Applying simulation inference to city planning tools

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Abstract

The way cities are structured and designed can have a massive impact on everything ranging from human health, to climate change, to societal equity. Understanding the relationship between a city's features to these qualities is paramount to designing cities according to our goals as a society. Simulation-based inference is a method in which a simulator is described by a joint distribution over some output of a simulation and some latent variables, contitioned on some input. We thereby can attempt to learn the relationship between the output and the input parameters. We apply this technique to A/B Street, a traffic simulation tool, by investigating the impact of an intersection's structure on the average trip time in the wider area. We find that.... We hope that these results show that simulation inference can be applied on the wider urban planning field as a whole.

Background

City and infrastructure design is only becoming more crucial as we as a society become more cognizant of out impact on climate change, public health, and racial and socio-economic equity. It is widely understood that the structural design of our cities have a marked impact on our wellbeing both individually and collectively, so it is therefore in our best interest to design and propose policy that actively strives towards "better" cities.

However, a major impedance of this goal is the number of conflating factors and differing goals (politically and technically) when considering optimal design. Each can have innumerable differences from another: their geographic topology, climate, socio-economic and race composition, historical features, and so on.

As a result, a deeper understanding of a city's design on its residents, resource usage, and so on, is extremely desirable to motivate better policy and design recommendations, but correspondingly can be difficult to pin down.

To approach this problem, we attempt to apply an inference technique developed by Papamakarios and Murray [1] on A/B Street, a road/city planning simulation [2], as a proof-of-concept application of simulation inference on city planning simulations to broadly learn the impacts of traffic and road design on the efficiency and resource use of a city.

Method

[inference]

[ab street]

A/B Street is a city and traffic simulator developed by Dustin Carlino, built using the Open Street Map (OSM) format [3]. It is widely flexible and supports importing any map through OSM, changing lane type (driving, bus, bike) and speed limits, traffic light timings, among others. It also has built in visualization, data aggregation, and an API through which we can control the simulation headlessly via Python code. We chose A/B Street due to these factors, contributing to its ease of using it as a black box for the simulation inference.

Street

GUI

output

We plan to write an inference package that runs and accepts output from the A/B street simulations and understand the underlying posterior of road structure on city and travel efficiency.

Expected Results

Using simulation inference, we hope to gain deeper insight on the design of intersections and intra-city roads on overall travel time and throughput, which may be counter-intuitive to what we may expect.

Future Goals

As stated above, we use A/B Street and road design as a preliminary proof-of-concept on the application of simulation inference on city design. However, there are many more ways we can utilize this technique beyond just roads.

A burgeoning field is that of understanding city design on the emissions produced by a city, and understanding how the block and road structure impacts the city's contribution to climate change. Gim performed a global study of land-use on a various city's emissions, for example, congestion leading to longer trip times leading to greater emissions [4]. By using a model and performing inference on it, we can potentially understanding how to more granularly change current cities or motivate future cities to reduce resource use and CO_2 emissions.

Relatedly is the concept of urban heat islands–when the city itself is warmer than the surrounding areas, resulting in greater air-pollution, heat-related illnesses. Understanding how building material and block structure impacts this could be of massive benefit. Gober et al. explored this for Phoenix, Arizona, by modeling three different scenarios based on gathered data [5]. We could potentially use simulation inference on their model to more fundamentally understand the land-use and heat island relationship.

Another area of interest is how policy changes can influence land-use in certain areas, thereby influencing everything about the city itself–from emissions to all the other qualities discussed above. Landis investigated this using their California Urban Futures Model, where they simulated the results of three different scenarios: "business as usual", "Maximum Environmental Protection", and "Compact Cities" [6]. By applying inference on the model, perhaps we can obtain more optimal, fine grained policy recommendations than just three scenarios would illuminate.

We've discussed several potential paths and application for this research moving forward, however, there are many more that can and should be investigated. Urban planning as a field is growing rapidly, and in turn, applications of computational techniques in the urban planning space are similarly growing. With the results we have presented here, we hope to have shown that the application of computational techniques developed for physics, math, and so on could have countless uses in urban planning, and could serve to benefit society as a whole.

Author Contributions

J.H. proposed the paths and topics that could benefit from applying computational methods upon. S.G. proposed applying the inference technique to city planning simulations and found the specific simulator A/B Street. Both members discussed the potential areas of exploration using A/B Street. S.G. wrote the inference wrapper upon A/B Street and J.H. ran and enabled the software to run (via singularity container) on the USC computing cluster.

References

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