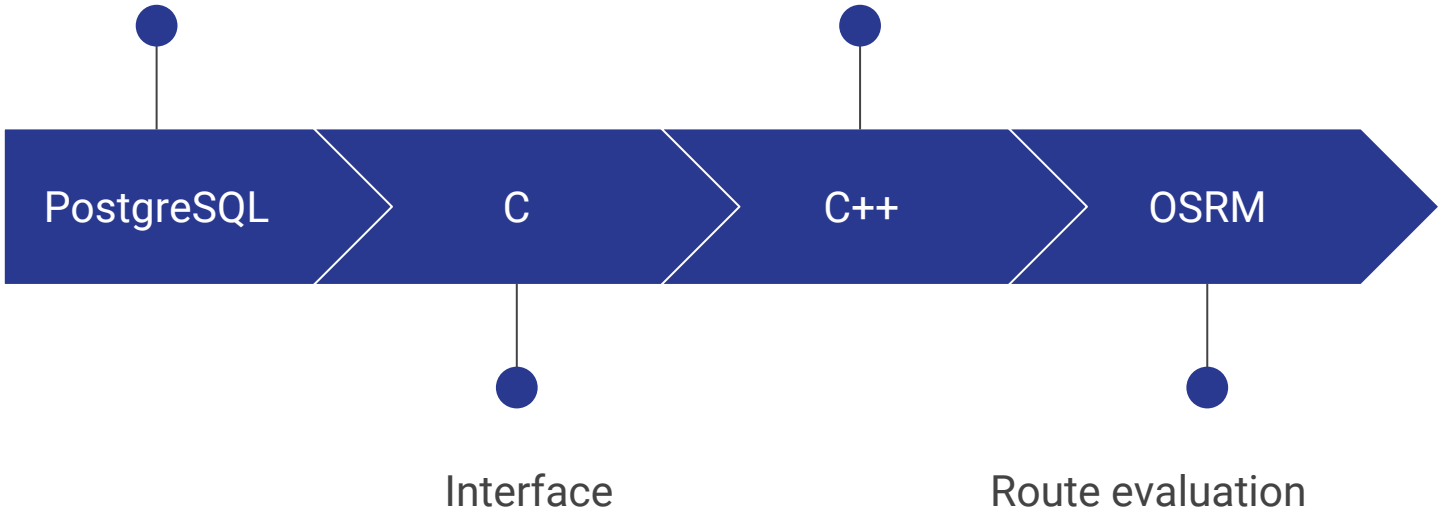
- OSM: Map
- Be able to:
  - Select Containers
  - Select Trucks
  - Select Depot and Dump sites
- Query the Database
- Display results:
  - Route on a map
  - Projected timings
- Global Restrictions handling

Note: The front end is not the focus of this presentation

BACKEND

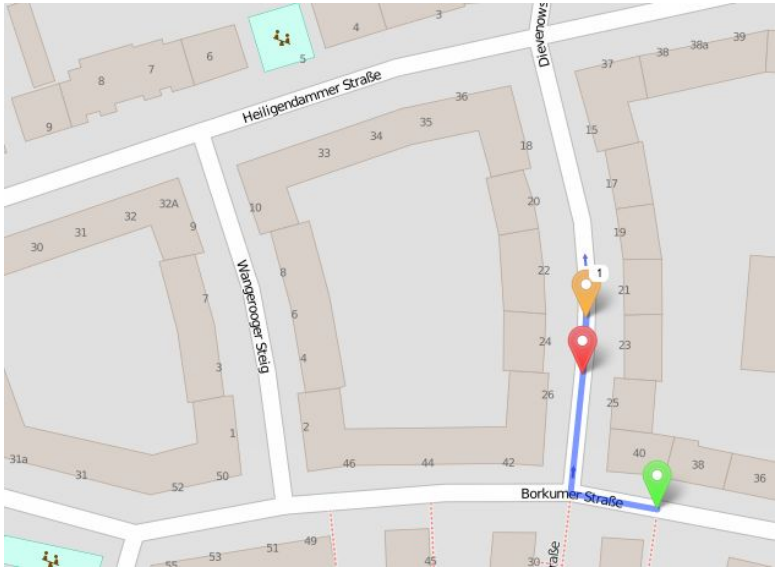
- Trucks
- Containers
- Locations

- Initial Solution
- Tabu Search
- Detail restriction handling



OSRM

- Version 0.3.3
- Instead of calling using web api:
  - a C++ interface class
  - Increased performance
- Difficult to maintain a travel time matrix.
  - Strange loops
  - Strange routes



Almost ... Tabu Search

- Shake operation is done by having
  - 7 different initial solutions.
- Optimize
  - Trip ordering
  - Minimize cost

```
...
case 1:
      insertBestPairInCleanTrip(trip);
      insertBigSubPathAtBegin(trip);
      break;
...
```

The Cost Function

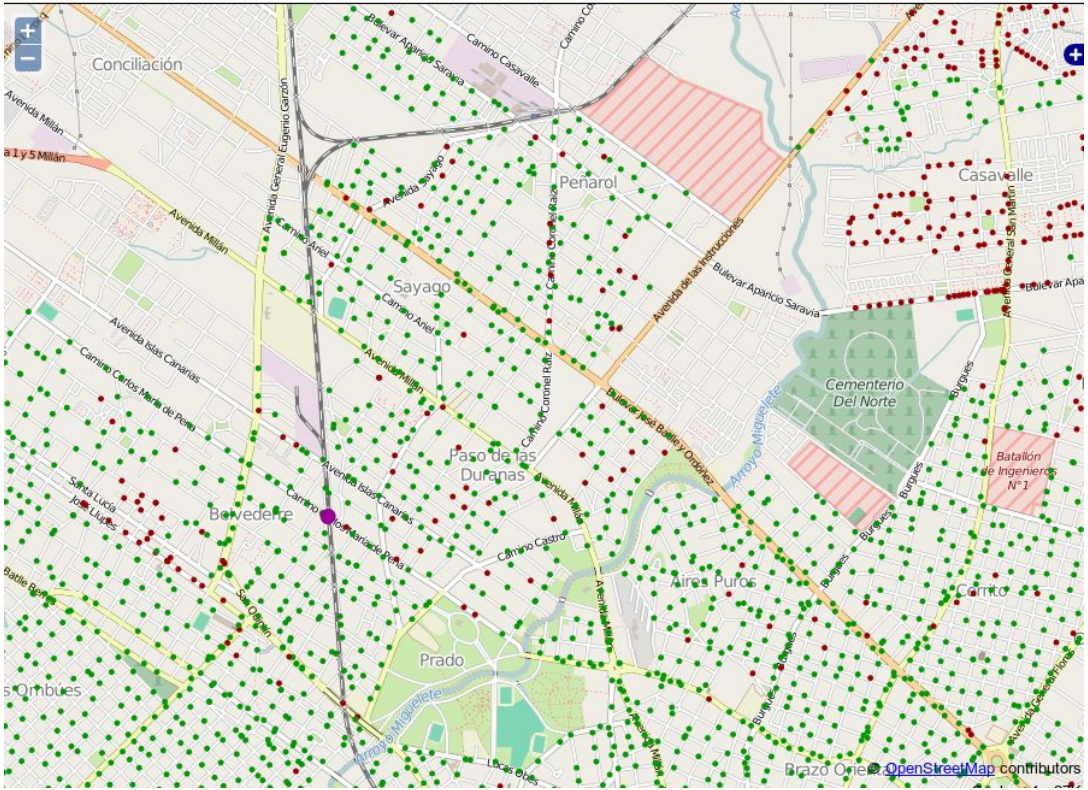
- Integrate theory with reality
  - Deep mathematical analysis
  - Reflect the analysis within the code

```
 //estimated:
  // forcedWaitTime > 0: truck finishes duties before the shift ends
  // forcedWaitTime < 0: truck finishes duties after the shift ends
  // For this problem: serviceE == 0
  // From the point of view of the truck the endingSite closes at end of
shift
  // therefore the expected value is positive otherwise a time violation
exists
  // at the ending site
  forcedWaitTime = endTime - (arrivalEclosesLast(C)  +  serviceE());
```

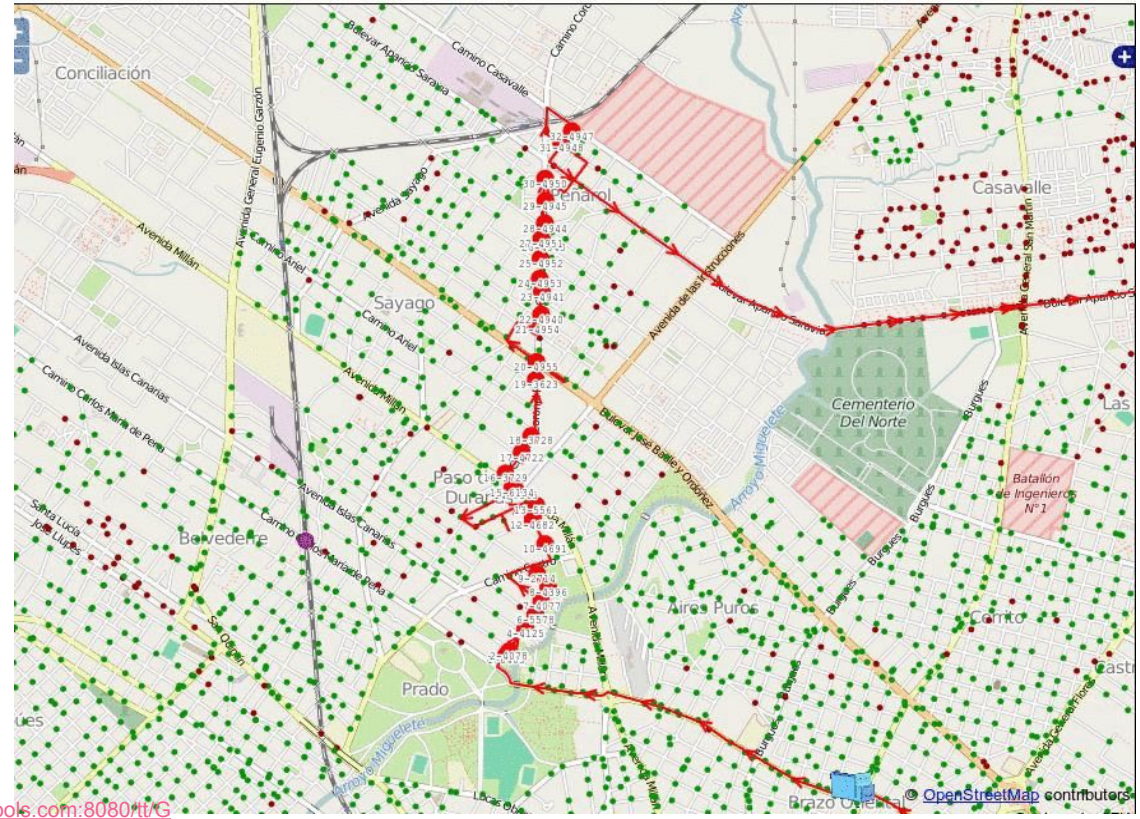
Code snippet taken from:
https://github.com/woodbri/vehicle-routing-problems/blob/montevideo-release-v4/src/trash-prob/trashWithMovingDumps/solverTrash/costvehicle.cpp#L104

A preview

Containers

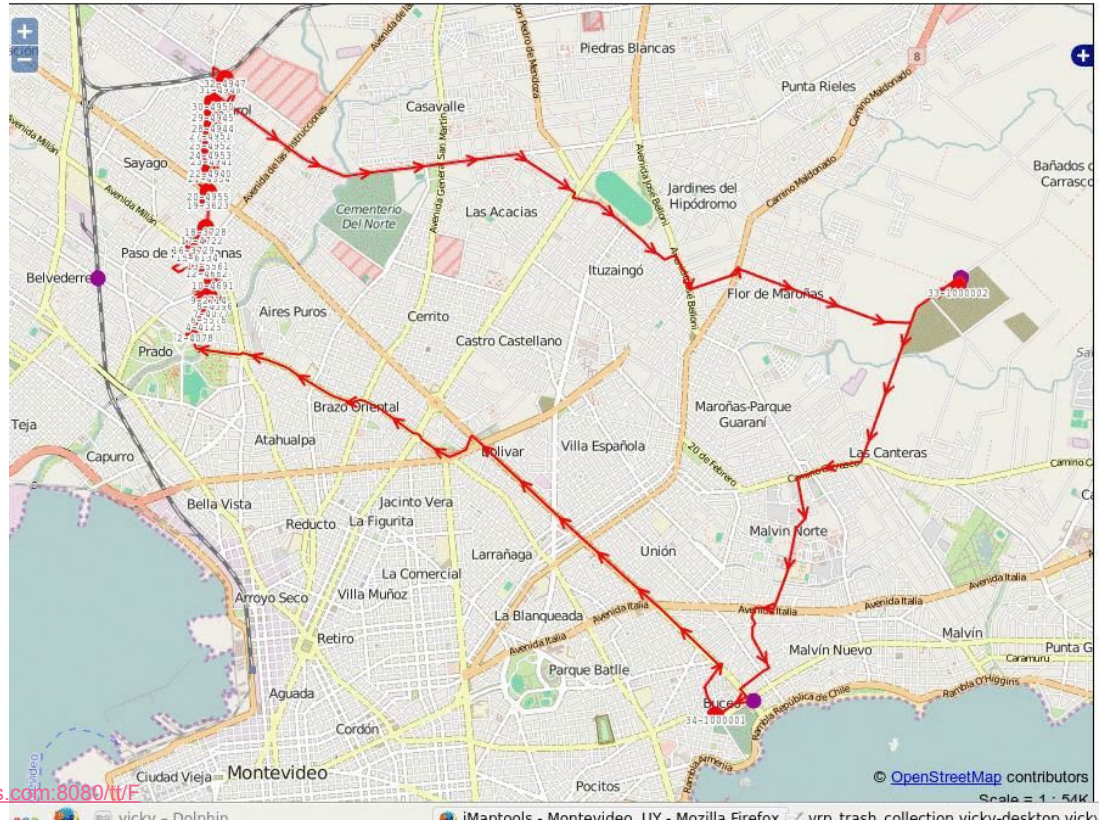

Conciliación
Penarol
Casavalle
Sayago
Paso de las Duranas
Belvedere
Aires Puros
Cerrito
Prado
Ornbues
Cementerio Del Norte
Batallón de Ingenieros N°1
Avenida Millán
Avenida Islas Canarias
Camino Ariel
Camino Castro
Avenida de las Instrucciones
Bulevar Aparicio Saravia
Arroyo Miguelete
Burgues
© OpenStreetMap contributors

insertBestPairInCleanTrip



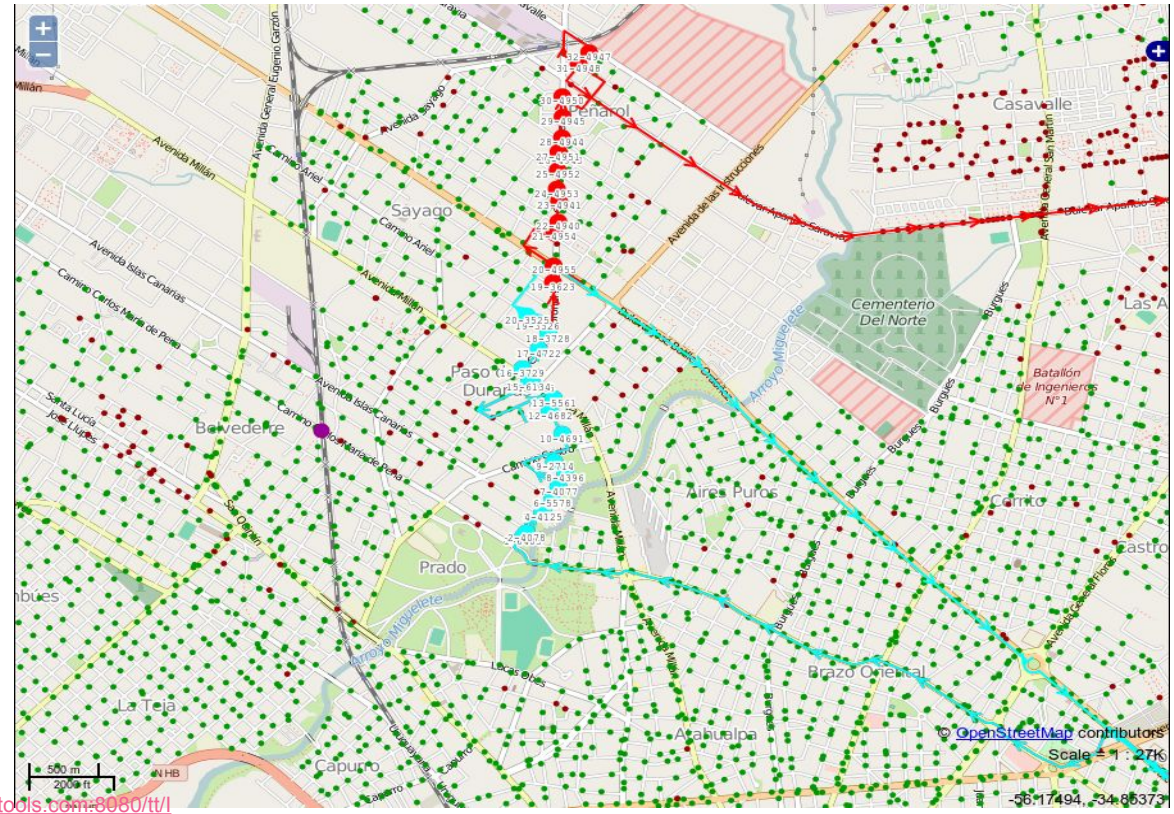
Link to animation: http://imaptools.com:8080/tt/G

The complete Route



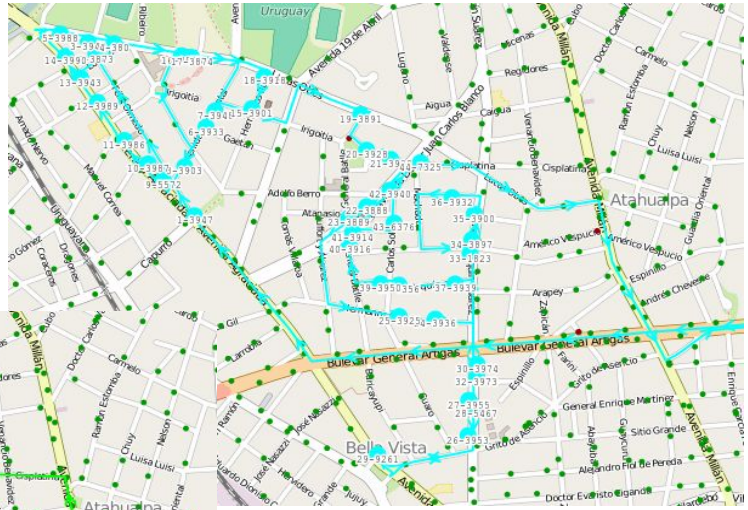
Link to animation:http://imaptools.com:8080/tt/F

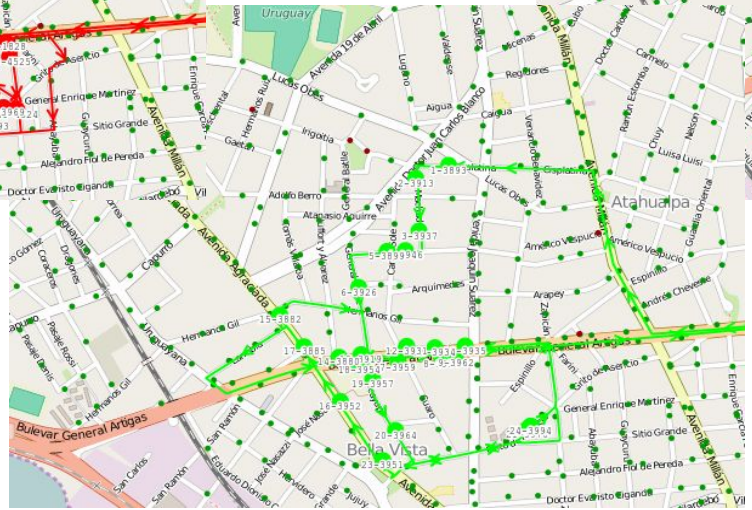
insertBigSubPathAtBegin



Link to animation:http://imaptools.com:8080/tt/l

Truck With 3 Trips

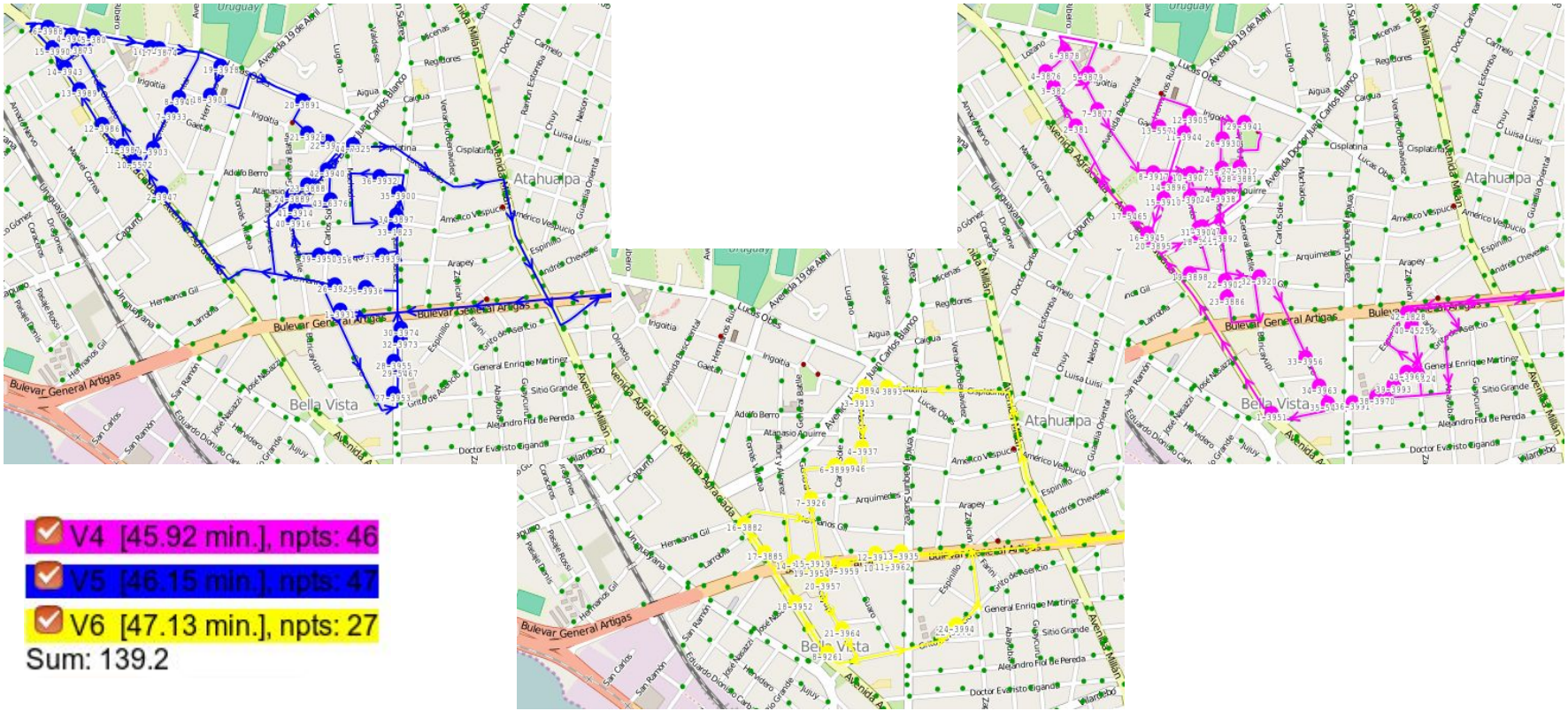




V1 [45.75 min.], npts: 46
V2 [49.08 min.], npts: 47
V3 [50.33 min.], npts: 27
Sum: 145.16

Link to animation: http://imaptools.com:8080/tt/J

Optimized Truck With 3 Trips



Link to animation:http://imaptools.com:8080/tt/J

What’s next

Code

- Many ideas were coded and discarded.
  - There is a lot of unused code.
- Upgrade to be used with OSRM 5.3
  - Under development
- Migrate the code to C++14
  - Originaly coded with C++98
  - Currently OSRM use C++14
- Improve the function library
- Develop an open Frontend

Side effects

Incorporated some ideas into pgRouting

- With Points family of functions
  - Pass in front and visit concepts
  - Left /right driving sides
  - http://docs.pgrouting.org/2.2/en/src/withPoints/doc/withPoints.html#withpoints

Lessons learned

- OSM data
  - Evaluation with OSRM
    - Own storage
  - PostgreSQL (one place have it all)
    - Storage for front end
    - Storage of the problems data
    - Evaluation can be done with other tools like pgRouting

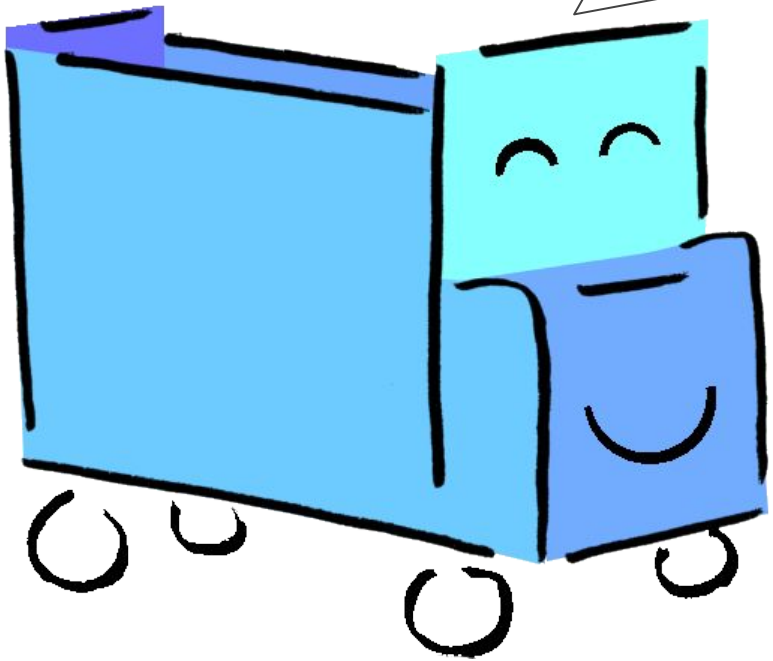
Theory

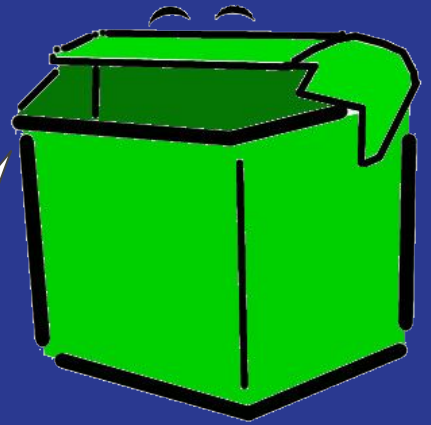
- NP problems.
- Exponential growth on time execution
- High level abstraction
  - Not many restrictions
- Euclidean approximations
  - Not good for real problems.

Reality

- They are NP problems
- User wants small execution times
- User has many restrictions
  - Restrictions might change between users
- Implied restrictions on a city graph.

See three Trucks on a municipality





http://imaptools.com:8080/tt/M