Chair of Architectural Informatics
Department of Architecture
Technical University of Munich

PixBike

Ozan Karaali, H. Yildiz Basol

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Chair of Architectural Informatics
Prof. Dr.-Ing. Frank Petzold

Algorithmic Design
Ivan Bratoev, Frank Petzold
Ozan Karaali, H. Yildiz Basol
[redacted]

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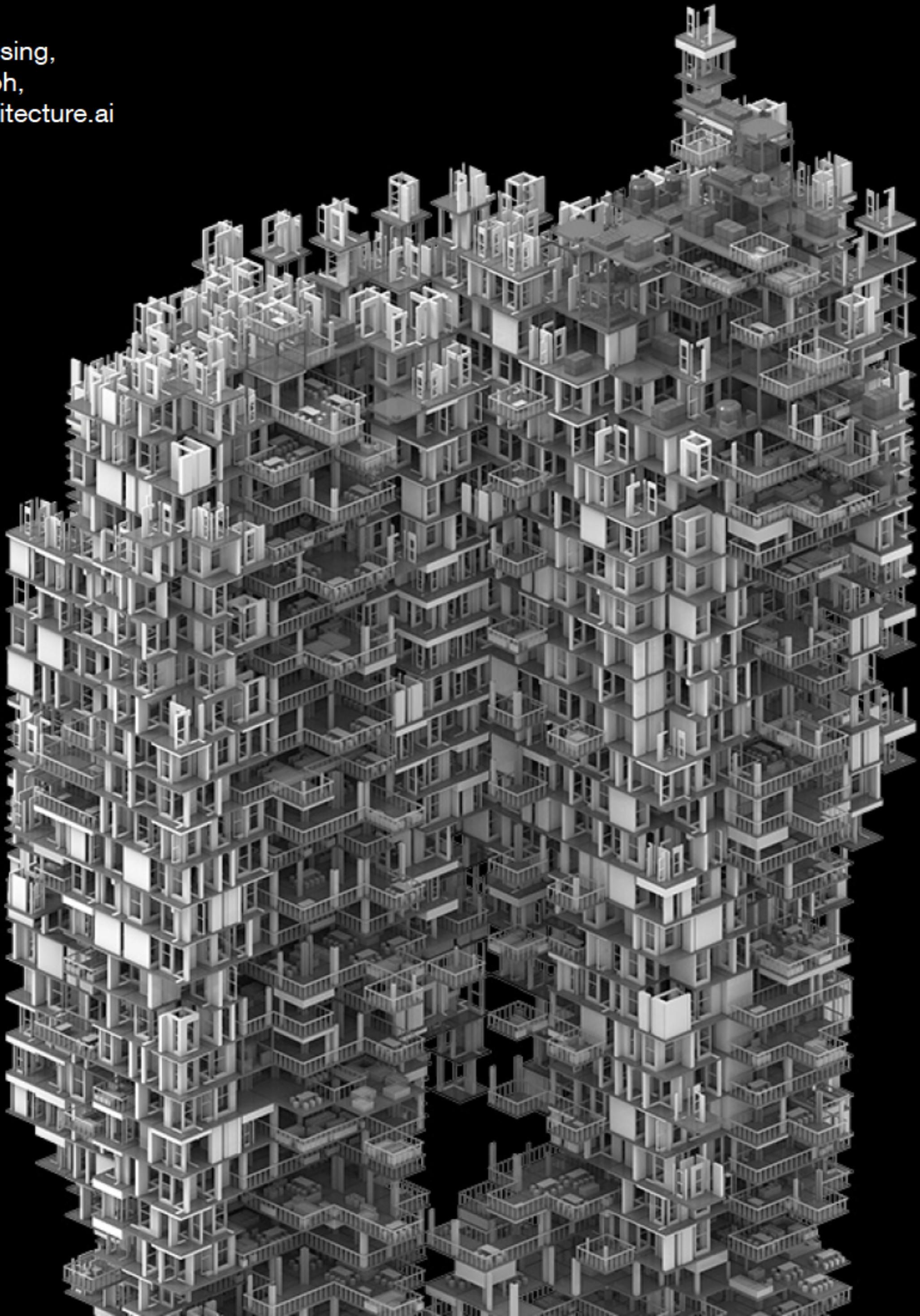
The Course

The Algorithmic Design course explores the role and application of artificial intelligence approaches and methods in all facets of architecture and urban design. These methods range from simple classifications of plans and facades, to segmentation and recognition of different objects in images, to exploring the possibilities of AI methods to predict simulation results and convert data from one type to another, e.g. from CAD drawings to BIM models.

Our first task was to come up with concepts where AI could be applied in an achitectural concept. In an interdisciplinary team we focused on how we can utilise AI to develop an easy and accessible tool for architects and urban designers, to help improve our environments.



3D GAN Housing,
Immanuel Koh,
artificial-architecture.ai

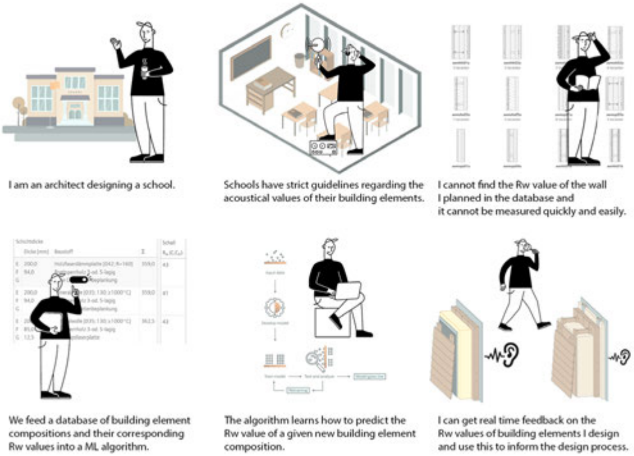
Storyboard Concepts

Our original concept ideas covered two very different topics on different scales. The first idea zoomed into an element detail scale whereas the second one had a wider focus on an urban scale.

The first idea addressed the how laboursome and complicated it is to find out how well a designed wall element would acoustically perform. The standard Rw-Value is a measured value and cannot be easily calculated in the design phase. The idea was to train an AI that could predict what the Rw Value of a planned wall element would be. The AI would be trained with already existing wall strucutres and theire Rw Values as input.

We decided not to follow this idea because it would not provide an advantage over a regular algorithm simulation and more importantly, the dataset we thought we could use, DataHolz, was not comprehensive or accessible enough and we did not have the time or resources to address that problem within the scope of this seminar.

The second idea addressed the traffic and public transport issues cities face. The idea was to utilise data from taxi companies to simulate traffic and pick the best routes and times for public transport vehicles such as busses.
The data available is much bigger and more clear in this concept. We also discussed the importance of improving sustainable urban mobility alternatives in today‘s world and decided to develop this concept idea further.



1. predicting the acoustical properties of a timber wall element

2. using traffic data from taxis to improve the public transport routes

Concept Development *the idea*

During the concept development stage, we tried to pinpoint how we could train an AI with traffic data in a way that would help re/design public transport.

We considered trying to solve the efficiency problem by optimising the time tables of a given bus route, or to pick which roads a bus should avoid at a given time to not get stuck in traffic, or to identify where the bus stops should be built so that there would be the least amount of stops still covering the needs of the citizens.

What we came to was that most those ideas fell into the data analysis category. We would be gathering valuable information yet would not be creating anything new with it. As traffic is a very complicated phenomenon with a lot of things factoring into it, the data could get really complicated to deal with within the scope of this seminar. Other than that, we realised that the taxi data represented the behaviour of only a small group of people, that might not behave in the same way public transport users would: does intense taxi use in an area tell us about the infrastructure of an area or the rather the ideologies of its inhabitants?

After confronting with the fact that we could not come up with a viable concept using traffic and taxi data, we started to consider alternatives and moved towards cycling themes.

We are drawn to urban mobility solutions, because of its importance in today‘s world. The way we move around in our cities is not sustainable, and if we want to move towards more sustainable means of transport, our cities need to be designed accordingly.

During our search for relevant papers, we found the one by Szell et al. called „Growing Urban Bicycle Networks“. In this paper the researchers „explore systematically the topological limitations of urban bicycle network development. [...] For 62 cities [they] study different variations of growing a synthetic bicycle network between an arbitrary set of points routed on the urban street network. [...] [They] also find pronounced overlaps of synthetically grown networks in cities with well-developed existing bicycle networks, showing that [their] model reflects reality. Growing networks from scratch makes [their] approach a generally applicable starting point for sustainable urban bicycle network planning with minimal data requirements. “ [1]

The GrowBike project deliberately ignores second order effects in order to be able to achieve global results. This is why the results must not be treated as concrete recommendations for new bicycle facilities. Any transport network has various local factors that would need to be accounted for, including: „road category, speed limit, volume of motorized traffic, or aspects of comfort“. [1]

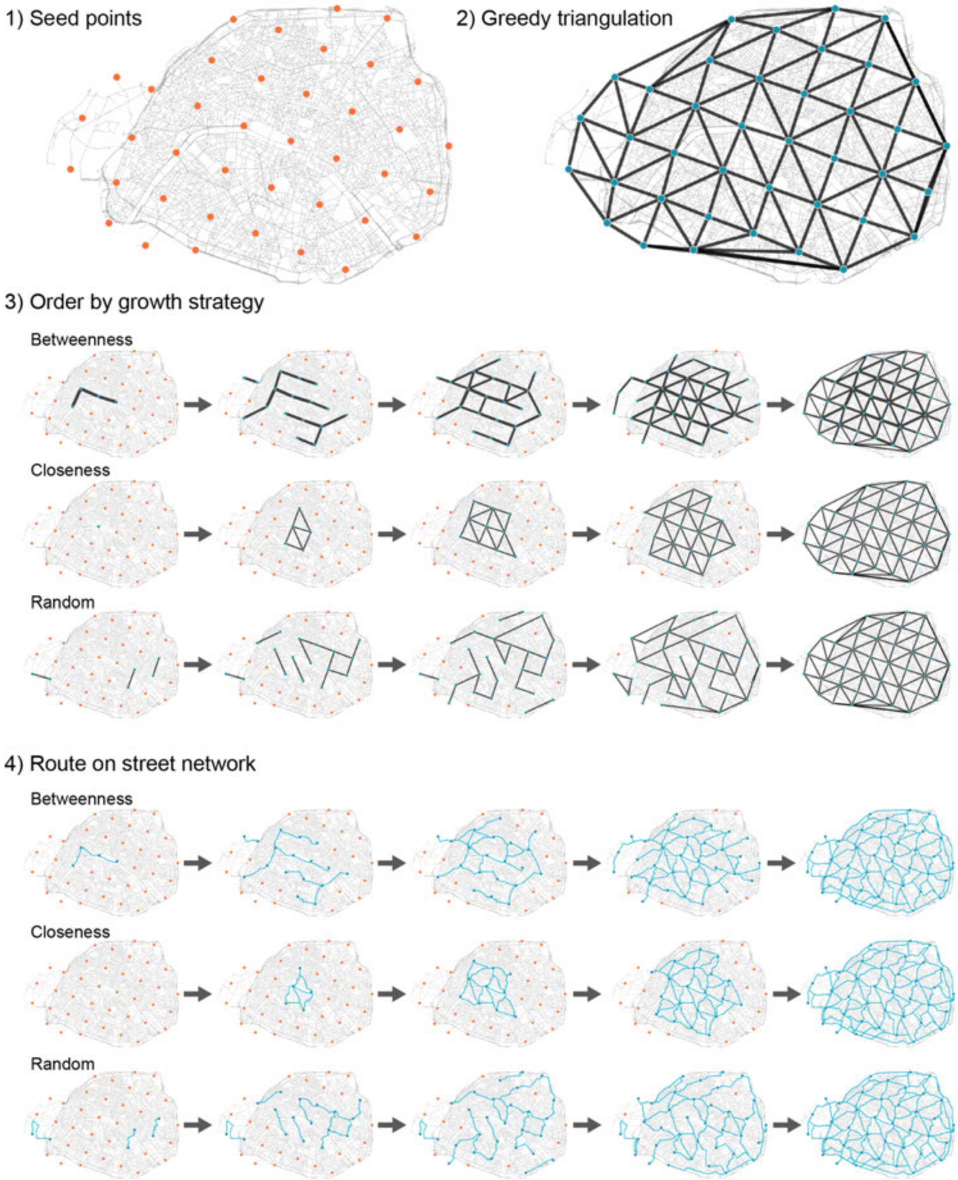
„*Despite the importance of these aspects, a transport network’s geometry is its most fundamental limitation*.“

That is the reason Szell et al. chose to explore the geometrical aspects of existing car networks as a first step. The results do not offer concrete solutions for each urban situation but are still valuable in planning context „for easily generating an initial vision of a cohesive bicycle network – to be refined subsequently.“[1]

The researchers‘ approach inspired us to develop our own take on the subject matter. Their solution was a simulation requiring high perfomance computing and it does not utilise artificial intelligence methods.[1] We decided to develop an AI based on their simulation data that would provide a glimpse of what a developing city‘s ideal cycling network could look like in a quick and easy way.

We followed the researcher‘s example and also chose to ignore second order effects and „sacrifice specifity for generalizability“.[1] We assume that the existing street networks can be retrofitted into cycling networks - maybe in near future when car use goes down.

Our intended user group is urban designers and experts, who can then make decisions for their specific local situations, taking this input into consideration.

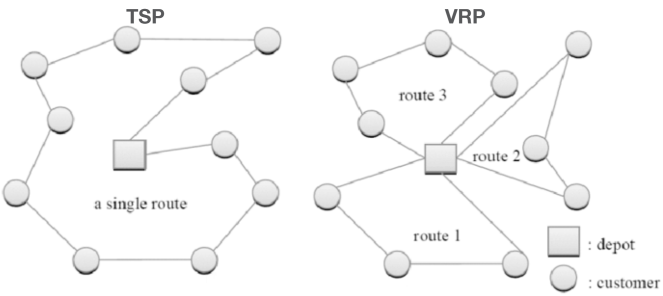


The process and different strategies of growth analysed in the „Growing Bicycle Networks“ [1]

Artificial Intelligence Research

Our aim has been to develop a tool that has a supporting role during urban planning and design takes place. That is why it is important for us that it is very easy to use, intuitive and accessible.

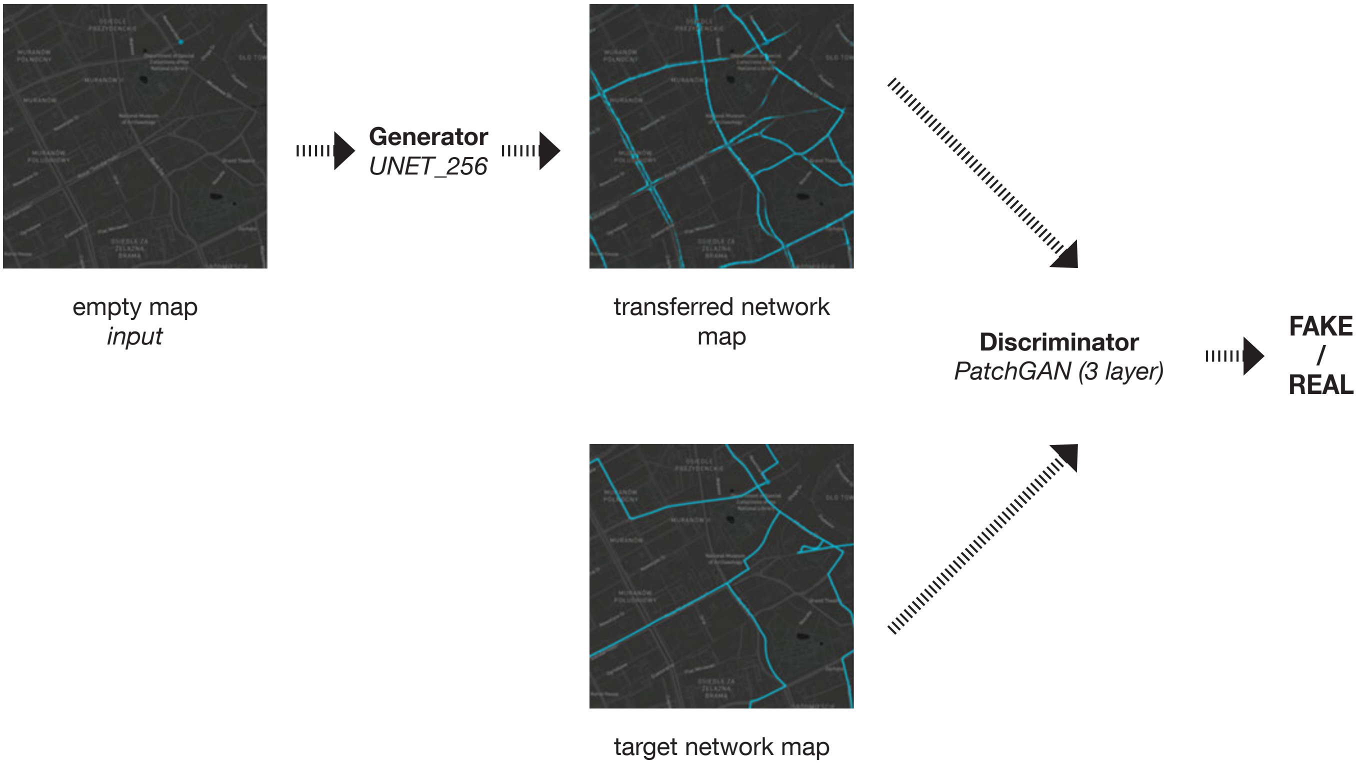
We decided to use **Pix2Pix** to translate „empty“ city plans into ones with cycling networks because it only requires a visual input from the user. The output produced is also very intuitive for an urban planer - it is a visual representation of the best network, a plan. We found it important to use a form of input/output that our intended user group is very well familiar with, in order to be able to achieve the supporting role in a planning process. A city plan is the most basic type of data any city would have readily available, even in developing countries where data might be scarce.



Travelling Salesman Problem
vs Vehicle Routing Problem [3]

Another way to approach this problem could be treating it as a vehicle routing / travelling salesman problem and using a graph machine learning approach between each grid dots as nodes and roads as edges to detect efficient paths. [2][3] We were more interested in exploring how machine learning highlights the efficient routes by using a **image to image transfer** between empty map and route simulation output.

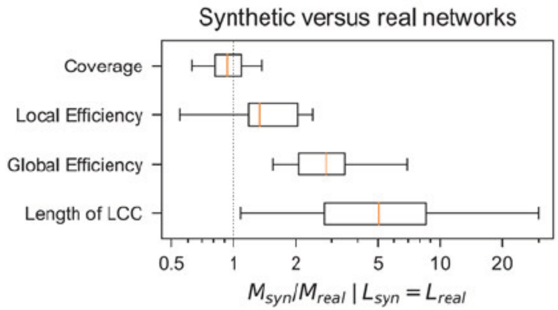
Pix2Pix Flow

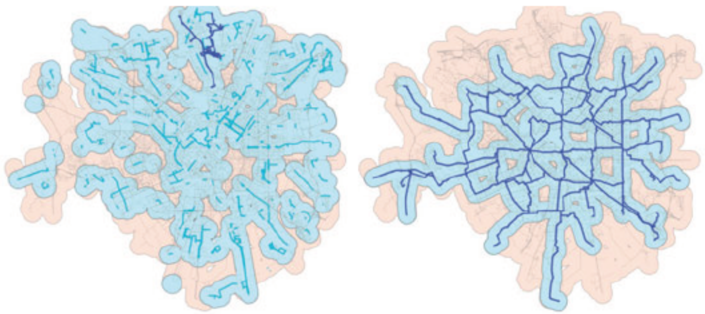


Pix2Pix - we worked with a Batch Size of 32 and a Learning Rate of 0.001

Data Structure

We chose to use the simulated data from the „Growing Bicycle Networks“ paper. This means less noise and more accurate input for us but more importantly, the synthetic bicycle network is shown to perform several times better than existing ones. [1]





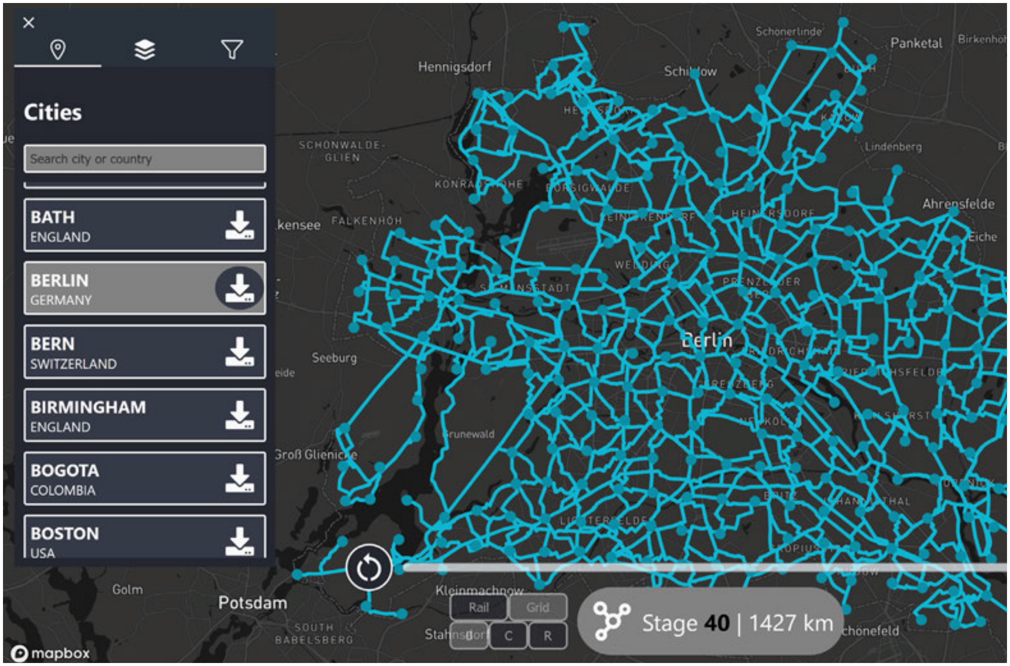
Real Milan

Synthetic Milan

The researchers run a website where they visualise their results and this is where we gathered our data: GrowBike.net

Using Selenium, first the cities were loaded and zoomed in. Then it navigated around until 10000 blue pixels were found on the given area. After that, two screenshots were taken of the central area - one with the cyclig network and one without. It kept navigating and the process repeated itself.

1279 screenshots (combined) were taken as dataset.



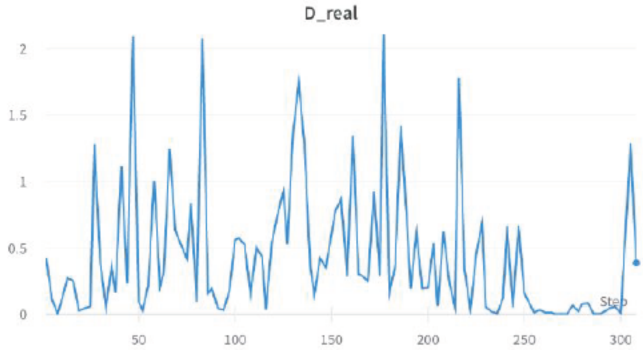
GrowBike.net interface

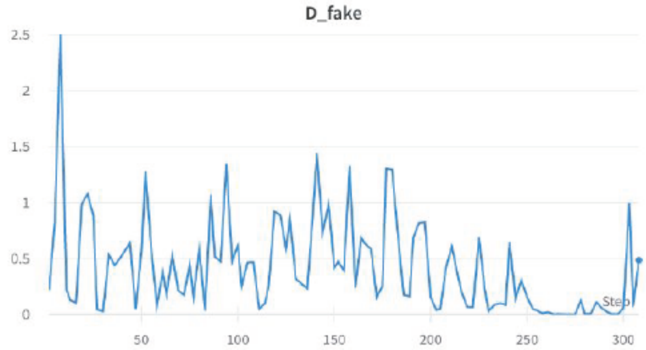
combined screenshot for the dataset - 1200x600

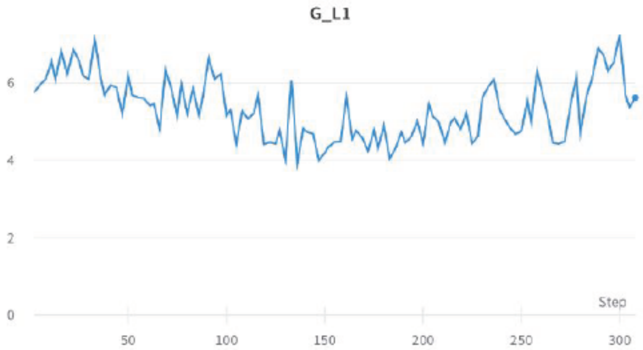
Prototype

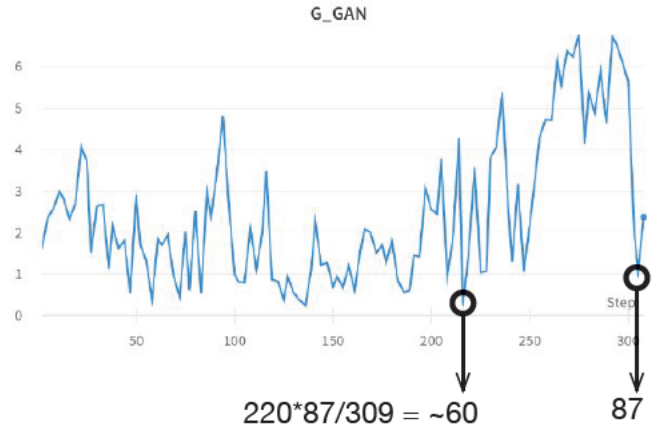
We have trained the model until **87th epoch** with a **learning rate of 0.001** and a **batch size of 32.**

This was sufficient enough to gather meaningful outputs. As shown in the 4th figure (G_GAN), the loss increases significantly after 60th epoch. We have saved the verification outputs for each epoch and we have encountered some visual artifacts -discussed further on the next page- due to the competition between generator and discriminator: the generator finds ways, or patterns, to fool the discriminator network.


D_real
Step


D_fake
Step


G_L1
Step


G_GAN
Step
220*87/309 = ~60
87

visual artifacts

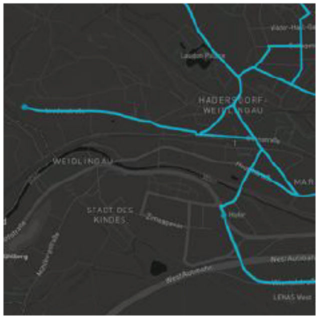
In order to address this issue we loaded different checkpoints and manually controlled for artifacts. Through this process it became clear that our problem was overfitting. The epochs with the best results were 55. and 60. epochs.

repeating patterns:
Generator finds a way to fool the discriminator by applying irrelevant patterns around the map, which does not resemble a road/pathway and it is retained between different epochs, such as 86-87th epochs.

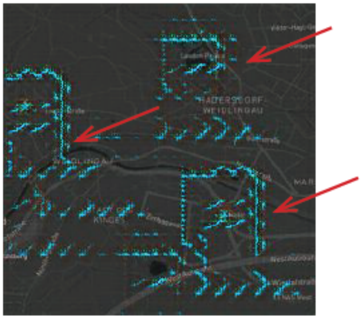
burn-in effect:
Generator finds a pattern looks like road/pathway on a part of map for each input that is given, there exists no roads to be built.

repeating patterns *86. epoch*

input



ground truth



output

burn-in effect

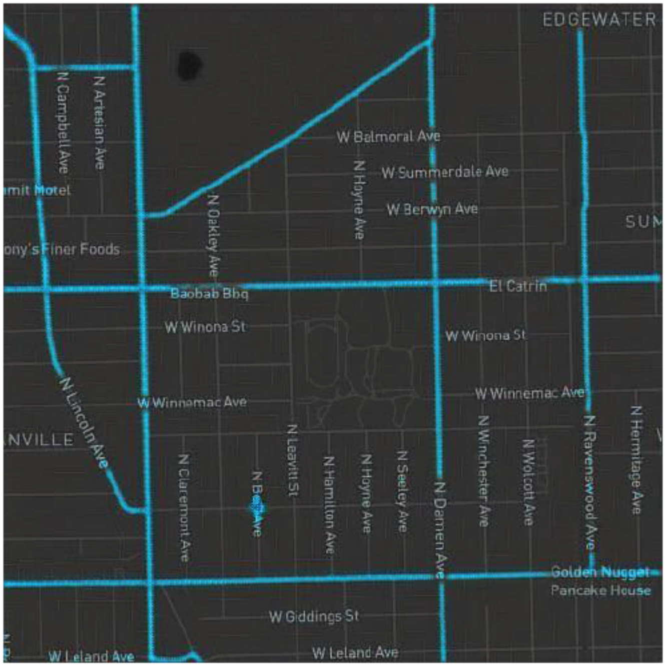
output 1

output 2

output 3

high resolution

Even though we haven‘t saved the weights for deliverable, we have tested to generate 512x512 outputs, as shown on the figures, it still does a decent work to generate pathways on important roads as advice for the designer. therefore, when there exists enough computational power, model can be trained to render higher quality maps and used later with computers which have less computational power with loading the pretrained weights!



output

ground truth

Reflection and Outlook

Working in an interdisciplinary team was great because we got to see how our approaches differ and got to learn from each other.
We see our prototype as a success - it achieved what we had set out to do within the limits of this seminar. We are happy with our choice to use Pix2Pix technology, but looking back on this process we realised that we could have done more research into other possibilities. Next time we will create space to take a step back and question before getting swept in an idea.

We find the next steps in the development would be to implement behavioral data (for example from a citywide bike sharing services) to improve the real life applicability in a certain location.

More resources such as high performance computers could be utilised to train the algortihm in higher resolution, to be used by simpler computers in the test time. This would increase the quality of the results without sacrificing the simple use we are aiming for.

At the moment, our algorithm creates fully constructed cycling network maps from scratch. In the future we could experiment with different stages between fully constructed and empty map to learn most important routes.

References

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[3] Herdianti, Wulan & Gunawan, Alexander & Komsiyah, Siti. (2021). Distribution Cost Optimization Using Pigeon Inspired Optimization Method with Reverse Learning Mechanism. Procedia Computer Science. 179. 920-929. 10.1016/j.procs.2021.01.081.

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[5] P. Isola, J. Zhu, T. Zhou and A. Efros, „Image-to-Image Translation with Conditional Adversarial Networks“, CVPR, 2017. Available: https://doi.org/10.48550/arXiv.1611.07004 [Accessed 31 August 2022].

Contact

Ozan Karaali
[redacted]
4, M.Sc.
ozan.karaali@tum.de
[redacted]

H. Yildiz Basol
[redacted]
4, M.A.
yildiz.basol@tum.de
[redacted]