Library Logistics Optimization System

Petros-Alexis Kofakis\(^1\), Katerina Marinagi\(^1\), Michalis Gerolimos\(^2\), Eftichia Vraimaki\(^2\)

\(^1\): Department of Logistics Management (DLM) - Agricultural Un. of Athens

\(^2\): National Library of Greece
Department of Logistics Management

- founded September 2006
- enrolls more than 1200 students
- is now part of the Agricultural Un. of Athens

https://www.aua.gr
National Library of Greece (NLG)

From the historic neoclassical building in the center of Athens
National Library of Greece

- New premises at Stavros Niarchos Foundation Cultural Center (SNFCC) in Athens
- Ground floor + 4 levels, nearly 24,000 m²
- Inauguration December 2018

18m tall square Book Castle
each side is measuring 20 meters
NLG - Transition

- 760,000 items moved
- Preparation: 2 years
- Lasted 4 months

Facts

- Estimated number of users (patrons): 100 / day
- Number of items / reader: typically 3, max 10
- Number of reading rooms: 6 (capacity: 236 seats)
- Number of service points: 6
- Number of buffers: 6 i.e. one / reading room
The problem

Daily operation requires trafficking of a great number of items

The storage, pickup and delivery of items from shelving to service locations, is a labor-intensive activity

Runways aren't always perfect, there are many empty runs

Requirements:

- The whole system should be based exclusively on Open Source Software
- It should be integrated with the ILS (Koha)
Planning problem

Optimize goals

- Maximize profit

With limited resources

- Employees
- Assets (trolleys, vehicles)
- Time
- Budget

Under Constraints

- Employees vs Working hours
- Employees vs Skills
- Assets vs Logistics conflicts
Problem Solution

Model the process as a pickup and delivery logistics problem

Capacitated Vehicle Routing Problem (CVRP) approach is used
The objective is to minimize the total route cost

The system calculates and indicates to the library staff
the optimal routes for pick and place,
according to hard (time, staff, capacity etc) and soft constraints

- The system is web based
- Fully integrated with koha ILS
Modular development

UI

VRP

Database

Geocoding

Koha

Map
System Architecture

- AutoCAD
- BIM
- Conversion, Editing, Tagging
- Indoor map
- Indoor graph
- Visualization
- Foom
- VRP
- Koha plugin, scripts
- Dashboard (constraints)
- Visualisation
- Analytics
- Web interface
- Bootstrap
- Apache
- CodeIgniter
- MariaDB
- MySQL
- Leaflet
- Tile Server
- PostGIS
- PostgreSQL
- Ubuntu
- Open Source Routing Machine (OSRM)
- Google Optimization Tools
- Perl
- Koha

ELAG2019 - Library Logistics Optimization System
4 levels

36 areas / rooms
Pick (forward)
Pick Sequence (steps)

1) At specific times the system creates a list of the items to be retrieved

2) A list of items grouped by pick zone is displayed

3) For each pick zone, the VRP solution is calculated based on available staff

4) The list of items is sorted according to the pick sequence (route)

5) The staff retrieves the items from the shelves according to the planned route

6) Picked items from various zones are placed in a buffer (table)

7) The items are grouped by destination, i.e. by service point rather than by user

8) The grouped items are transferred to relevant service point

9) At the service point items are consolidated per reader and placed in a box

10) Documents are ready for check-out by Koha
Place (reverse)
SELECT
bi.itemtype,
b.title,
b.author,
i.itemcallnumber,
``i.barcode`,
i.itemnotes,
bi.size,
bi.pages,
date(r.timestamp) AS `hold date`,
r.`timestamp`,
r.branchcode AS `pickup branch`,
i.homebranch AS `owning branch`,
i.location,
p.surname,
p.firstname,
p.cardnumber
FROM reserves r
LEFT JOIN biblio b ON (r.biblionumber=b.biblionumber)
LEFT JOIN items i ON (i.biblionumber=b.biblionumber)
LEFT JOIN biblioitems bi ON (b.biblionumber=bi.biblionumber)
LEFT JOIN borrowers p USING (borrowernumber)
WHERE i.itemnumber NOT IN (SELECT issues.itemnumber FROM issues)
AND i.itemnumber NOT IN (SELECT branchtransfers.itemnumber FROM branchtransfers WHERE datearrived IS NULL)
AND r.waitingdate IS NULL AND i.homebranch='EBE'
GROUP BY b.biblionumber,p.borrowernumber
ORDER BY i.location ASC
SQL query: items to place

```
SELECT
biblioitems.itemtype,
biblio.title,
biblio.author,
items.itemcallnumber,
items.barcode,  
items.itemnotes,
biblioitems.size,
biblioitems.pages,
items.homebranch,
items.location,  
old_issues.returndate
FROM old_issues
LEFT JOIN items ON old_issues.itemnumber = items.itemnumber
LEFT JOIN biblio ON items.biblionumber = biblio.biblionumber
INNER JOIN biblioitems ON items.biblioitemnumber = biblioitems.biblioitemnumber
WHERE old_issues.returndate
BETWEEN '2019-02-01' AND '2019-02-20'
ORDER BY items.location ASC
```
Cartography and digital maps are now present in every aspect of our day life.

OpenStreetMap (OSM) is a collaborative web-mapping project that collects geospatial data to create and distribute online maps, freely available to anyone.

OSM started because most maps we think as free actually have legal or technical restrictions on their use.

A considerable number of contributors edit the world map collaboratively using the OSM technical infrastructure.
Map creation: JOSM

JOSM is an extensible OSS desktop editor for OSM for Java 8+. Aerial imagery can easily be downloaded as a background for tracing. Once you have completed your edits, you can upload them to OSM.

Pros
- Fast fluid panning and zooming.
- Highly configurable and extensible via plugins, Map Styles, Presets
- Advanced editing functionality e.g. change set reverting
- Built in validator, which checks for common mapping errors before data upload
- Can work offline using downloaded data files, and can work with local photo files
- Tags are shown to user directly. Many tags are recognized by the "presets"
- Very active development. Bugs are often fixed fast.

Cons
- The finer points of the interface take a while to learn
- Desktop software, have to download the software to run it
JOSM: ground plan

Human friendly, city street like
JOSM: editing

~25,000 objects
Shelf location encoding

A2.01.001-B.FBC.123

- Shelf number
- Block
- Area (~36 areas / rooms)
- Level
- Building

building
level
area (~36 areas / rooms)
block
Shelf number

ELAG2019 - Library Logistics Optimization System
Shelf No ➔ location

Columns do not have the same shelf count
Geocoding

Geocoding is the process of transforming:

- a physical address description (the name of a place)
- to a location on the Earth's surface (numerical coordinates)

**Nominatim** (from the Latin, 'by name')

is a tool to search OSM data by name and address
Location ➡ map ➡ navigation plan

Tile Server

Web interface

navigation plan

parameters (constrains)

Leaflet

Google Optimisation Tools

Koha

OSM

PostGIS

Distance Matrix

route (sequence)

VRP

OSRM

book location code

Map address

Map coordinates

Koha

ELAG2019 - Library Logistics Optimization System
Vehicle Routing Problem (VRP)

The objective of the VRP is to optimize the route, deliver a set of customers with known demands on minimum-cost vehicle routes originating and terminating at a depot.

Source: http://neo.lcc.uma.es/vrp/vehicle-routing-problem/
Open Source Routing Machine (OSRM)

- C++ implementation of a high-performance routing engine for shortest paths
- Designed with OpenStreetMap compatibility in mind
- Shortest path between any origin and destination within a few milliseconds
- Licensed under the permissive 2-clause BSD license

Leaflet is the leading open-source JavaScript library for interactive maps. Designed with simplicity, performance and usability in mind. It works with all major desktop and mobile platforms, can be extended with lots of plugins.

Leaflet Routing Machine

Leaflet Routing Machine is an easy, flexible and extensible way to add routing to a Leaflet map. Using the default is just a few lines of code to add fully functional routing, but you can still customize almost every aspect of the user interface and interactions.
OSRM - Routing
OSRM - Routing
OR-Tools includes a specialized routing library to solve many types of vehicle routing problems:

**Vehicle routing problem with capacity constraints**
CVRP is a VRP in which vehicles with limited carrying capacity need to pick up or deliver items at various locations. The problem is to pick up or deliver the items for the least cost, while never exceeding the capacity of the vehicles.

**Vehicle Routing with Pickups and Deliveries**
A VRP in which each vehicle picks up items at various locations and drops them off at others. The problem is to assign routes for the vehicles to pick up and deliver all the items, while minimizing the length of the longest route.

**Vehicle Routing Problem with Time Windows**
Many vehicle routing problems involve scheduling visits to customers who are only available during specific time windows. These problems are known as vehicle routing problems with time windows (VRPTWs).

code licensed under the Apache 2.0 License: github.com/google/or-tools
Vroom

VROOM is an open-source optimization engine written in C++14

Fast
Good solutions real-life vehicle routing problems within small computing times
Can scale to handle big instances

Open
BSD-licensed
Rely on OpenStreetMap data
Full integration with OSRM
https://github.com/VROOM-Project/vroom

Customizable
Support for user-defined cost matrices
Extensible to work on top of any routing engine
Frontend available
Vroom API

- **Matrix**
  An array of arrays of unsigned integers describing the rows of a custom travel-time matrix as an alternative to the travel-time matrix computed by OSRM.

- **Vehicle locations**
  Start and end are optional for a vehicle, as long as at least one of them is present.
  For round trip, just specify both start and end with the same coordinates.

- **Skills**
  To describe a problem where not all jobs can be served by all vehicles. Job skills are mandatory, i.e. a job can only be served by a vehicle that has all its required skills.

- **Capacity restrictions**
- **Time windows**
Optimized route sequence
Project Extensions

Indoor positioning using beacons

Integration with other NLG premises

Indoor items tracking using passive UHF RFID
Conclusion

- Solution to library indoor logistics
- Exclusively Open Source
- Successful application of OSM indoor
- Interoperability with Koha
- Open, extensible system
Thank you.

kofakis@gmail.com