

Imaging the City: **GPU simulation in space & time**

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Habidatum

Analytics and Visualization for Urban Planning

30+ cities across
the globe

More than **70**
projects

15 people

Benoy

Heathrow



CRUX



MEGANOM

MLA+

Zaha Hadid
Architects

KPIT

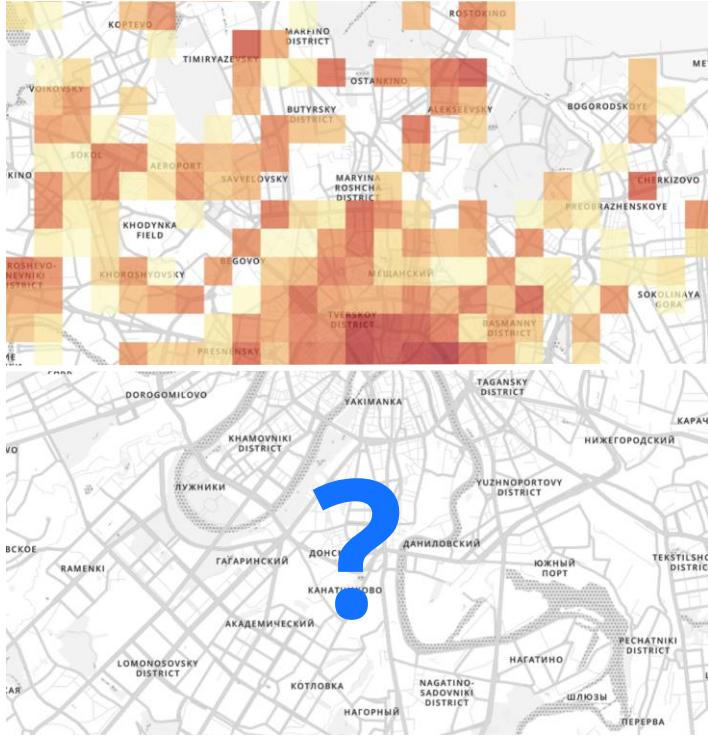


BUROHAPPOLD
ENGINEERING

Prediction of a City Map

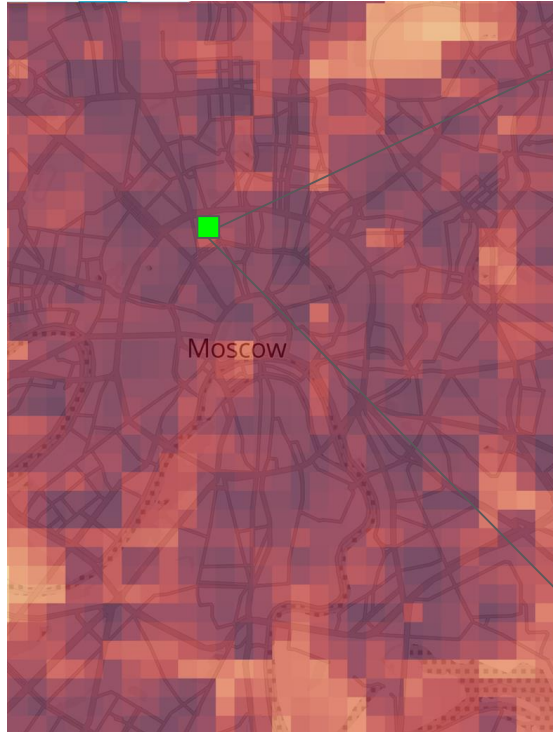


Activity



Spend

What-If Analysis: Let's build a Community Center



Understanding the Economic Impact

City Map: Discrete vs Continuous

What is the best representation of the city data to learn the spatial patterns?



Continuous



Discrete

?

Our Choice: Grid Cell

A universal data point

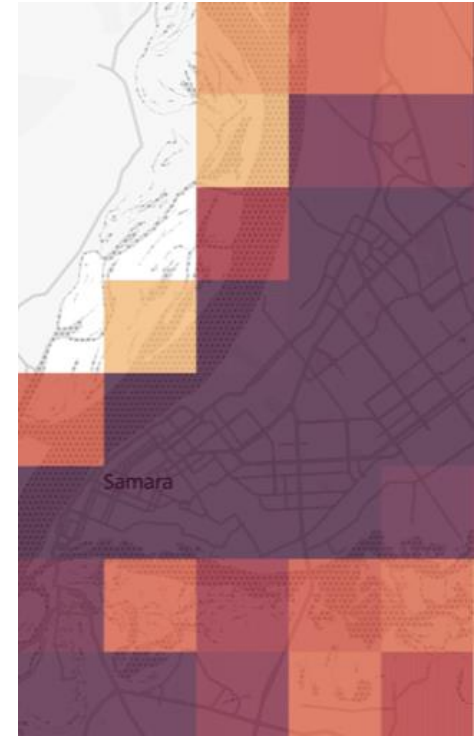
Different spatial scale: 10m to 10km

Uniform throughout the city

Comparable across territories

Fast computations

Relationship between adjacent cells



City Map: Discrete vs Continuous

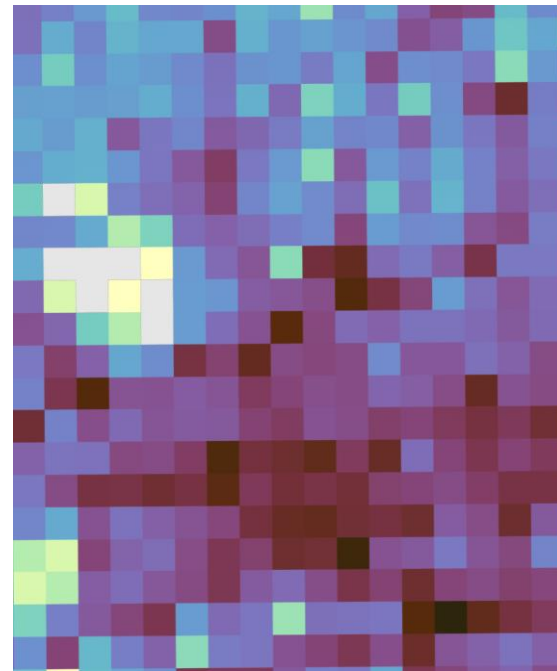
What is the best representation of the city data to learn the spatial patterns?



Continuous

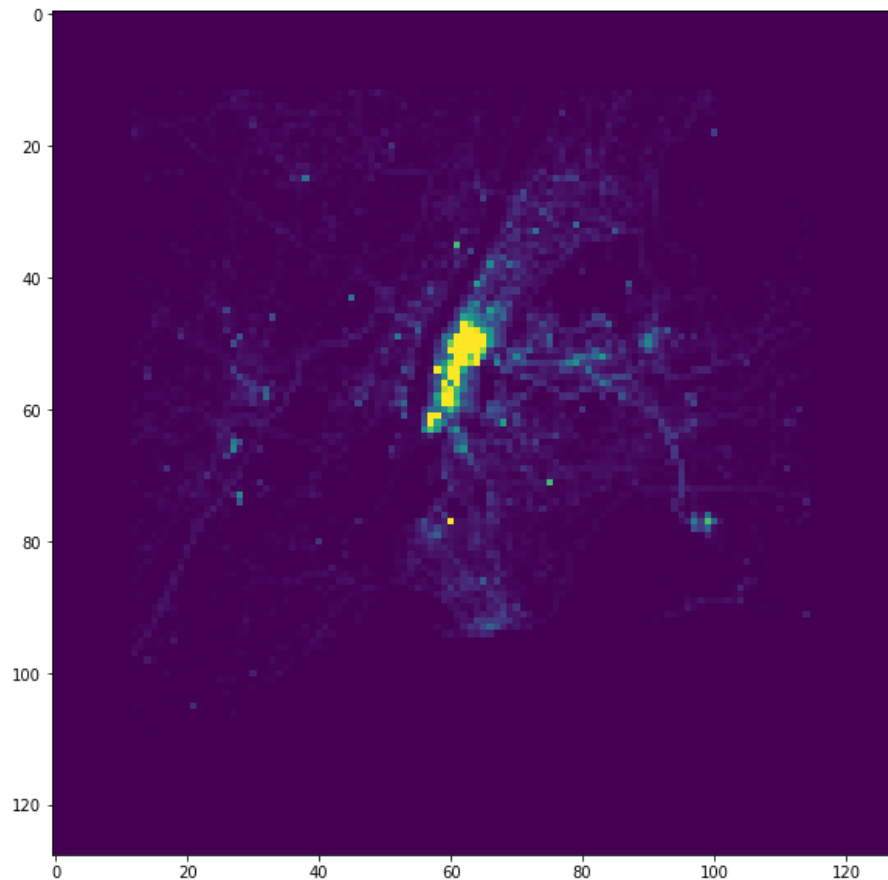


Discrete

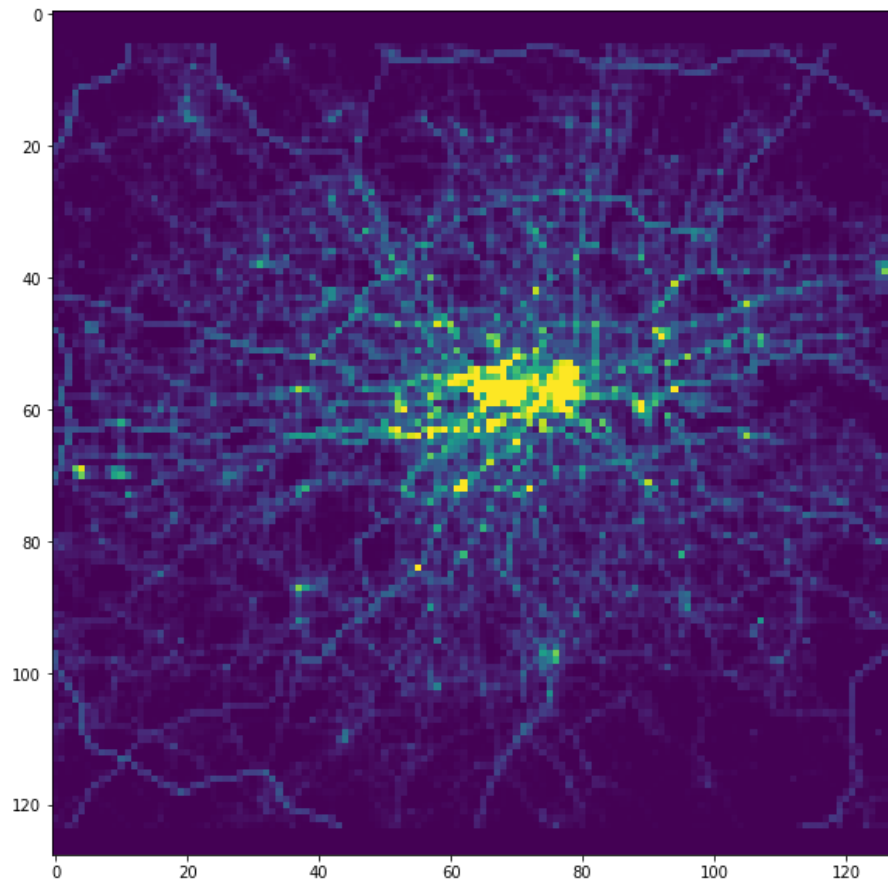


Raster

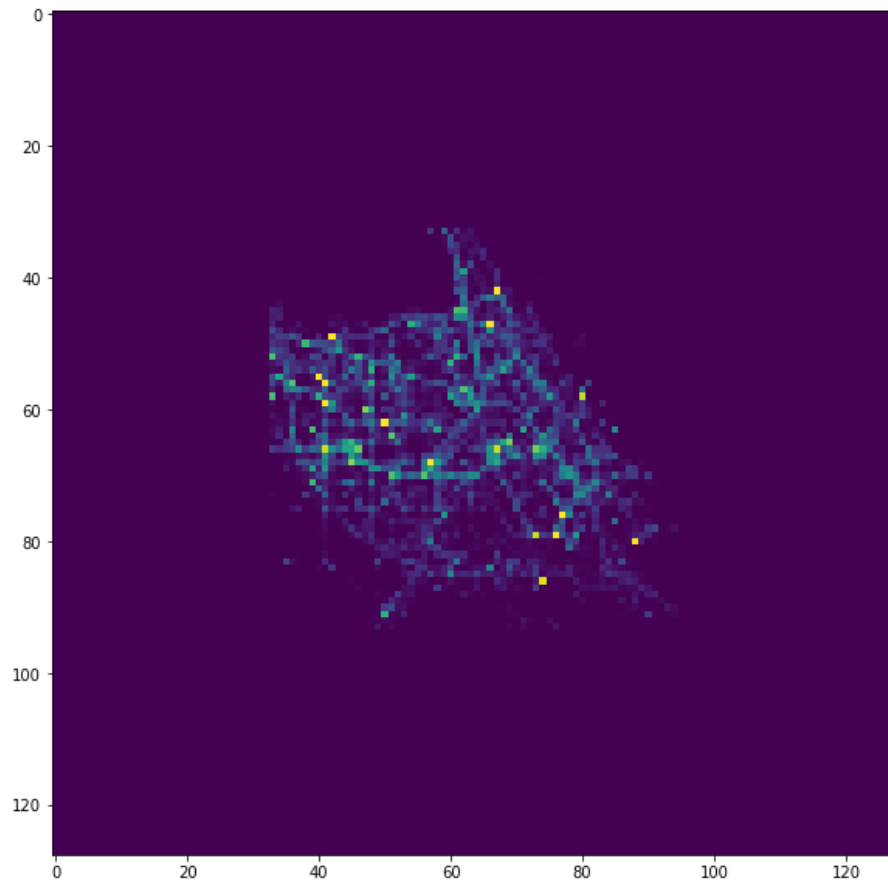
Discrete Grid Map: City as an Image



Discrete Grid Map: City as an Image



Discrete Grid Map: City as an Image



Simulation Example: From Activity to Sales

Activity: aggregate anonymous levels of activity based on cellular data

Spend: aggregate spend level based on a financial data provider



Mobility

Location data



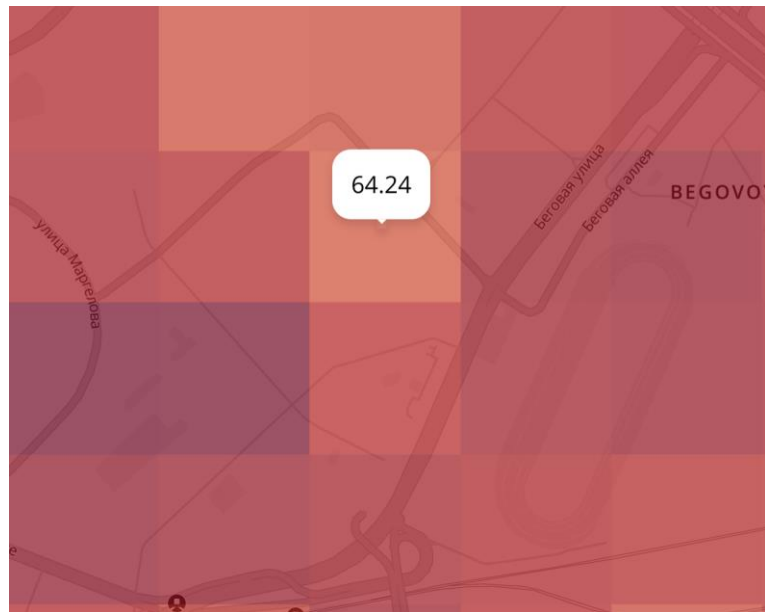
Consumption

Consumer activity data

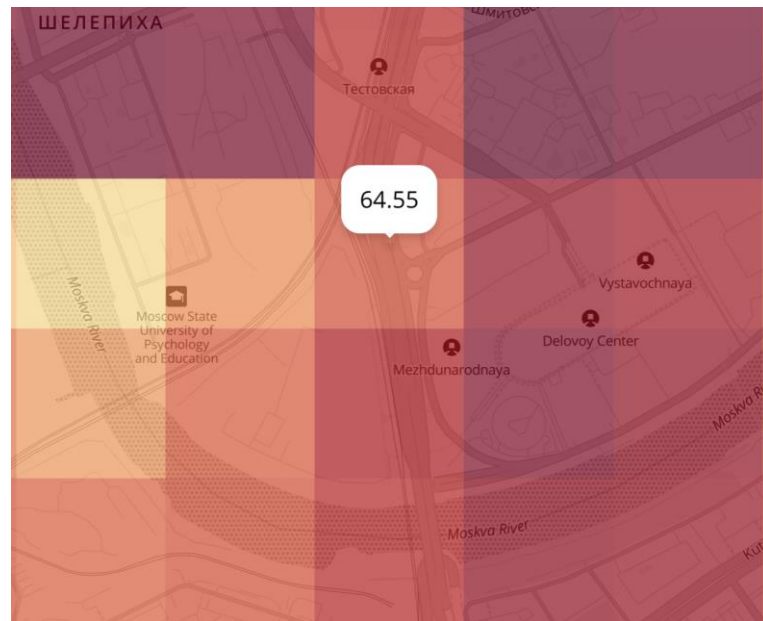
Single Value is not Enough

Same value inside, different patterns around it

Need to understand spatial patterns

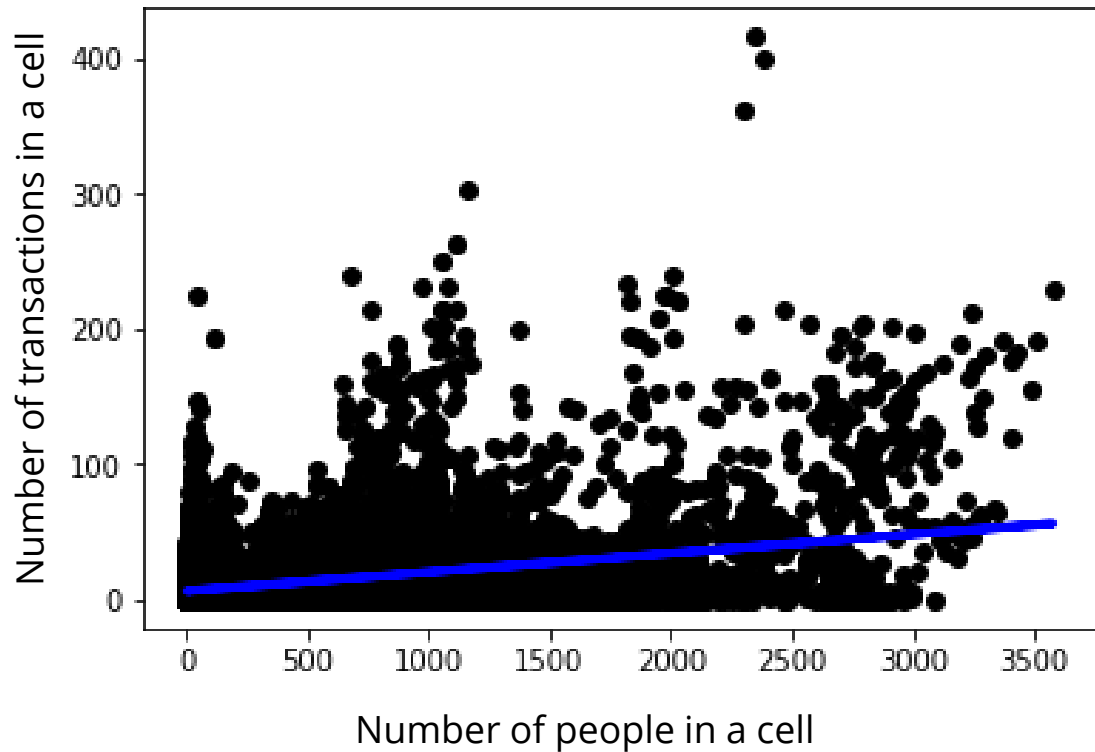


VS

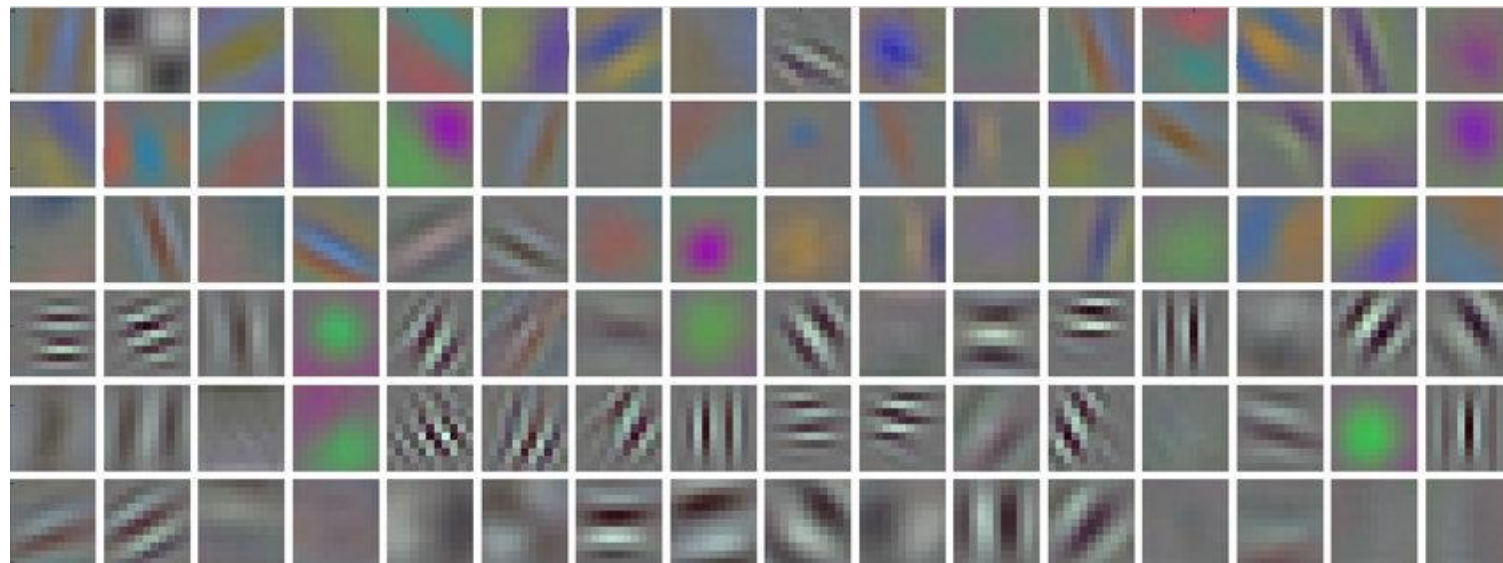


Single Value is Not Enough

Activity vs spend



Convolutional Neural Network: Spatial Patterns Champion

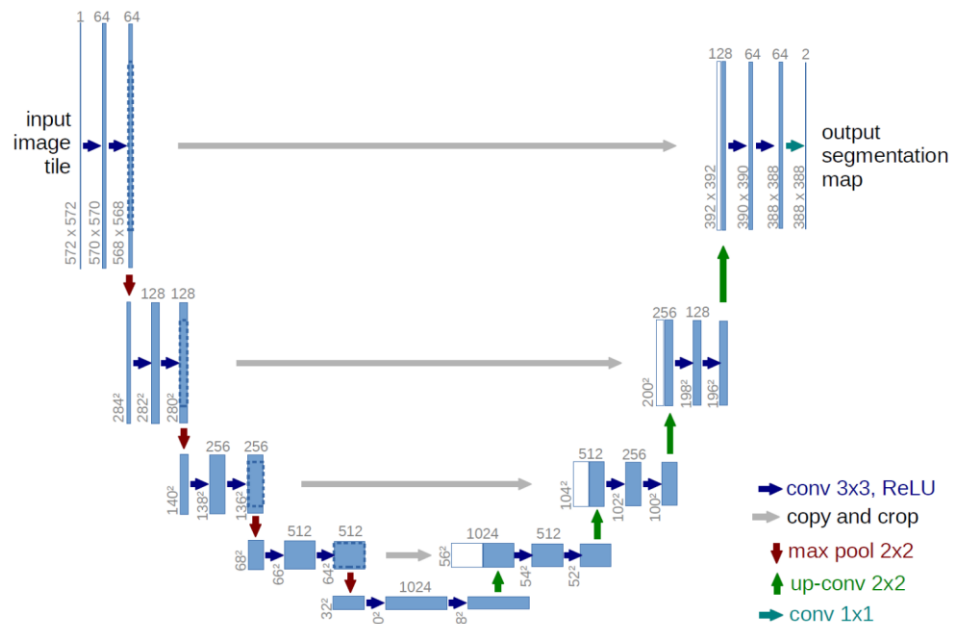
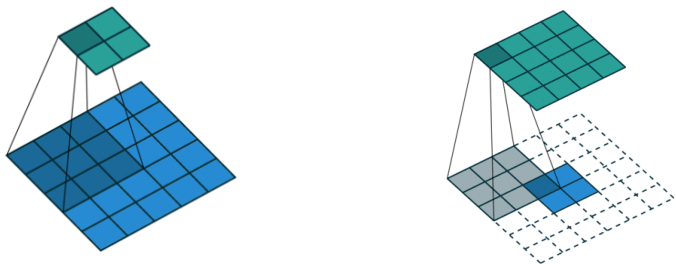


UNet: Pixel-wise predictions

Encoder-Decoder architecture

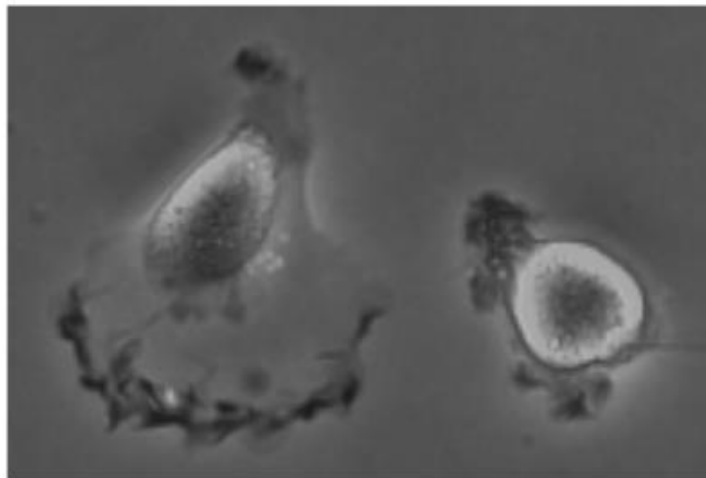
Learns features in the encoder

Generates full size image in decoder

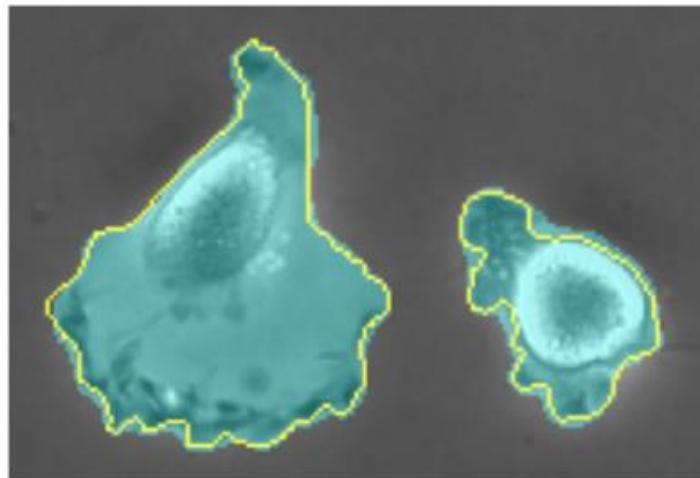


Classic UNet Application: Image Segmentation

Training data: 30 images, 512 by 512



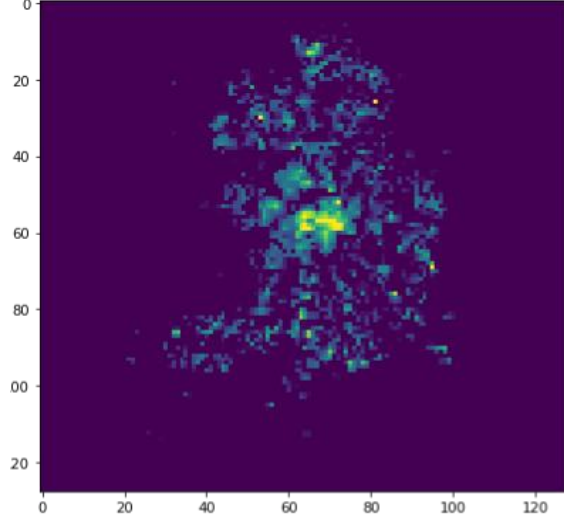
Part of an input image



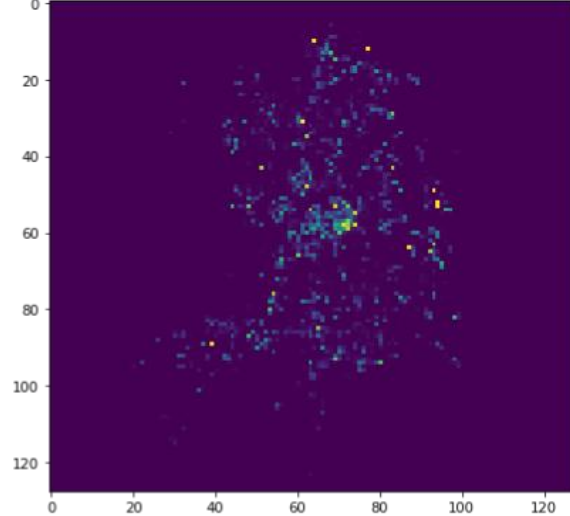
Segmentation result

Simulation Example: Saint Petersburg

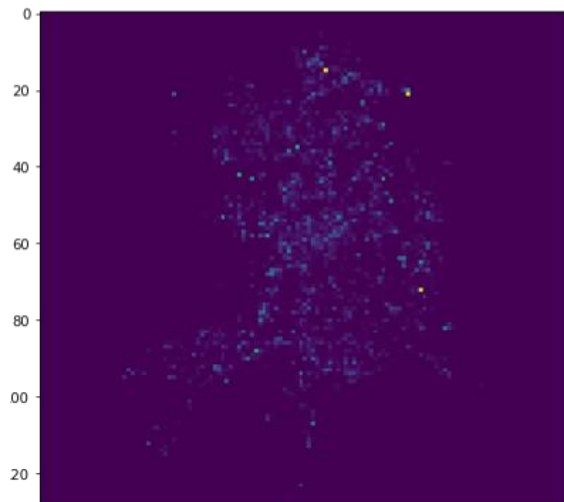
Input: Activity



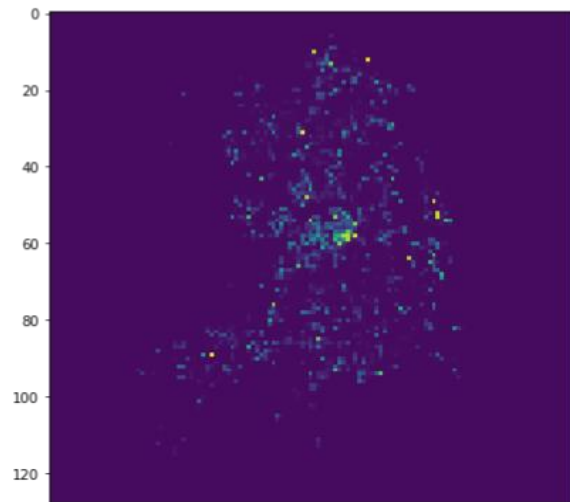
Spend: Actual



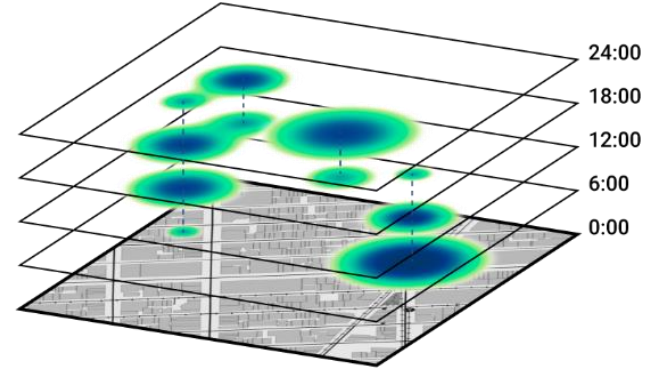
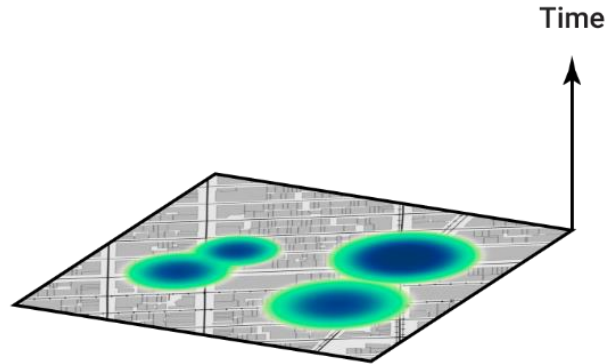
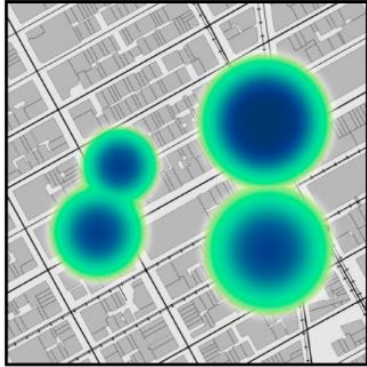
Error: Absolute



Spend: Simulation

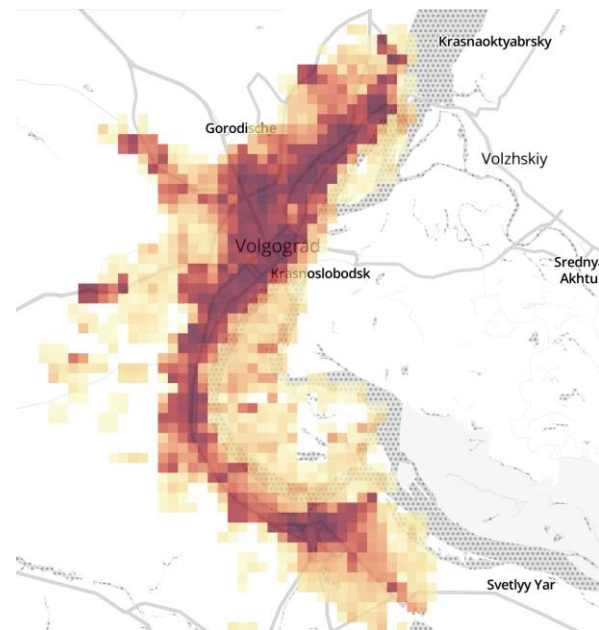
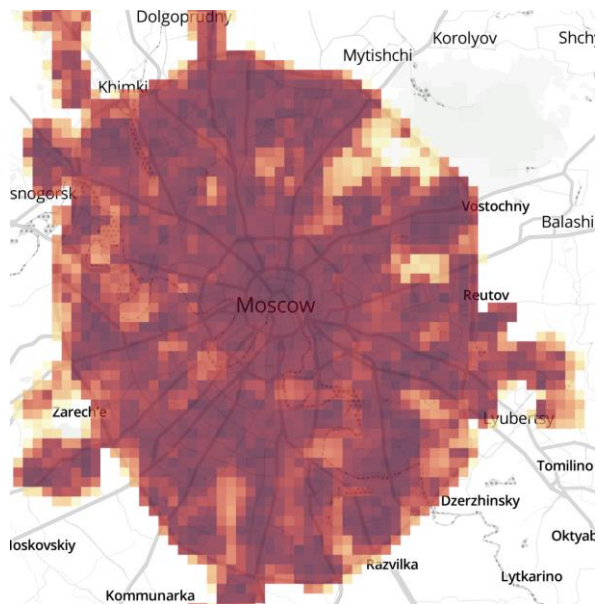


Viewing Map through Time



Working with Multiple Cities

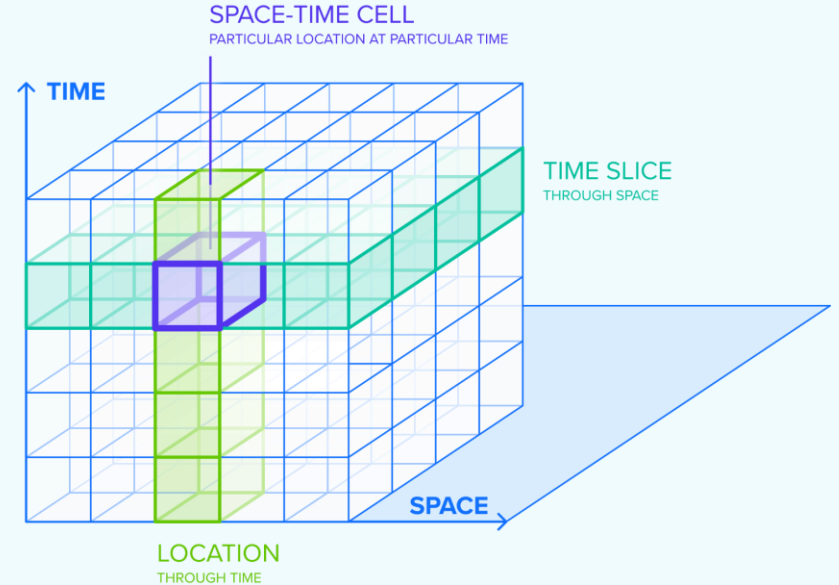
How to treat data from different cities as a homogeneous dataset?



Chronotope Grid

Chronotope Grid is a data standard and database for space-time data.

Chronotope Grid allows aggregation, processing and storing data with location and time attributes.

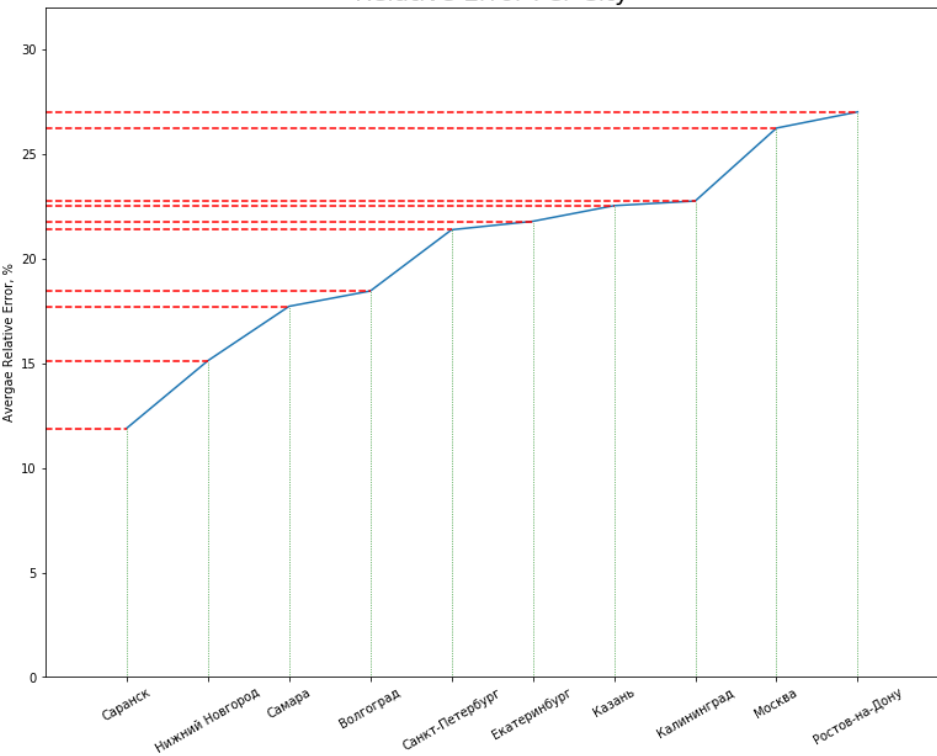


Model Training

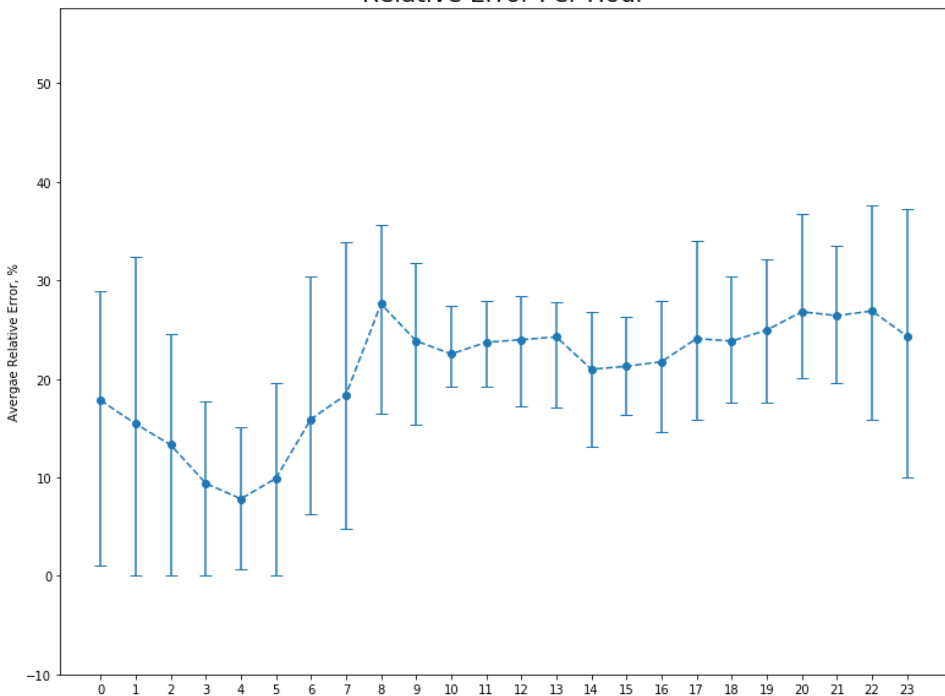
- 10 cities, 2 weeks, 24 hour images per day
- ~ 2.5B aggregated activity records, ~ 100M aggregated spend records
- Images: 128 x 128 pixel, each pixel is a 350 meter cell
- Zero padding for smaller cities
- Error estimation: relative error in spend prediction, in %
- Average error across space and time: 23%

Model Accuracy

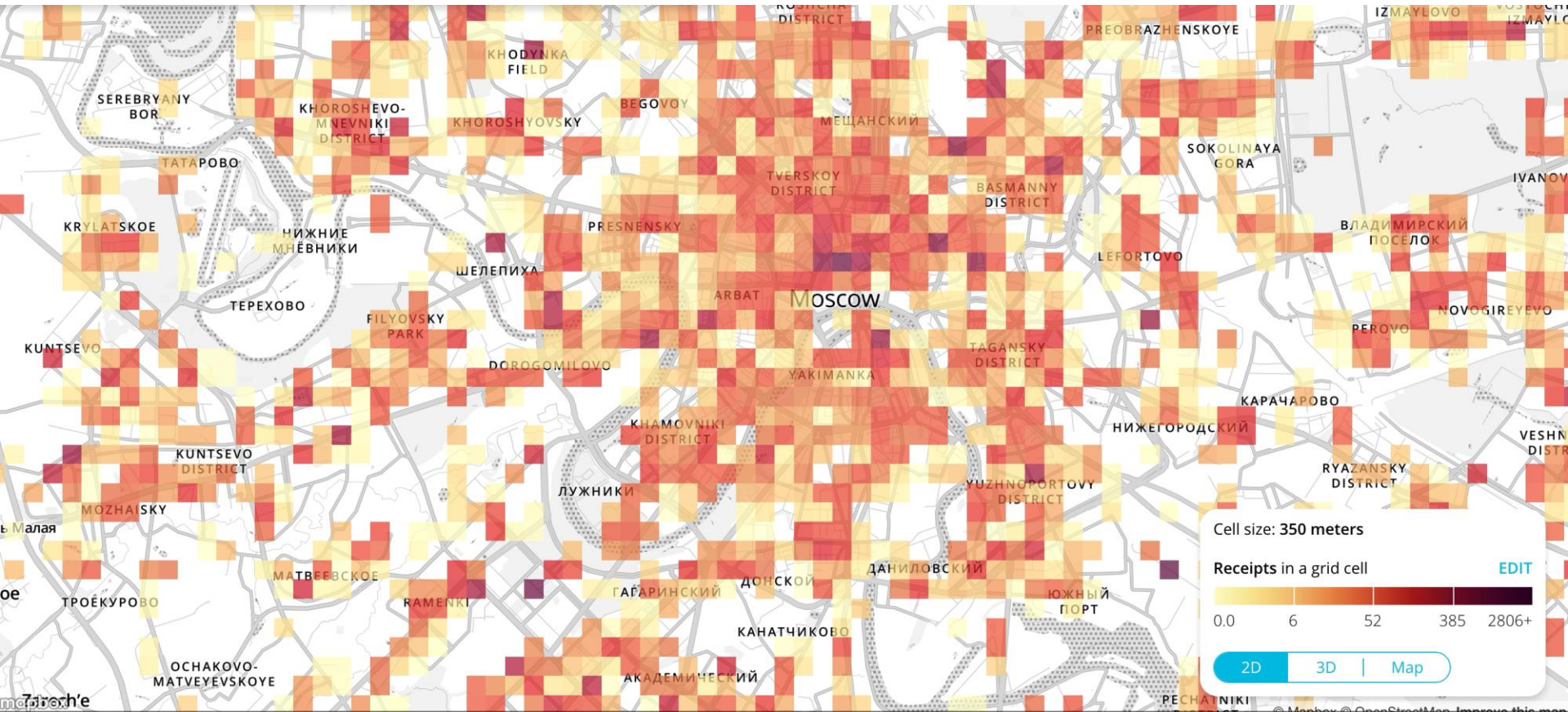
Relative Error Per City



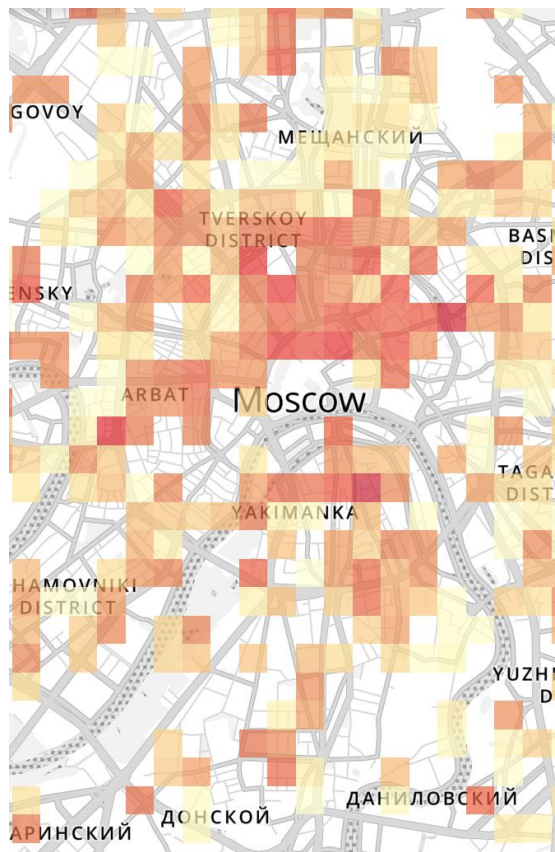
Relative Error Per Hour



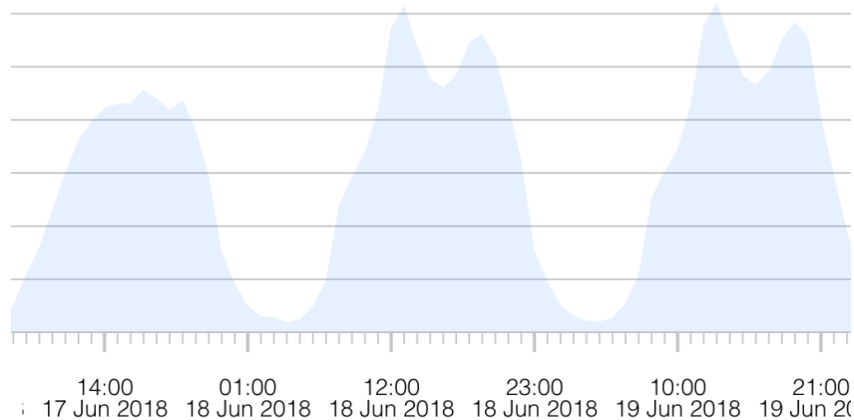
Prediction in Space and Time



Spatial

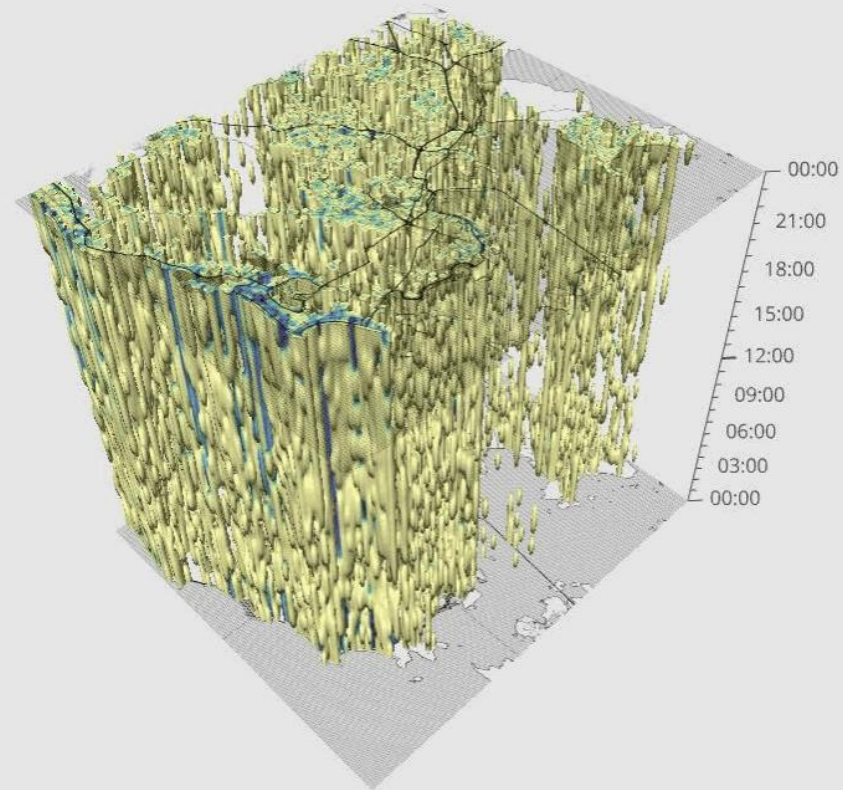
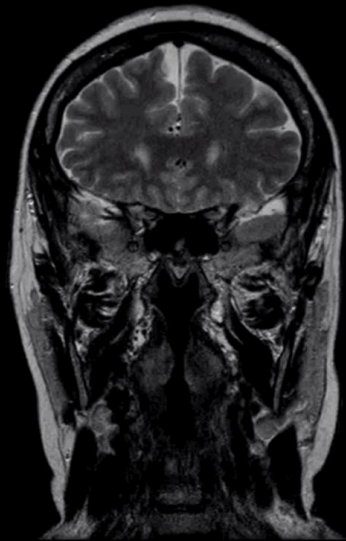


Time Series



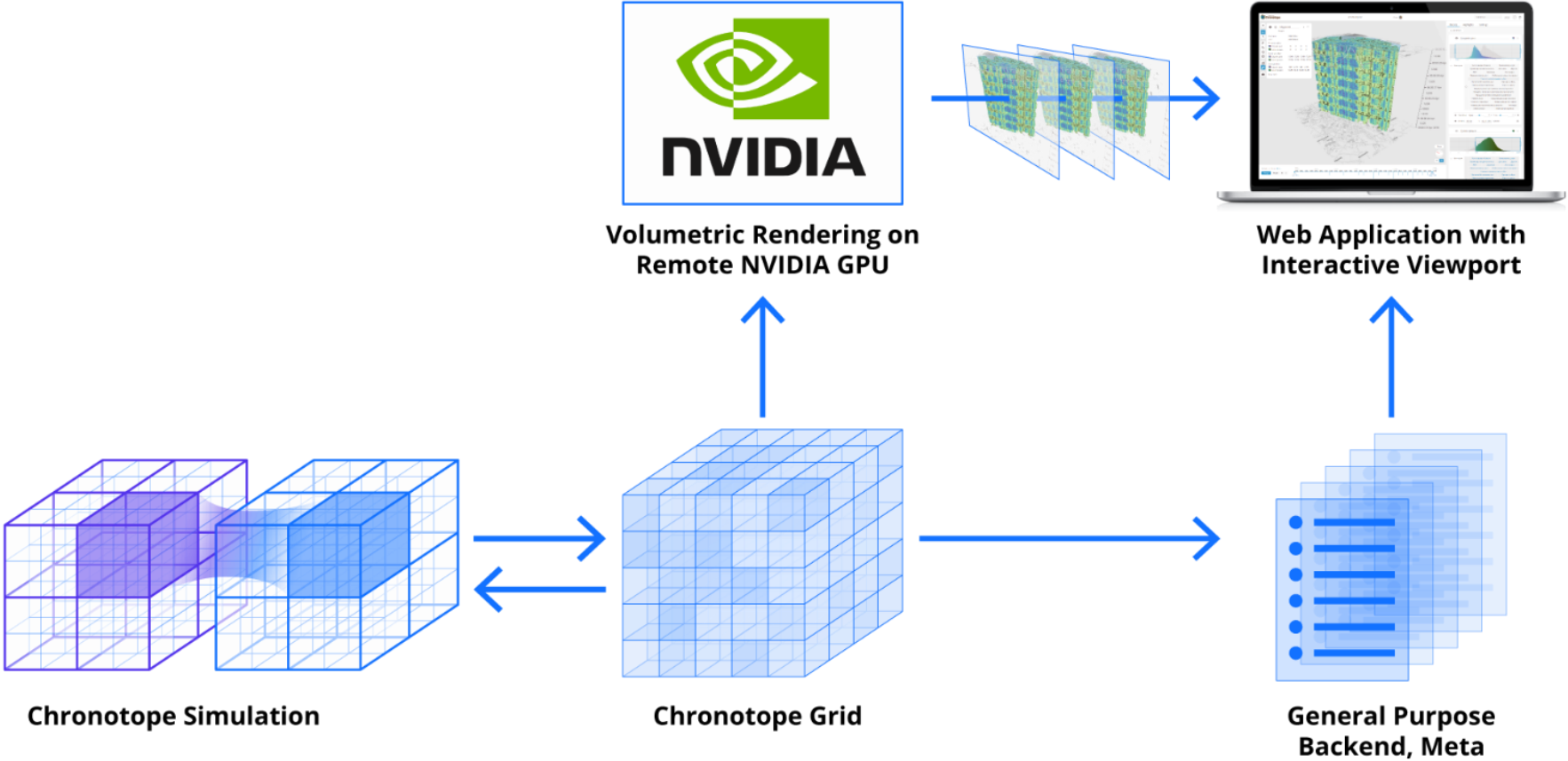
Is there a way to show map + time together?

Chronotope: Map + Time

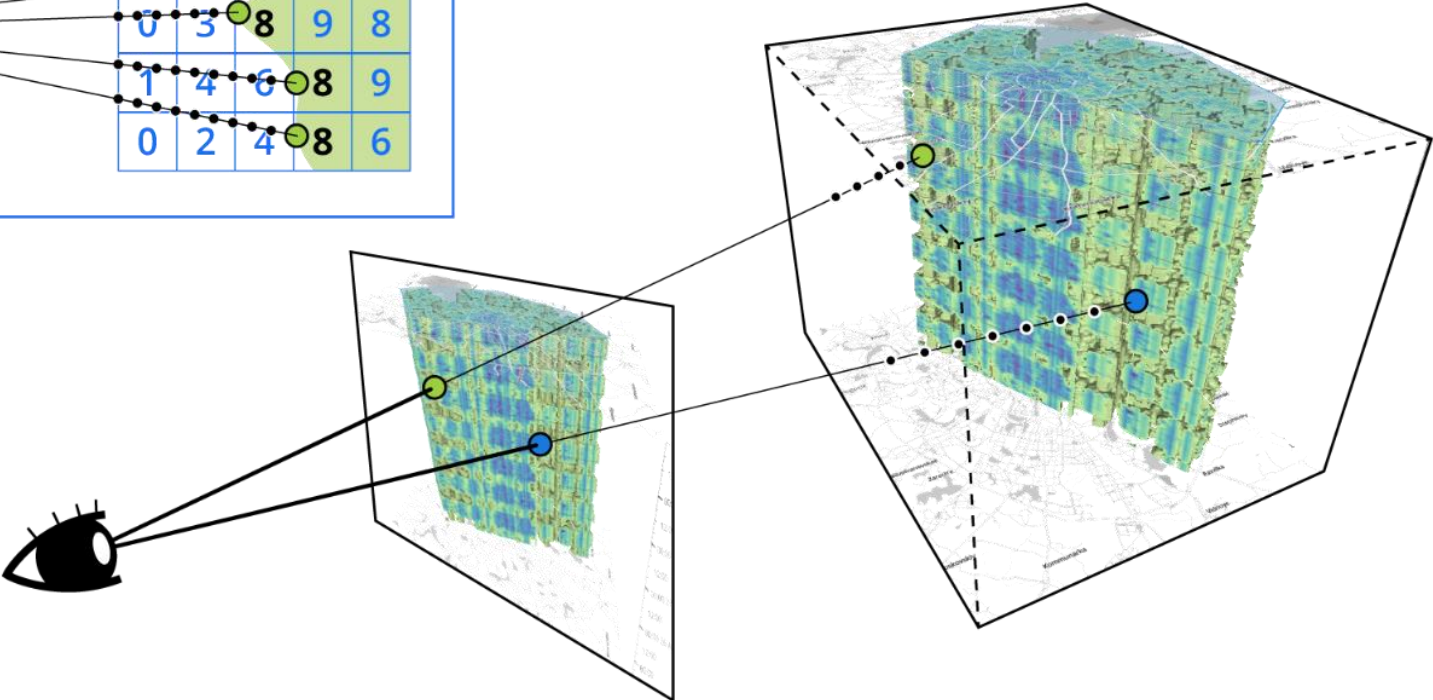
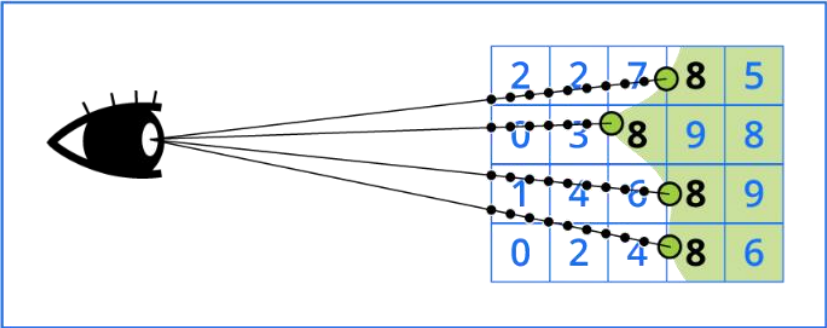


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Chronotope Architecture



Ray Tracing the City with NVIDIA

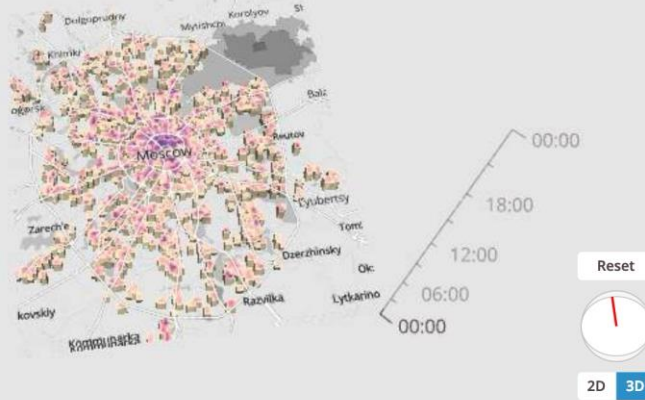
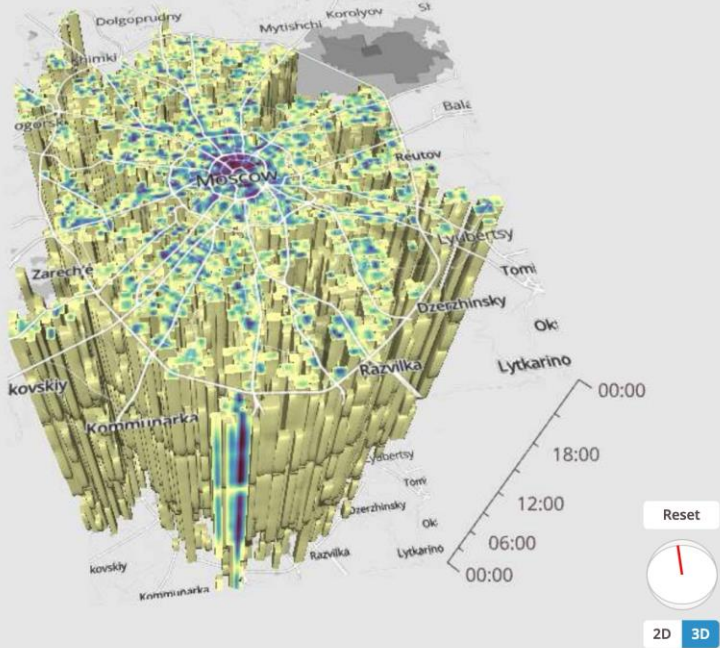


Eye

Projection plane

Ray-traced cube

Real Spend vs Predicted Spend in Space-Time



Simulation Limitations

- **Only a certain level of spatial granularity: not a small shop simulation**
- **Requires some minimal area to work: at least a 10 by 10 km city**
- **Works best as a rapid scenarios exploration tool**

Next Steps

- **Prediction for multiple categories of spend: Grocery vs Entertainment**
- **Adding data layers as input image channels: POI density, zoning**
- **Generation of maps for desert areas: starting without and input**

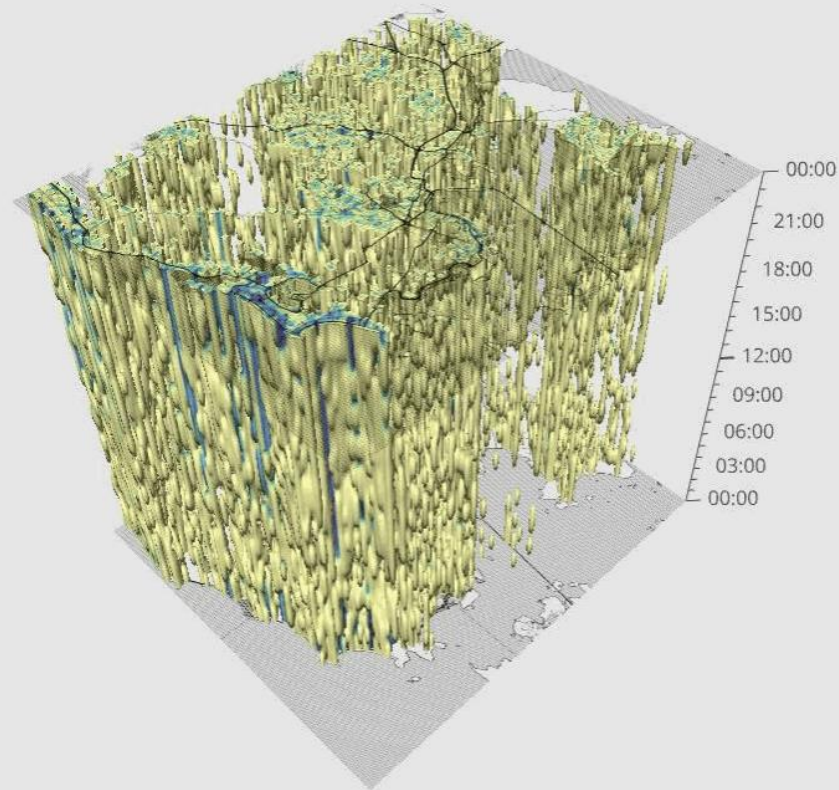
Chronotope: Imaging the City

City Scale Simulation

Rapid Exploration of scenarios before detailed field work and modelling

Nvidia GPU based visualization in **Space and Time**

Try it at cube.chronotope.io



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