ab-walkable Cities

A Grid-Based Analysis Method to Identify Walkable Neighborhoods for Goal-Directed Pedestrians

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Current research treats walkability in cities as an urban asset, to be identified by formal methods in order to let people benefit from it. In this paper, we take an activity-based view on the subject, arguing that walkability is not an end in itself but must always be seen from the standpoint of a specific activity to be performed. More precisely, we look at the specific walkability when seeking to perform an activity 'a' (e.g. shopping) within a given time budget 'b' (e.g. 15 minutes). Based on these two factors, we have devised a grid-based analysis method that computes transitions between grid cells. As result, we get a walkability map that extends the traditional 'proximity-based' understanding of neighborhoods by the notion of goal-directed pedestrians. To argue for the applicability of our approach, we showcase i it in two cities with different urban structure (Yerevan and Wiener Neustadt) before concluding.

Keywords: *Walkability, Agent-Based Simulation, Activity, Time Budget*

INTRODUCTION

Walkability is *en vogue*: Vienna, the city in which this eCAADe conference is held, has for example declared a 'Year of Walking'[1], sporting a multitude of events and conferences around the subject. However, what 'walkable' actually means is still far from clear: One might see it as an *objective for urban development*, leading to walkable cities, other methods see 'walkability' as *analytical measure* deduced from spatial configuration. Our approach falls into the latter category. It integrates two notions of spatial configurations - global configuration of pedestrian walkways (as seen from above for a whole city) and the localized configuration of walkways (as seen by each individual pedestrian) - into a common framework. In more detail,

1. we present a novel method that computes walkability as time taken to walk to a place serving a specific activity a, given a time budget b. The approach uses a grid-based computation of transition times between the starting cell and all target cells (see Figure 1), utilizing a shortest-path search (Dijkstra algorithm) on the underlying path network as a means (also see Details)
2. apart from an individual starting spot, we may also determine walkability within a specific

district, from a specific district to all districts and between all districts of a city; in this way, an Integration Analysis can be made on different levels of a city or neighborhood (Figure 2)

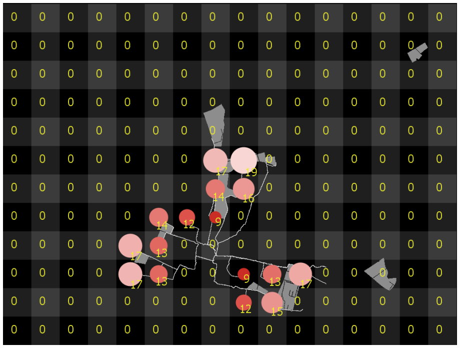

Figure 1
Reachable education sites in Wiener Neustadt within 20 minutes of walking, starting at the main railway station of the city.

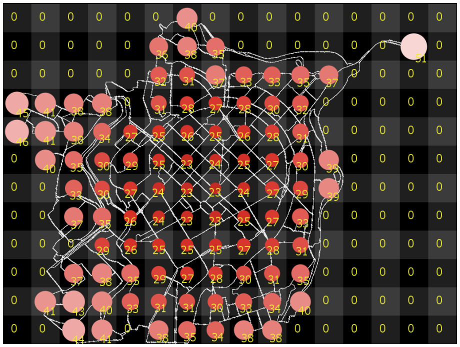

Figure 2
Global Integration Analysis of the Inner district of Yerevan

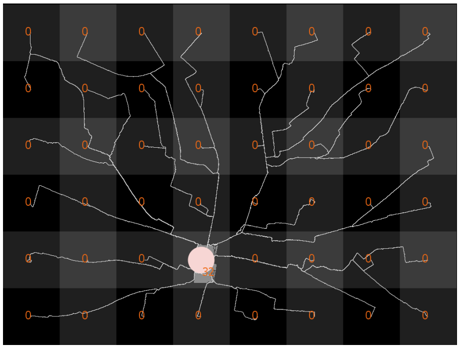

Figure 3
Location study of the main railway station in Wiener Neustadt, average time taken from the whole city.

As a further benefit of our method, we may perform location studies for specific sites under the constraint of a specific set of activities (Figure 3). A calculated number showing the average time taken to an area where these activities are served gives an easily comprehensible indicator for theoretically possible walkabilities when having different locations as options. In that context, the relation with real-estate development lies at hand.

The location study in Fig. 3 uses starting points for virtual people (agents) on the whole map of Wiener Neustadt. These agents walk over the citie's roads on shortest paths to the main railwaystation (target). At the target, the agents have moved a certain time that is shown as the average time of all agents together. The railwaystation in this case can be reached within 32 minutes (average time) from all over the city.

Furthermore, we can use our method to compare different cities with regards to their walkability. In that case, we use a gradient based on travel times, as given in the examples in Figures 4 and 5.

BACKGROUND

Global Walkability

The methods of *Space Syntax* (Hillier and Stutz 2005) [2] have been used to analyze

- the static configuration of walkways (*axial analysis*, using lines along pedestrian routes),
- the agregation of all potentially visible areas (*visibility graph analysis*, typically achieved by regular subdivision of a space, where a viewshed is computed from each subdivision cell's midpoint) and
- the aggregated pattern resulting from pedestrian route choice using a dynamic agent-based model (*EVAS spatial agents* performing wayfinding by their vision),

resulting in the determination of spatial configurations that influence movement (*Walkability Index*). Sevtsuk et al. (2013) capture walkability based on *urban intensity* in addition to *urban density*: Density refers to the concentration of people and built features, leading to a potential for walking. Intensity refers to the concentration of activities in an area, i.e. the utilization of that potential. Chian and Janssen (2014) explore walkability in a high-density context (100,000 people on 1km^2) using a multi-objective genetic algorithm to find urban space configurations minimizing travel times and maximizing accessibility to open space. They show three types of *advantageous urban typologies* surrounded by open space: (1.) compact town typology consisting of a single compact area, (2.) segregated town typology consisting of clusters of areas and (3.) stretched town typology consisting of an area meandering through the site.

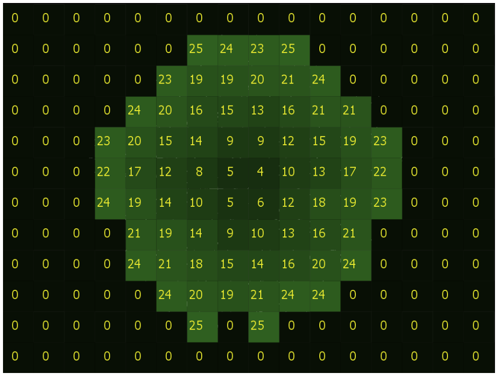

Figure 4
Wiener Neustadt

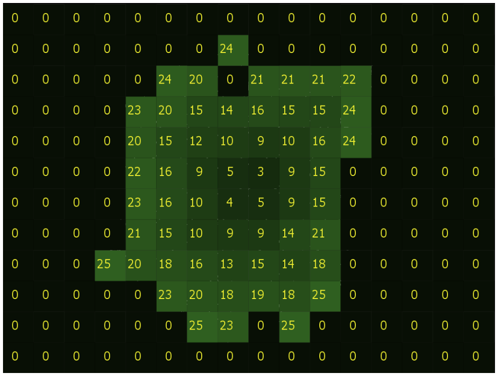

Figure 5
Yerevan

Individual Walkability

This type of walkability analysis examines the effects of the urban configuration based on the experience of individuals. Lynch (1960) famously argued for a view of cities as neighborhoods formed by the "mental pictures" of their inhabitants. In a recent extension, Pak and Verbeke (2013) have presented a *mobile assessment tool* for surveying walkability in two different modes: (1.) Qualitative statements regarding walkability at specific spots in the spirit of Lynch, entered as geolocated notes which are classified in a post-step, (2.) a subsequent quantitative survey on these classes, when seeing walkability as a performance indicator of the urban configuration.

RELATED WORK

Apart from the approaches mentioned in the Background section, a large body of work on activity-based travel analysis exists. The group of Harry Timmermans at TU Eindhoven is of specific importance in that field: Based on surveyed activity envelopes of travelers, the group typically analyses multi-modal travel choices and connected factors such as environmental impact. One example among many others it the recently-published study on childrens' travel behavior (Kemperman and Timmermans 2014), in which the authors investigate to what extent children walk or take the bike to reach their next place of activity. The approach also models the impacts of different degrees of urbanization and car possession on mode choice.

Including multi-modal transportation into our approach would seemingly be a good extension to our approach, which we have explored in a different setting (options for modal switch of intra-city commuters in Vienna, Hartl and Wurzer 2013). The insights gained in that context where strikingly simple - the fastest mode of transport is dependent on travel distance (short ways by foot or bike, longer ways by public transport or car); cases in which time was saved by multi-modal switching where marginal (<5% of cases) in uncondensed situations. For high-density traffic (mornings, evenings), we could in principle save some time by switching (e.g. car to public transport), however, the additional switch time leads to the situation that only long-distance travellers can get a benefit.

For this work, we have opted to use constant velocity and no congestion for our agents. The resulting travel times can always be mapped to a mode of transport by static assignment (<10m walk, <30min bike, <60min public transport, else: car). Including congestion, dynamic route choice and diversified behaviour would require more input, but might lead to more realistic space-time geographies.

Another area where we have chosen to stay simple is the actual distribution of travelers throughout an area of interest and individual characteristics of the trips conducted. We so-far assume that travels can potentially take place between each two (rasterized) grid cells of the urban area, this is: we treat all cells equally and do not take any form of densities into account. Each travel is represented by a single agent with a single desired activity, who travels from a source cell to a target cell in which this activity can be served. However, we are aware that several methods have been brought forward (most of them again coming from Timmerman's group) that focus on exactly these aspects. Among uncountably many examples we want to name Ettema (1996), who has extensively surveyed activity-based travel demand, and Dijkstra et al. (2014), who have focused on microsimulating shopping streets with regards to planned and unplanned store visits. Making traveling behavior truly dynamic can always be achieved using the mentioned approaches, as we already use an Agent-Based Simulation as our platform.

METHOD

Our work is based on the simulation of individual pedestrians who act in a goal-directed manner (*Agent-Based Simulation*). The algorithm for doing this starts by importing the circulation as a black-and-white image in which all white pixels stand for "roads". In the center of each such pixel, we create a graph node. Graph nodes of neighboring pixels are connected by edges (we use 8-neighborship, although 4-neighborship would be sufficient as well). The result is a circulation graph (simply called "the circulation" from here on) which can be used to route agents. As next step, we load an indexed image in which every color corresponds to a specific function. The mapping is hard-coded at the moment, color 1 corresponding to "shopping", color 2 to "leisure" and so on, without loss of generality: We could always load this mapping in a more sophisticated manner (e.g. via a spreadsheet or directly by using formats that allow for a specification of per-pixel attributes such as ESRI .shp files found in the GIS world). In a next step, we load an indexed image in which each color corresponds directly to a zone (color 1 = zone 1, color 2 = zone 2 and so on). As last step of the setup procedure, we rasterize the map into a square lattice of parametrizeable resolution - each cell of the lattice then "owns" $r \cdot r$ pixels, r being the resolution):

```
Setup
 load black-and-white image
 build circulation graph from white
  ↪ pixels
 load indexed image
 map color indices to functions
 load indexed image
 map color indices to zones
 rasterize map into lattice of given
  ↪ resolution
End
```

The actual computation of transitions takes a source cell and computes paths leading to cells serving a specified activity. In further detail, we simulate the path of an agent leading from center of the source cell over the circulation of a city to the destination cell. If the cell on which an agent is standing does not have a circulation node, we lead him on a direct path to the nearest circulation cell. Now that the agent is standing "on" the circulation, we can determine the route over the circulation by using a Dijkstra algorithm (least cost path). If the destination cell does not have a circulation node contained, we instead use the nearest circulation node as a target and afterwards lead him on a direct path to the destination cell's center:

```
ComputeTransitions
  determine paths from source cell to
   ↪ cells serving the activity a
End
```

Each agent carries a time budget (in minutes), which makes it either (a) reach its destination or (b) stop beforehands (goal not reachable). For all reachable cells, we accumulate the time taken until there. This yields either an absolute number or the average time of all arrived agents:

```
MeasureWalkability
  for each path, simulate transition
   ↪ using agent with time budget b
  accumulate time needed for
   ↪ transitioning in each cell
End
```

The aggregation of times in each cell gives a measure of "walkability" - i.e. how easy it is to arrive at that spot from the viewpoint of time taken. It does, however, not offer insights on legibility of routes or other qualities as given by the aforementioned literature on individual walkability. However, by repeating this process also from every cell into every other cell, we get a global measure of walkability throughout a city which is comparable to the methods of space syntax. An elaboration of the different choices in that context (within-district walkability, district-to-city, whole-city walkability) will be given and discussed in comparison to space syntax in the full paper. Furthermore, we give a case on the comparison of cities using a overlayed time-map (see Figure 2), using the two examples of Wiener Neustadt (close to Vienna) and Yerevan as a showcase.

OUTCOMES

These two very different cities were chosen to proof the unrestricted usability of the model. On the one hand, there is Yerevan, a very old city with over one million inhabitants, located in a valley between some mountains. A city that went through many changes during its first appearence on the map. On the other hand, there is Wiener Neustadt, a very small city, completely planned and not even 1000 years old, located on a flat ground, not even cut by a river. These two cities were the base for testing the model, and there are some interesting outcomes of walkabilitymeasures. As shown in Fig. 4 and 5, the global walkability in Wiener Neustadt is much better than in Yerevan. The bigger the time budget is, the better Wiener Neustadt becomes. The graphics show a time budget of 25 minutes in both cities - the green areas can be reached within this time, start walking in the map center.

DISCUSSION AND FUTURE DIRECTIONS

The range of different analysis, that can be made by the model, is compareable with some existing methods of measuring the walkability. The most important ones are the integration analysis of Space Syntax, the walkability analysis of Walk Score, and the walking audits (e.g. PERS).As shown in Fig. 1, the shortest paths from a certain starting point to all targets can be identified. This analysis cannot say anything about the path quality, but it shows the roads which would be useful to be developed for pedestrians. Target should be a seperation of pedestrians and vehicle drivers, to reach the best safety outcome for the walkers. After this analysis could follow a walking audit on the identified paths, to gain informations about deficites on these paths.In Fig. 2, a global integration analysis has been made for the inner district of Yerevan. In every cell, the average time to walk there from every other cell is measured. This type of integration analysis should be compared with the integration analysis of Space Syntax. Space Syntax identifies the most driveable roads in this analysis, while our method shows the most walkable paths.Fig. 3 shows a location study for the main railway station in Wiener Neustadt. It measures the averyge time from all over the city to get there by foot. This analysis can also be compared with other cities. The reachability of certain places in different cities, for example: walking to the city center, show the theoretical friendliness of walking. Walk Score is doing nearly the same things, as shown in Fig. 1 and 3. A travel-time-map can be shown and activities like schools, shopping,... are implemented. The differences are, that walk score cannot identify shortest paths to specific targets and is not able to do the integration analysis.

CONCLUSIONS

The conclusion of the work is, that there is no perfect method for measuring the walkability. To gain nearly perfect outcomes, some methods have to be combined. Our method can be considered to be a connector between methods - a base analysis that goes before the walking audit, to save resources there. An integration analysis of the view of the pedestrian itself, instead of the global observer - or a tool for location studies. It can be used for traffic- and city-plannings to seperate driving paths from pedestrian paths, under respectation of the wishes from both groups. And...it is useable all over the world, wherever map material is provided.

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