How Zalando Accelerates Warehouse Operations with Neural Networks

Calvin Seward
Big Data Berlin v. 6.0

28 January 2016

Outline

- Picker Routing Problem
- Order Batching Problem
- Neural Network Estimate of Pick Route Length
- Order Batch optimization via Simulated Annealing

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This was a project that was a collaboration between Rolland Vollgraf, Sebastian Heinz and myself. Some of the figures have been shamelessly stolen from Roland.

Zalando's Logistics Centers

- 13.8 Million orders from 01.07.15 – 30.09.15
- 174,684 orders send per working day (Mo. – Sa.)
- Every second handling time per order requires 160 man-days of work / month
- Any increase in efficency has a big impact

Picker Routing Problem

The locations that must be visited

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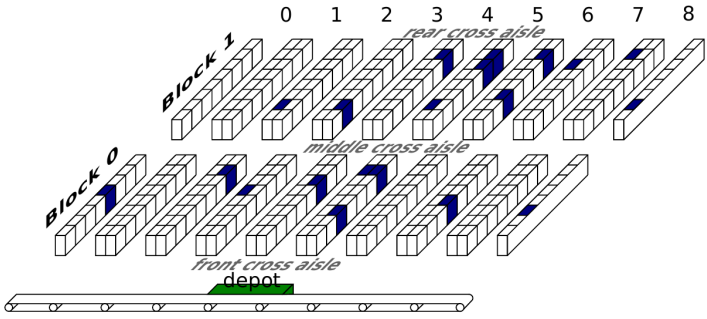
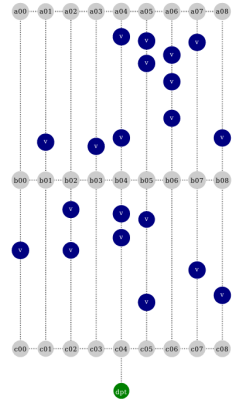
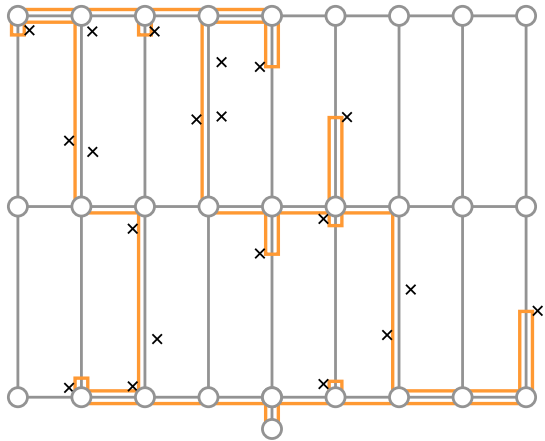




Picker Routing Problem

The Pick Route



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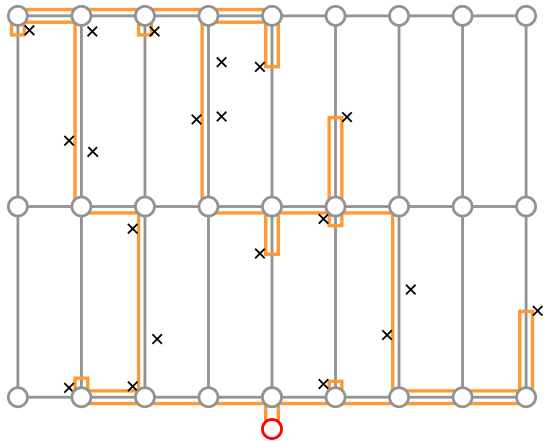

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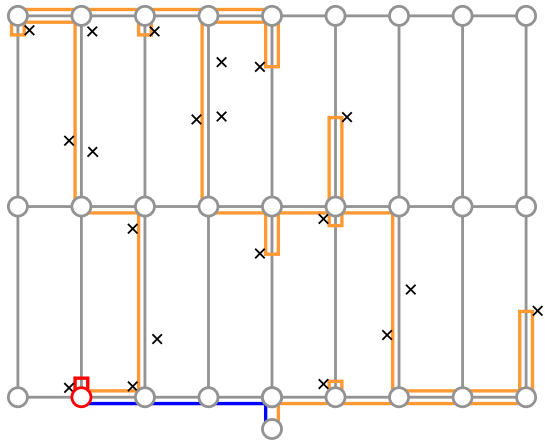

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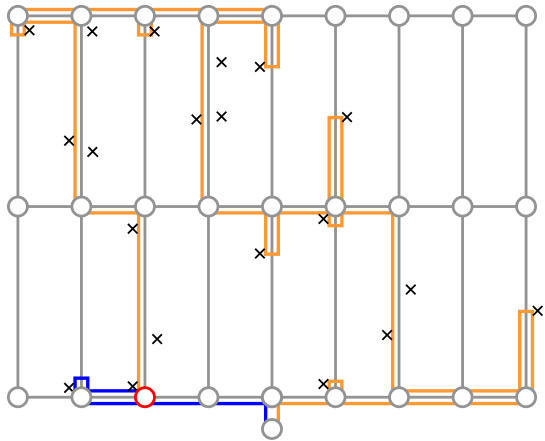

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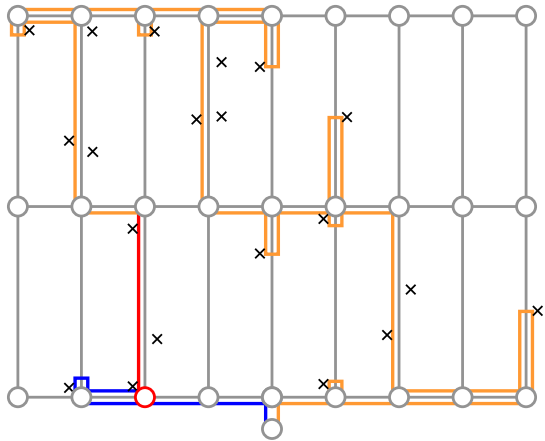

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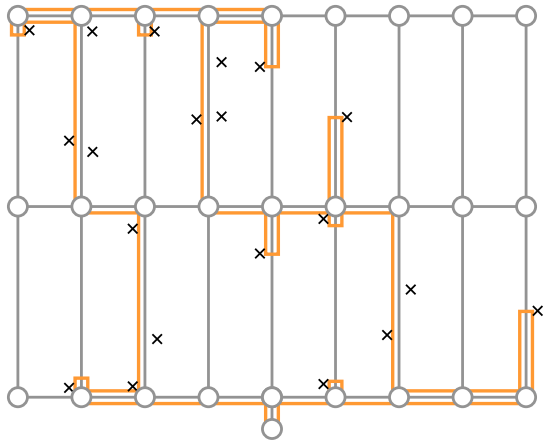

OCaPi Algorithm

Optimal CArt PIck

- To solve picker routing problem, we developed the OCaPi Algorithm
- Calculates the optimal route to walk
- Also determines optimal cart handling strategy

Figure: The Okapi – Our Mascot

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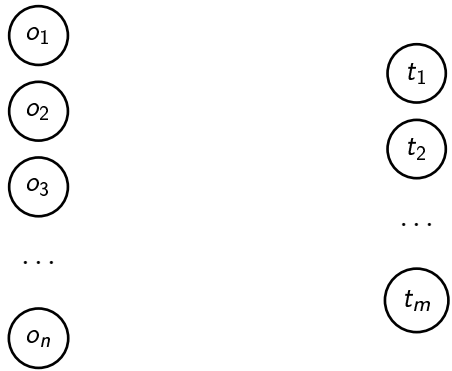
- Calculates the optimal route to walk
- Also determines optimal cart handling strategy
- Has complexity that is linear in the number of aisles
- Unfortunately still has a runtime of around 1 second

Figure: The Okapi – Our Mascot

Simplified Order Batching Problem

Bipartite Graph Formulation



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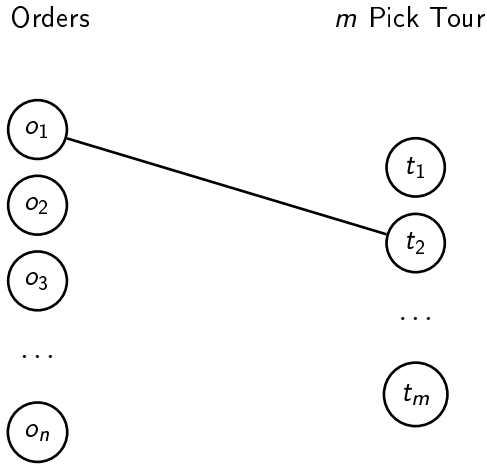

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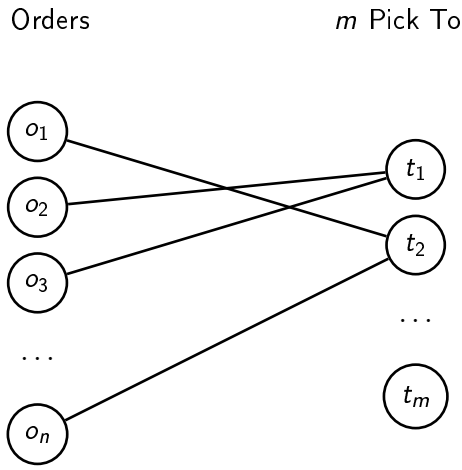
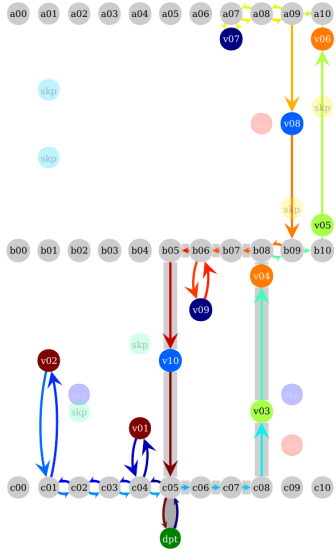
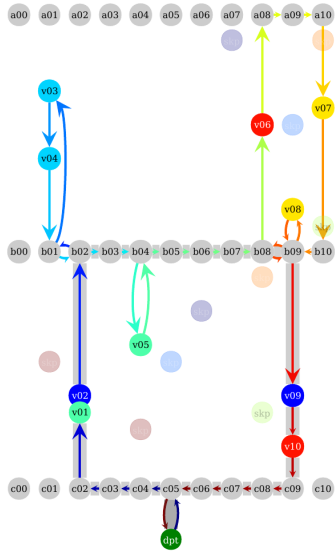


Order Batching Problem

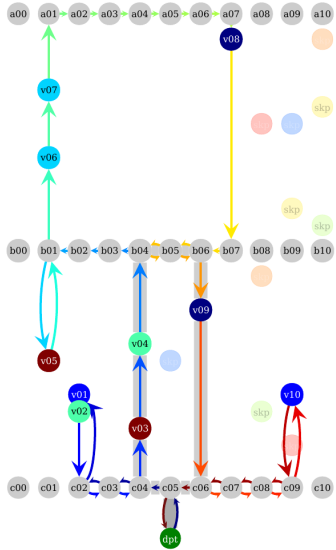
Random Split of 10 Orders à 2 Items Into Two Pick Routes

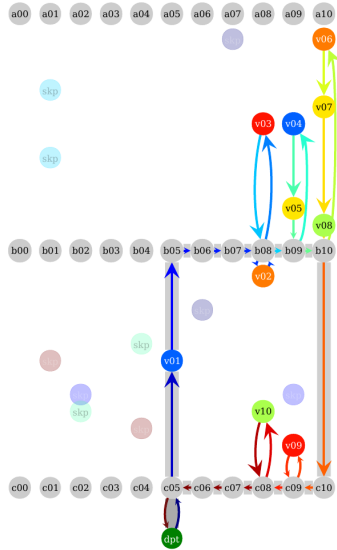




Order Batching Problem

Brute Force Split of 10 Orders à 2 Items into Optimal Two Pick Routes → 8.3% Boost





zalando

Neural Network Estimate of Pick Route Length

- This simple example could be done with brute force
- A realistic example with 40 orders à 2 items has a complexity of

$$\frac{40!}{2 \cdot 20! \cdot 20!} \approx 6.9 \cdot 10^{10}$$

at 1 second per route, you'd wait 2185 years

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  at 1 second per route, you'd wait 2185 years
- Use clever heuristics like simulated annealing
- Estimate pick route length with Neural Networks

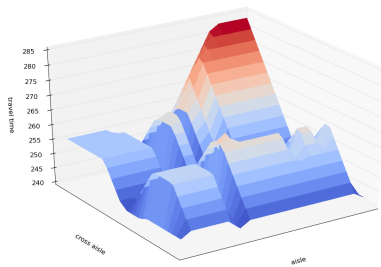
Neural Network Estimate of Pick Route Length

- OCaPi cost landscape

$$f : (\mathbb{N} \times \mathbb{R})^n \to \mathbb{R}_+$$

is a nice function because it is:

- Lipschitz continuous in the real-valued arguments
- Piecewise linear in the real-valued arguments
- Locally sensitive



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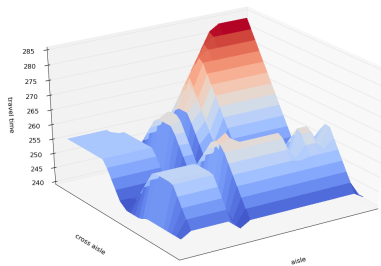
  - Lipschitz continuous in the real-valued arguments
  - Piecewise linear in the real-valued arguments
  - Locally sensitive
- Perfect function to model with Convolutional Neural Networks with ReLUs:

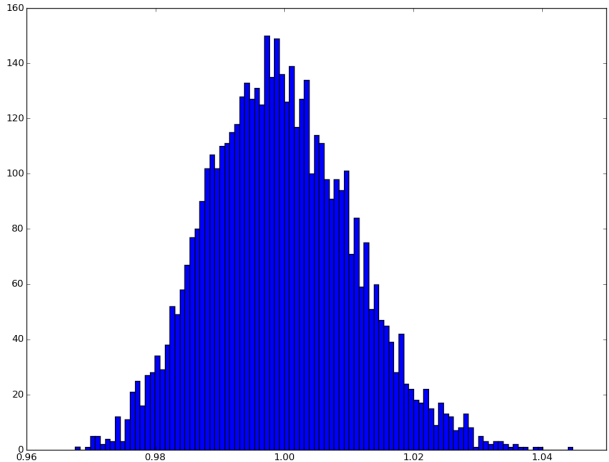
$$\tilde{f}(x) := (W_2(W_1 x + b_1)_+ + b_2)_+$$

- Train convolutional neural network with 1 million examples



Neural Network Estimate of Pick Route Length

Estimation Accuracy – Frequency of relative estimation error $\frac{\text{estimated travel time}}{\text{calculated travel time}}$



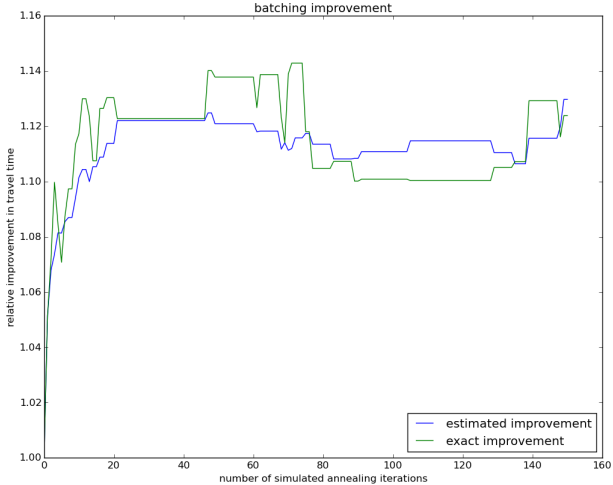
Neural Network Estimate of Pick Route Length

Estimation Speed – Time Per Route on two Intel Xeon E5-2640 and two NVIDIA Tesla K80 accelerators

number pick lists	OCaPi	CPU network	GPU network
1	5.369	2.202e-3	1.656e-3
10	1.326	1.991e-4	1.832e-4
100	0.365	6.548e-5	5.919e-5
1000		3.086e-5	2.961e-5
10000		2.554e-5	2.336e-5

Order Batch optimization via Simulated Annealing

Estimated and Exact Improvement in Example Simulated Annealing Run



Questions?

Thanks for listening

Get The Slides On

`github.com/cseward/ocapi_neural_net_blog_post`