United-and-Close: An interactive visual platform for assessing urban segregation within the 15-minutes paradigm

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The ‘15-minute city’ paradigm is an urban model based on the concept of ‘hyper-proximity’: citizens should be able to access fundamental services and facilities (such as schools, shops, parks, doctors, and markets) within 15-20 minutes on foot, by bicycle or by public transport. Compliance with the ‘15-minute city’ paradigm is supposed to reduce pollution and social inequalities. It is supposed to bring the psychological fragility of the citizen back to the center of the urban redevelopment debate. Although the concept has gained great attention and interest from policymakers and urban designers, we still lack tools that can help to validate, on a data-driven basis, the assumption that hyper-proximity is eventually correlated with lower urban segregation, which is one of the driving forces that lead to social inequalities. We aim to define a data-driven methodology to analyze the urban areas where services should be accessible within 15 minutes; network analysis is exploited to estimate services proximity as well as the connectivity of different urban areas with each other, in order to gather signals of the general resilience or exposure to urban segregation. We also aim to compute a set of city-agnostic metrics that will include user-specified parameters and personalized weights for each Point of Interest’s category. United-and-Close is the resulting Web platform designed to be accessible to citizens, policy and decision-makers, and investors, but also for researchers involved in disciplines such as urban informatics that need support to better assess the 15-minute paradigm and its actual impact on our cities.

CCS Concepts: • **Information systems** → *Geographic information systems*; *Personalization*; • **Mathematics of computing** → **Paths and connectivity problems**.

Additional Key Words and Phrases: 15-minute City paradigm, inclusive urban design, accessibility

ACM Reference Format:
Mirko Lai, Salvatore Vilella, Federica Cena, Viviana Patti, and Giancarlo Ruffo. 2023. United-and-Close: An interactive visual platform for assessing urban segregation within the 15-minutes paradigm. In *UMAP ’23, the 31st ACM Conference on User Modeling, Adaptation and Personalization, June 26–29, 2023, Limassol, Cyprus.* ACM, New York, NY, USA, 8 pages. https://doi.org/3563359.3597443

1 INTRODUCTION

Nowadays, according to The World Bank [1], the most of world’s population lives in urban areas and this trend is expected to continue. People move to cities in search of better living conditions, job opportunities, education, and welfare. The ability of cities to guarantee access to services for a growing number of citizens is a key issue that needs to be addressed in the current “Automobile City”.

Manuscript submitted to ACM

In this context, the "15-minute city" concept [8] is one of the most successful urban planning paradigms that have been proposed recently and that gained a lot of attention during the pandemic era. It has been proposed to create a liveable environment by providing basic amenities and services (such as schools, shops, parks, doctors, markets) in a radius of 15 minutes by soft mobility (walking, biking, or using public transit) from any point in the city, in a "hyper-proximity" vision [7, 10, 15]. The idea is in this way to decrease car reliance and consequently traffic, impacting both air and noise pollution and the physical and mental health of citizens. The concept is finally intended to reduce the services accessibility gap between neighborhoods, making the city more accessible. The covid-19 pandemic crisis has exacerbated those issues [2, 4, 5, 8]. Lockdowns highlighted social disparities and accessibility gaps between neighborhoods demonstrating the importance of providing access to essential services within a few minutes from home for all citizens.

It is known that socioeconomic inequalities between neighborhoods have a significant impact on health conditions and life expectancy [14]. The economic shock increased mental health problems and the spread of harmful social behaviors [16], which are probably an indication of a very profound disease, perceived or real. Furthermore, reducing travel demand could positively impact congestion, noise, and air pollution (as observed in different cities during the COVID-19 lockdown period [6]), and oil dependence. In such a challenging context, it is no wonder that the '15-minute city' paradigm was relaunched even further as a post-COVID strategy in historical European capitals [3]. Therefore, the 15-minute paradigm supporters stress the importance of spatial and urban development based on careful planning and strategies to foster mental and physical health, without neglecting sustainable growth and the fight against climate change.

Despite the growing popularity and appeal of this paradigm, the principle itself has attracted criticisms [9]: some urban designers such as Jay Pitter recall that European and North American cities suffer from "segregated neighborhoods, deep amenity inequity and discriminatory policing of our public spaces". Under this perspective, improving walkability or creating more bike lanes, can be opposed by citizens living in marginalized communities, because these approaches can amplify segregation (by confining citizens in isolated neighborhoods with their own services) or also trigger new gentrification processes. This represents an intrinsic paradox of the '15-minute' paradigm: although its main objective is to implement the hyper-proximity principle, it could fail by stretching already existing distances between different neighborhoods [9]. Spatial segregation is a well-known and widely studied phenomenon. Just to mention at least one of the most important contributions that aim to understand the emergence of segregation in a city, we cite the work of the Nobel laureate T. Schelling [12]. He demonstrated, through an agent-based model, that a highly segregated society may easily emerge even if we assume that people have only a very mild preference towards the presence of other individuals in their own group in the neighborhood. In other words, spatial segregation could emerge spontaneously in a very tolerant society, and urban planning must be designed accordingly to promote higher levels of integration. Therefore, it is not surprising that our cities' neighborhoods often show a heterogeneous distribution of access to services.

The main question that we try to tackle with the creation of United-and-Close, our web-based interactive visual platform, is if we can estimate a given city's neighborhoods segregation altogether with compliance with the 15-minute paradigm of the same neighborhoods. With our approach, we want to support the empirical investigation of how often *local* hyper-proximity coexists with *city-wide* sustainable distances. Our purpose is that such a platform would be used as a tool by researchers and policymakers aiming at spotting actual opportunities and challenges in the realization of the 15-minute paradigm in a given city; also, the United-and-Close platform could be adopted by ordinary citizens looking for a personalized application of the paradigm when they are engaged in finding an area of the city where to live, according to some user-specified parameters.

2 OUR PROPOSED APPROACH

We aim at defining a data-driven methodology to compute the urban areas accessible in 15 minutes, taking up the following main questions:

(1) When we focus on city areas, can we get rid of the official administrative districts and compute our metrics on more naturally emerging neighborhoods?
(2) Can we evaluate actual neighbors' and cities' compliance with the "15-minute city" paradigm, using mainly quantitative metrics that can be calculated from available open data?
(3) How far are the urban areas from fully implementing the '15-minute city' paradigm?
(4) Can we estimate how time-based distances from one point to all the others vary within the borders of a municipality? In other words, can we estimate how urban segregation is distributed?
(5) Can we compare different neighborhoods in terms of local services' availability and city-wide reachability (from and to other neighborhoods)?

To answer these questions, we aim at finding metrics that are i) city-agnostic, ii) able to be computed for any given urban area, and iii) including user-specified parameters and personalized weights for each type of Point of Interest (PoI)

3 METHODS

Topologies and connectivity properties are naturally modeled by networks. We adopt graph-based metrics to:

(1) define areas as *network communities*;
(2) calculate distances from every residential address in a city to their closest PoIs (naively aggregated by categories: healthcare, food, education, culture, entertainment, services - there is no agreement among scholars on which and how many categories use to aggregate the pois, neither what amenities include in each category. We aim to implement a tree like structure for allowing the selection of categories and sub-categories belonging to the OpenStreetMap top-level taga 'amenity' and 'leisure');
(3) define baselines to estimate how far is a city (or an area) from being fully compliant with the "15-minute" paradigm;
(4) calculate centrality measures, such as closeness and betweenness, for estimating segregation as the variability of time-based distances from one point to all the others;
(5) locate in a map higher and lower densities of centrality scores to allow comparisons between different neighborhoods and their compliance to the "15-minute city" paradigm.

Given a city (in this paper, we consider Turin, Italy, as a reference example), a directed network (or graph) $G = (N, E)$ is built from OpenStreetMap data. Each node $n \in N$ corresponds to a street intersection, and an edge $e_{ij} \in E : e_{ij} = (n_i, n_j)$ is the street segment between two nodes n_i and n_j. An edge's weight w_e is the time that occurs to walk the corresponding street's segment on foot [1]. As a consequence, a weighted path's length is the time taken to walk the corresponding path, from the source node to the target. We used the Infomap community detection algorithm [11] to find a city's neighborhoods. We chose this method because it works well to reveal community structure in weighted and directed networks, and it uses the probability flow of random walks to decompose the network into modules by compressing a description of the previously calculated probability flow. This approach models the behavior of a traveler that, at each intersection, takes a street randomly to reach another intersection. If some nodes are tightly coupled together, they are

[1] Analogously, we build the underlying graphs with weights calculated on bikes' and public transports' time travels.

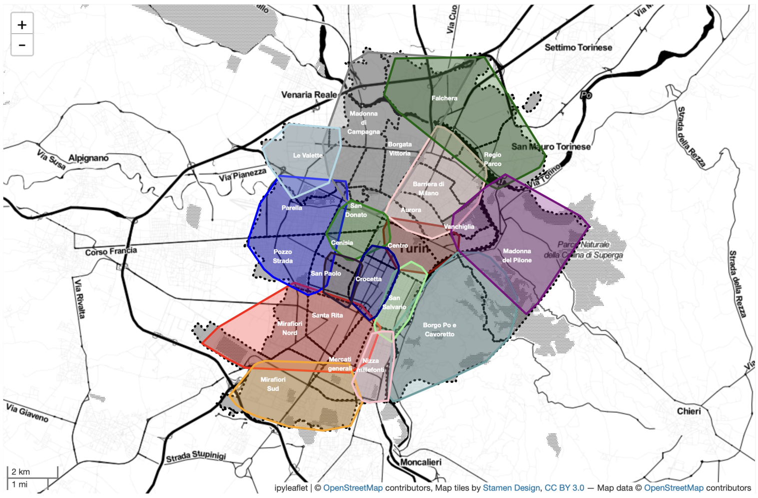

Fig. 1. Graph-based neighborhoods compared to administrative districts in Turin, Italy

likely to be traversed more than once by the same traveler: when the walking process ends, it returns a modular and natural structure of the underlying street network. Fig. 1 shows how Infomap communities fit well with the official administrative districts in Turin, sometimes merging or dividing some of them [2]. The reader should notice that Infomap provides a city-agnostic method for detecting natural neighborhoods, and also to untie the quantitative analysis from probably outdated urban strategies that defined administrative neighborhood boundaries years ago.

To understand how segregation may be varying in a city, we calculated the closeness and betweenness centrality scores for each node in the network.

Definition 3.1 (Closeness). The (normalized) closeness of node n_i is calculated as $c_i = \frac{|N|-1}{\sum_{j \neq i} l_{ij}}$, where l_{ij} is the weighted shortest path length from source node n_i to target n_j.

Definition 3.2 (Node Betweenness). The betweenness of node i is $b_i = \sum_{s \neq t \neq i} \frac{\rho_{st}(i)}{\rho_{st}}$ where ρ_{st} is the number of shortest paths from s to t, and $\rho_{st}(i)$ is the number of shortest paths from s to t passing through i.

These two measures are particularly interesting for our purposes: a node that is very close, on average, to all the other nodes has typically a high closeness centrality score; conversely, nodes with high betweenness centrality are topological bridges and they must be necessarily traversed if a traveler wants to reach some distant area of the city. Nodes with high betweenness are responsible for the overall network's connectedness: if they are removed (or inaccessible for some reason), the whole city would be disconnected, and it can be difficult, if not impossible, to reach some neighborhoods when their surrounding "bridges" have been interrupted.

4 UNITED-AND-CLOSE

United-and-Close is a web-based platform that allows for a visual interactive exploration of a city's map. We employ the Shiny python package for building an interactive web application and we use the `ipyleaflet` package for enabling

[2]As a side anecdotal note, it should be noted that the authors, that live in Turin, found that the Infomap communities do make more sense than the official administrative neighborhoods.

the map to capture user input. Adopting the classic Shneiderman's mantra [13] (i.e., "overview first, zoom and filters, details on demand"), the user is asked first to select a city, then the map of the municipality, with all the neighborhoods as detected by Infomap, is shown. The user can select one or more areas (see Fig. 2), filtering in the PoIs' categories they wish to focus on. Let's observe that every reachable point in the given city, including residential and PoI addresses, can

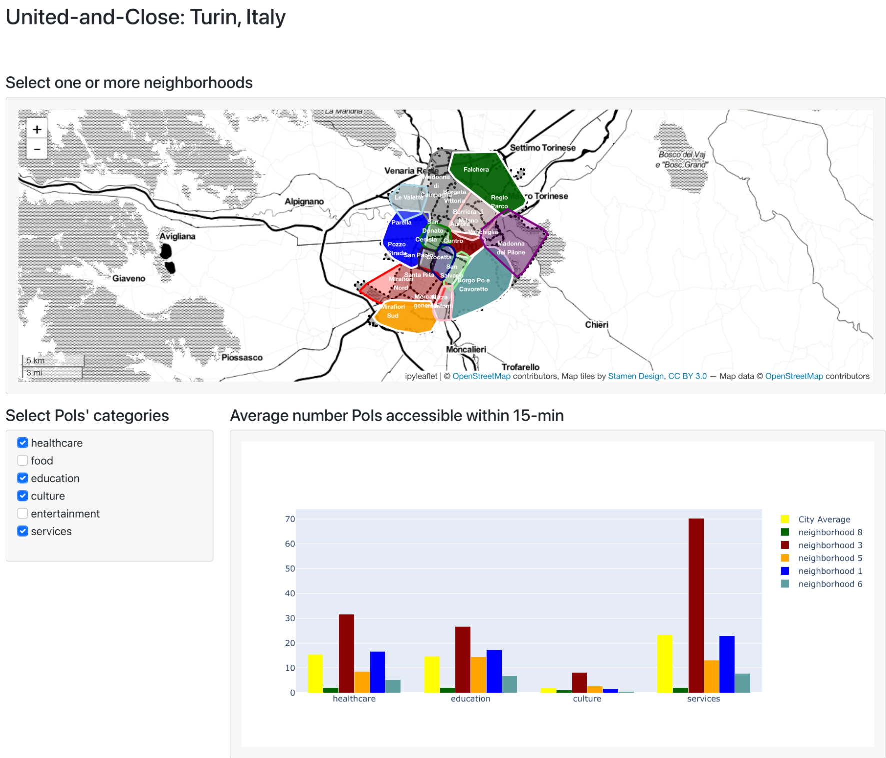

Fig. 2. Selected neighborhoods and their average access to PoIs within 15-minute walks.

be located on one edge. This allows us to calculate, for every residential address in a neighborhood (or cluster), the time distance to the closer PoI for each selected category. Therefore, we can show the average number of PoIs, aggregated by category, that are reachable within 15 minutes on average by residential addresses that fall into the cluster. We can compare this information between different selected clusters, and also with a city's average. To this extent, we plotted this information with multiple bar chars, to encourage the comparison along the PoIs categories values and between the selected clusters. Estimations of how far clusters are from being fully compliant with the "15-minute city" paradigm are calculated with the proportion of internal points that do not have PoIs of a given category in their (hyper-)proximity. This measure is not displayed in this paper for the sake of brevity.

Densities of nodes with high closeness (Fig. 3) and high betweenness (Fig. 4) are displayed through geographical heatmaps.

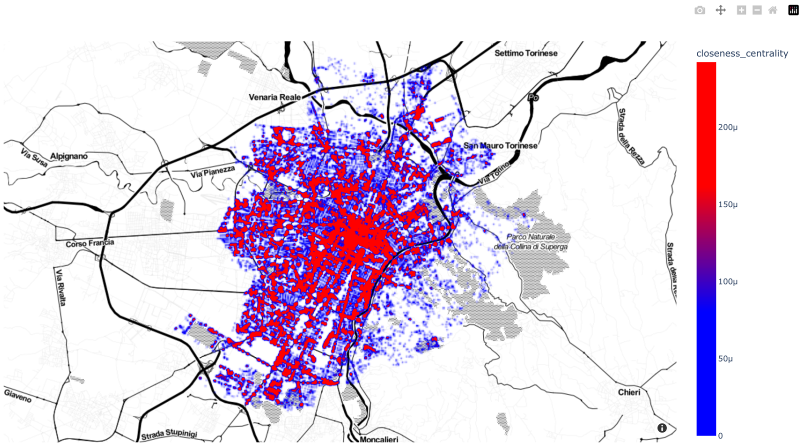

Fig. 3. Spatial distribution of intersections' closeness centrality scores (on foot walking times between points considered here).

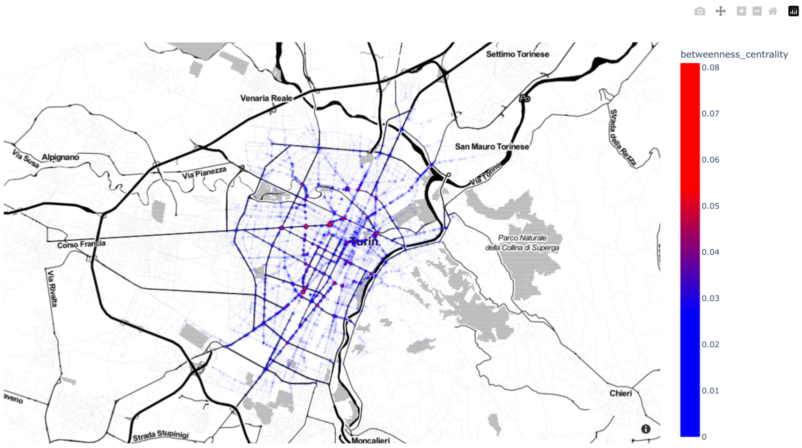

Fig. 4. Spatial distribution of intersections' betweenness centrality scores (on foot walking times between points considered here).

The high heterogeneity of closeness distribution in the map suggests that also neighborhoods, where local hyper-proximity is guaranteed, can include residential addresses that are segregated from other parts of the city. Also, high betweenness distribution suggests that Turin is traversed by vital pathways responsible for the city's "blood flows": these points are at the same time the barriers against better social inclusion and the passages through which city-wide connectedness is allowed. For example, the city center (neighborhood 3 in Fig. 2) is, not surprisingly, well served by accessible services, and also well connected to the rest of the city (i.e., high concentration of high closeness scores in that area, as in Fig. 3), we have other areas (such as neighborhood 1) that perform well under the 15-minute paradigm, and that conversely contains many residential addresses that appear quite segregated from the rest of the city. Interestingly, the notoriously "richer" neighborhood on Superga's hill (topology-based neighborhood 6), is both highly disconnected from the rest of the city, and also far from being compliant with the '15-minute' model: apparently, giving up driving a car is still not an option over there.

All the calculations are made server-side. Some cities' measures have already been computed and cached; new queries would require data to be retrieved, processed, and finally rendered client-side. For reasonably containing the period of time a user waits for results, the cached cities will be the only ones available on web application. When a user query for a not available city, since some pre-processing is needed, the output is not returned in real-time and the user will be notified when it is ready. Results from the analysis can be downloaded for offline in-depth analysis. The possibility of comparing more than one city at once is under study.

5 CONCLUSION

Tools for measuring structural accessibility, analyzing the problems at hand and evaluating alternative solutions, and integrating transport and land use plan-making have already been proposed by scholars. There is however a lack of tools geared toward the personalized requirements of citizens' needs. This is important for at least two reasons.

First, in real-world situations, the urban environment needs time to become more sustainable, economic investments, a long-term political will for achieving the result, and the capability of preserving economic competitiveness and social equity. It takes time to renew the urban environment, but physical and mental health, noise and air pollution, oil dependency, and climate change are urgent problems. Second, self-selection's travel behavior significantly impacts travel demand. It is necessary to offer the possibility of adopting sustainable mobility to citizens who desire it; denying such an option would exacerbate existing urban segregation scenarios. The tools proposed by scholars until now are mainly oriented toward policy-makers and administrators. Conversely, a student, a family with children, or a couple of senior citizens have different passions, interests, and needs. Indeed, the amenities are grouped thematically, revealing general values of accessibility that are very useful for urban planning, but less so for providing personalized services.

As a planned work, the framework that we propose is a first step towards the creation of a personalized recommender system of residential addresses and PoIs in a given city. Given a model of the user with their preferences and requirements, the system could show on the map the most relevant places for them, supporting their search for a new house or encouraging positive residential travel behaviors. Due to the effect of time and distance vary by age groups, we planned to allow personalisation of walking speed and time and the optional use of public transit. Then not all streets and public transit are accessible to everyone, so the platform will have to consider accessibility needs of parents with strollers and people using wheelchairs. The 'details-on-demand' step of the interactive visualization pipeline will include the search of a given residential address and the calculation of all the platform's metrics for that specific point in the map, allowing for a better and personalized comparison with other areas of the given city.

ACKNOWLEDGMENTS

This work is partially supported by the project 'Quantifying access to services and facilities in inclusive urban spaces', CUP D11B21005800007, selected and funded by 'Ricerca e Innovazione' 2014-2020, Asse IV 'Istruzione e Ricerca per il recupero' Azione IV.6 'Contratti di ricerca su tematiche Green', PON.

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