SYMPOSIUM ON SIMULATION IN ARCHITECTURE + URBAN DESIGN
SimAUD 2020

Urban Public Spaces as Network Configurations Through Real-Time Traffic Data

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ABSTRACT

Based on the research of urban public spaces as network configurations, we present a novel methodology which takes into account real-time traffic data in order to determine and categorize the network's connections. Three means of transport produce respective variables per network connections at every instance which correspond to trip durations.

Through the application of k-means clustering, different categories of connections arise. As different time instances correspond to different traffic data, the network's connections change accordingly. The introduction of actual variations between the relationships of the network's nodes produces time sequences of network reconfigurations thanks to the network's inner dynamics.

Since the network's original structure is based on dynamic connections between urban public spaces, the resultant real-time sequences of network configurations reveal the self-adapting behavior of the network of urban public spaces.

Author Keywords

Dynamic network; real-time traffic data; urban public spaces; cluster analysis

ACM Classification Keywords

I.6.1 SIMULATION AND MODELING

1 INTRODUCTION

The study of the urban environment as a network configuration is based on the definition of the network nodes and their interconnections. Public spaces are treated as network nodes and their attributes come from urban analysis, as well as from their network function. Through the application of network algorithms (degree, betweenness centrality, eigenvector centrality, closeness centrality and eccentricity), attributes referring to the network structure are applied. These are called network characteristics of urban spaces [1].

In contrast to the hierarchical constructions, network constructions allow for multiple connections between elements [2], therefore being closer to the complexity of the associative forces found in the structure of the urban environment. The transition from the physical space to the network structure involves the retention of nodes' proximity through network's connections only, exempting any other analogy or dependency from the objects' Cartesian's coordinates at the physical space.

This research focuses on dynamic network connections. Ten public spaces of Zografos Municipality in Attica, Greece are selected (Figure 1) and the connections between them are determined and categorized through real-time traffic data. Car, bus and pedestrian traffic data form dynamic data sets corresponding to trip durations (Figure 2).

Given the fact that the nodes' attributes depend on the overall network structure, that is, the nodes and their connections, a dynamic network structure produces transitional data of network characteristics per network node. What is more, the use of real-time data reveals in real conditions the self-adapting behavior of the network of urban public spaces.

SimAUD 2020 May 25-27, Online

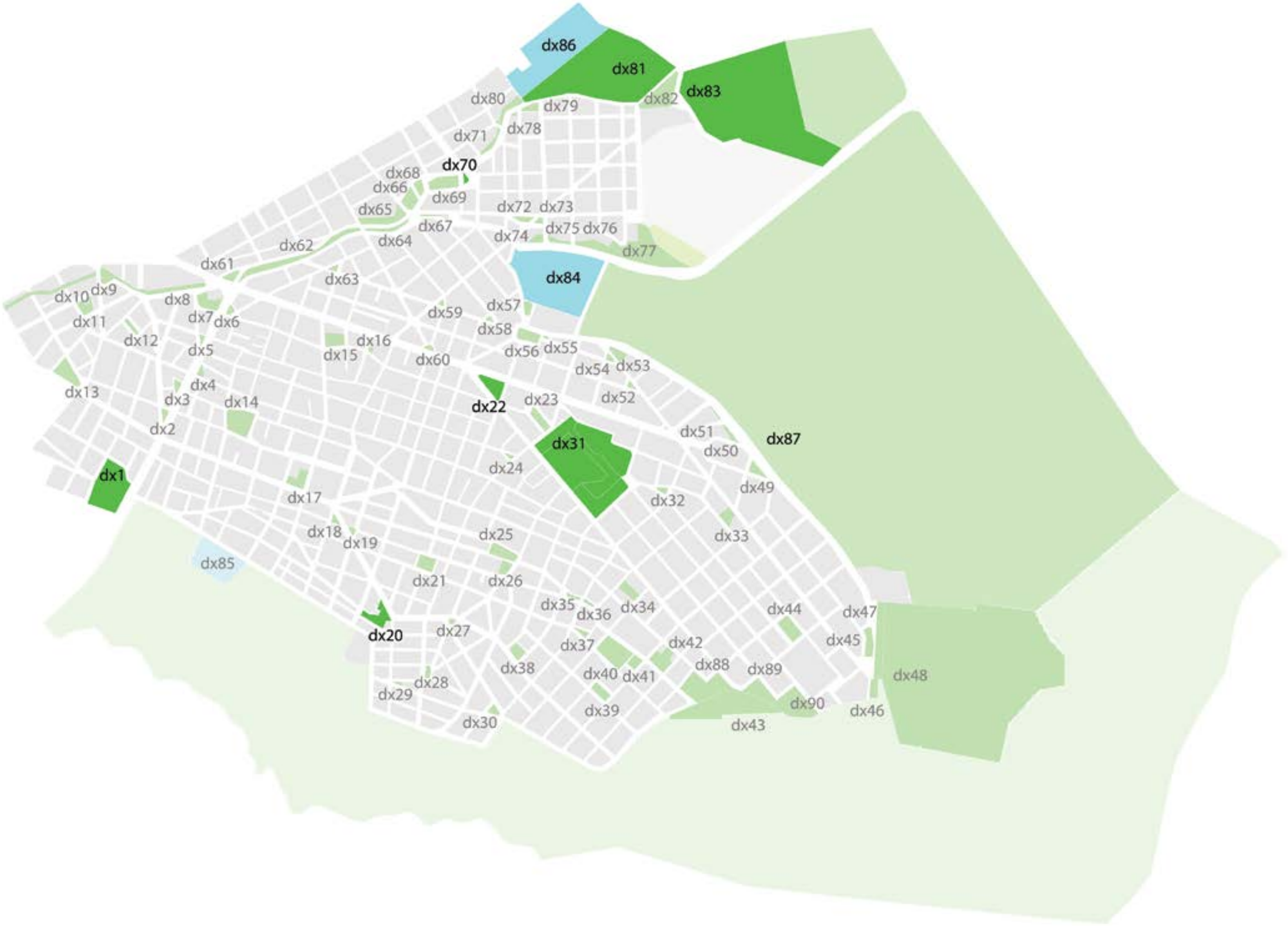


Figure 1. The selection of ten existing urban public spaces of the Municipality of Zografos. The three new metro stations will be located at Eleftherias square (dx70), Gardenia square (dx22) and Cyprus square (dx20), while Zografou park (dx1), Zografou Villa (dx31), Goudi park (dx81), Goudi grove (dx83), Zografou stadium (dx84), Zografou Sports Center (dx86) and National Technical University Campus (Zorgafou Gate, dx87) are highly visited public spaces of Zografos Municipality.

Figure 2. Car, bus and pedestrian traffic data are collected for every pair of urban public spaces.

2 REAL-TIME TRAFFIC DATA COLLECTION

The initial network configuration is formed through the mutual connection of every pair of public spaces. All ten public spaces are initially interconnected using bidirectional connections of equal strength (weight), each pointing to a node. This appears to be a symmetric graph, since all nodes are equally interconnected (Figure 3).

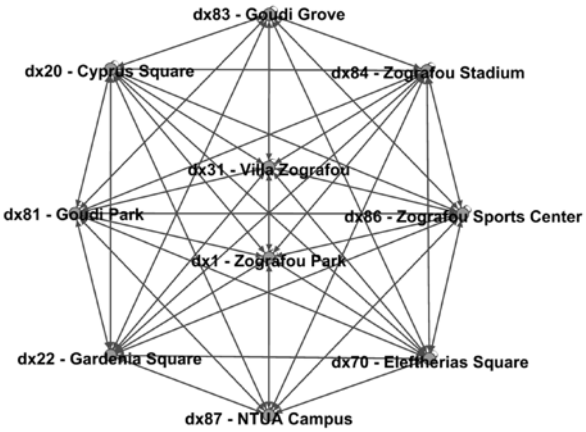
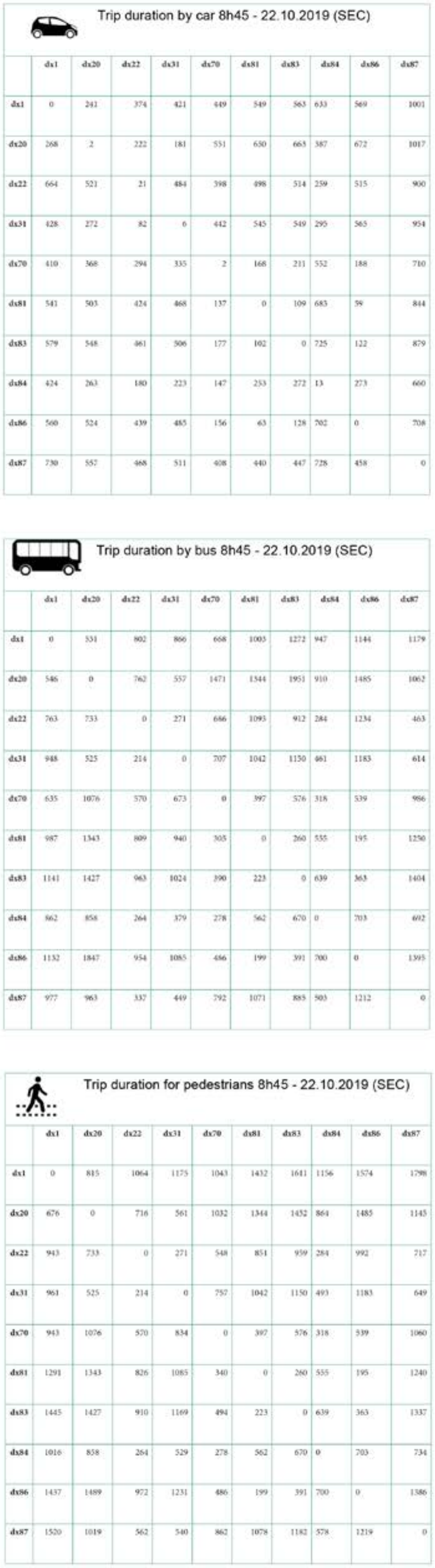


Figure 3. The symmetric graph produced if all nodes are interconnected using bidirectional connections of equal weight.

In order to construct a dynamic network whose connections will alter in strength according to real-time traffic data, car, bus and pedestrian trip durations from each node to every other node of the network are collected. For every connection between any pair of public spaces, the actual time needed to travel between them at the actual physical urban space is collected during 12 hours of a specific day (22.10.2019). Note that the time needed to reach urban space B from urban space A is not necessarily the same as the time needed to reach urban space A starting from urban space B using car or bus, as the proposed routes and the respective distances covered may differ (Figure 4). This is not the case for the pedestrian trip duration, as the shortest proposed route to follow is the same.

The collection of real-time traffic data is made possible through the use of data sets retrieved from Google Maps for the three means of transport. Trip durations from any given node (urban public space) to any other node are collected for a total time of 12 hours, starting from 08h45 to 20h15 and for a total of 24 steps, using 30 minutes intervals between them (Figure 5).

This produces 24 data sets of 100 time values in seconds (10x10 nodes) and for three means of transport, that is 7.200 values that depict real-time travel data.



Trip duration by car 8h45 - 22.10.2019 (SEC)

	dx1	dx20	dx22	dx31	dx70	dx81	dx83	dx84	dx86	dx87
dx1	0	241	374	421	449	549	563	633	569	1001
dx20	268	2	222	181	551	650	665	387	672	1017
dx22	664	521	21	484	398	498	514	259	515	900
dx31	428	272	82	6	442	545	549	295	565	954
dx70	410	368	294	335	2	168	211	552	188	710
dx81	541	503	424	468	137	0	109	683	59	844
dx83	579	548	461	506	177	102	0	725	122	879
dx84	424	263	180	223	147	253	272	13	273	660
dx86	560	524	439	485	156	63	128	702	0	708
dx87	730	557	468	511	408	440	447	728	458	0

Trip duration by bus 8h45 - 22.10.2019 (SEC)

	dx1	dx20	dx22	dx31	dx70	dx81	dx83	dx84	dx86	dx87
dx1	0	531	802	866	668	1003	1272	947	1144	1179
dx20	546	0	762	557	1471	1544	1951	910	1485	1062
dx22	763	733	0	271	686	1093	912	284	1234	463
dx31	948	525	214	0	707	1042	1150	461	1183	614
dx70	635	1076	570	673	0	397	576	318	539	986
dx81	987	1343	809	940	305	0	260	555	195	1250
dx83	1141	1427	963	1024	390	223	0	639	363	1404
dx84	862	858	264	379	278	562	670	0	703	692
dx86	1132	1847	954	1085	486	199	391	700	0	1395
dx87	977	963	337	449	792	1071	885	503	1212	0

Trip duration for pedestrians 8h45 - 22.10.2019 (SEC)

	dx1	dx20	dx22	dx31	dx70	dx81	dx83	dx84	dx86	dx87
dx1	0	815	1064	1175	1043	1432	1611	1156	1574	1798
dx20	676	0	716	561	1032	1344	1452	864	1485	1145
dx22	943	733	0	271	548	851	959	284	992	717
dx31	961	525	214	0	757	1042	1150	493	1183	649
dx70	943	1076	570	834	0	397	576	318	539	1060
dx81	1291	1343	826	1085	340	0	260	555	195	1240
dx83	1445	1427	910	1169	494	223	0	639	363	1337
dx84	1016	858	264	529	278	562	670	0	703	734
dx86	1437	1489	972	1231	486	199	391	700	0	1386
dx87	1520	1019	562	540	862	1078	1182	578	1219	0

Figure 4. The collection of real-time traffic for the three means of transport at step 1 (8h45).

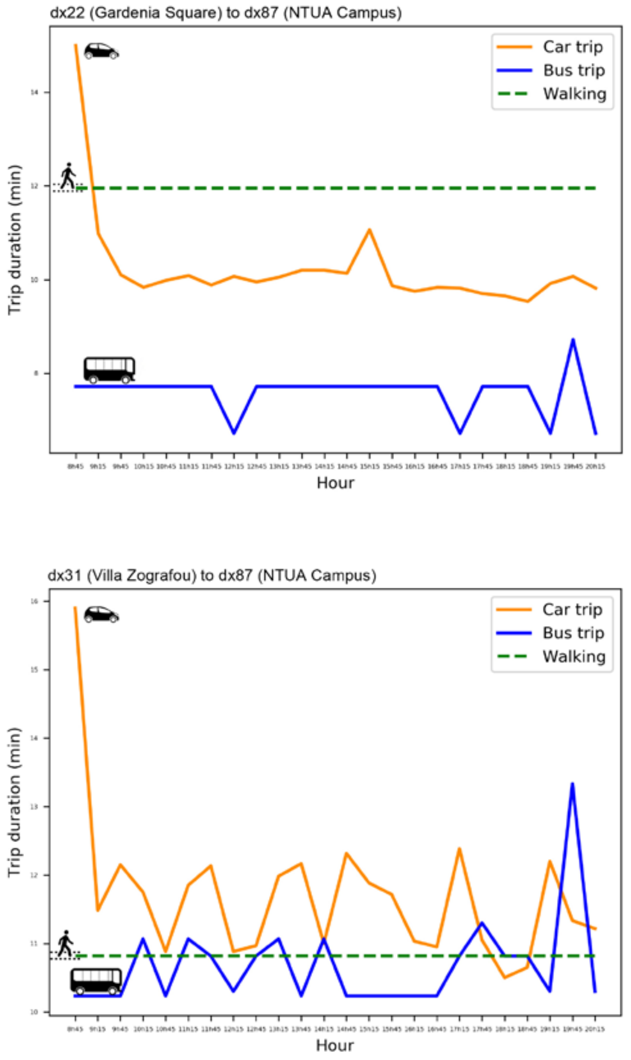


Figure 5. The collection of real-time traffic data for the three means of transport for a total of 24 steps (8h45 to 20h15)

3 CLUSTERING AND CATEGORIZATION OF NETWORK CONNECTIONS

The dynamic network construction presupposes requires a way of computing the transition from the actual connections of the urban environment to the network's connections, using real-time traffic data. These data refer to the actual time needed to travel from one public space to another. As the rules of the reconstruction of the urban environment to a network configuration may differ from one application to another, this research focuses on the constant alteration of the urban connections which produce respective alterations of the network's structure.

In order to be able to categorize the network's connections and produce variations of the network's structure which correspond to real-time traffic data, clusters of the connections between pairs of public spaces are produced, using K-means clustering algorithm. Within a labeled three-dimensional dataset (1:1, 1:2, 1:3, ..., 10:8, 10:9, 10:10 correspond to dx1:dx2, dx1:dx2, dx1:dx3, ..., dx10:dx8, dx10:dx9, dx10:dx10 connections), k-means algorithm searches for clusters of connections per instance. This way, each connection of three variables, car (sec), bus (sec) and pedestrian(sec), is grouped within a cluster whose center is closer to this connection than to other cluster centers (Figure 6).

For every instance, a different clustering result is produced. These 24 clustering results correspond to 24 different groupings of network connections, according to the k-means clustering algorithm application.

4 CONNECTIONS STRENGTH ACCORDING TO REAL-TIME TRAFFIC DATA CLUSTERING

4.1 Connections strength according to real-time traffic data clustering results

Being able to collect real-time data from the actual urban environment, a series of clustering results is produced. The translation of real-time traffic data into network connections is made possible through an interpretation of cluster results into connections weight (Table 1).

A specific weight value is assigned on connections belonging to the same cluster. Shorter trip durations are translated into stronger directed connections between network nodes, while longer trip durations are translated into weaker network connections. This way, different network configurations are constructed for every instance. Connection strength values alter continuously, following the alterations of the actual urban connections' groupings.

4.2 The dynamic network structure is based on transitional data

Since the time needed to travel from node A to node B (car (sec), bus (sec)) is not necessarily equal to the time needed to travel from node B to node A, all ten public spaces (nodes) are interconnected using pairs of bidirectional connections which differ in weight. Dynamic networks containing bidirectional edges produce transitional network characteristics per node, depending solely on the network structure. With the application of the weighted degree algorithm [5], the weighted bidirected network of public spaces acquires a ranking of public places, according to their average degree. The most powerful nodes in terms of weighted degree are those most strongly connected with the other nodes of the network. This means that the weaker nodes are these public spaces which require longer trips for the three means of transport to be reached. Weak urban spaces are exposed, appearing as less influential urban elements of the network overall structure (Figure 7).

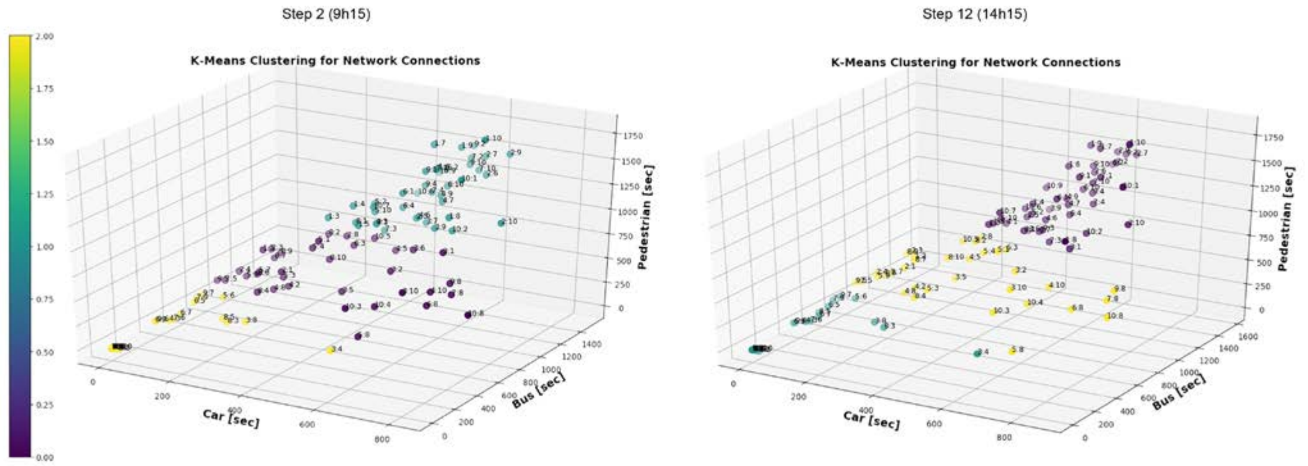


Figure 6. The scatter plots of the produced clusters using K-means clustering algorithm.

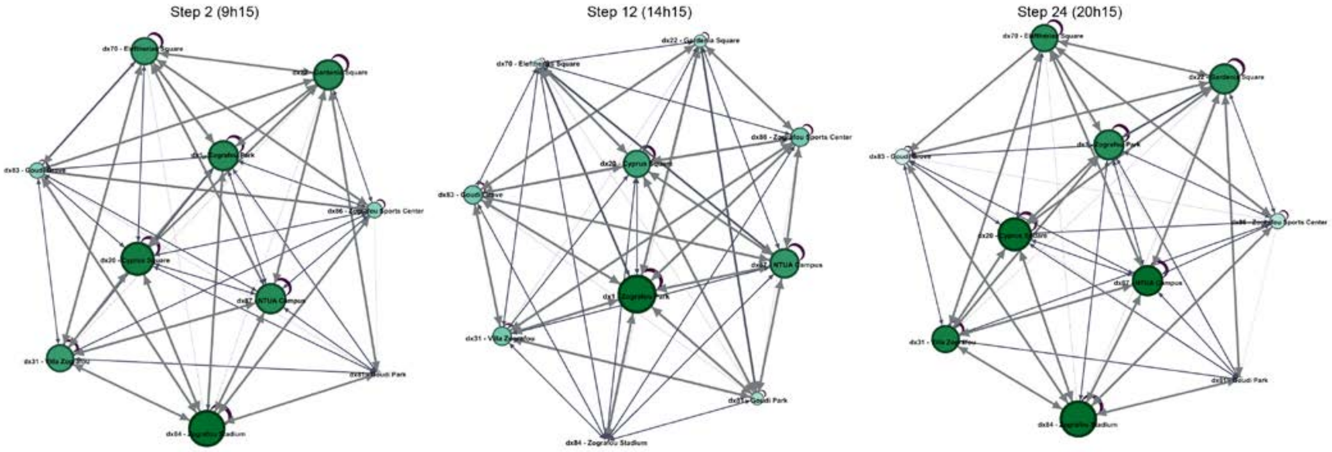


Figure 7. With the application of the weighted degree algorithm weak urban spaces are exposed, appearing as less influential urban elements of the network overall structure. The nodes' size and color correspond to the weighted degree value.

Source	Target	Cluster	Weight	Type
1	1	0	1	Directed
1	2	2	2	Directed
1	3	1	3	Directed
1	4	1	3	Directed
1	5	1	3	Directed
1	6	1	3	Directed
1	7	1	3	Directed
1	8	1	3	Directed

Table 1. Table extract of network edges for step 12 (14h15)

5 THE SELF-ADAPTING BEHAVIOR OF THE NETWORK OF URBAN PUBLIC SPACES

The transitional qualities of the urban environment produce simultaneous but not analogous changes at the network structure. The network configuration relies on nodes, and connections in order to reconstruct the urban environment. The clusters [3] and proximities between elements emerge from the topology produced by the strength of the connections and not from the Cartesian topology. Centrality studies [4], made possible through the network configuration, reveal the self-adaptation of the urban body, provoked by dynamic network connections.

Through the application of algorithms which re-evaluate the connection forces between nodes, as well as the mathematical rules witch define the cluster formations, the result-output is generated through the processing of the parameters that determine the urban structure. Real-time data determine the construction of the network itself, that is to say the relationships between component parts that describe the mutational procedure, while the alteration of the initial structure of the urban configuration produces a time-based sequence of urban mutations.

6 CONCLUSION

The multiple connections between elements, found inherent in the main body of the network construction involves the interpretation of the changing qualities of the urban environment. On the other hand, the mathematical rules describing the way the urban spaces relate to each other involves the reinterpretation of the urban change based on the forces that cause change and not on the result itself. With the combined management real-time data related to the actual urban environment and with the transition to an ever-changing network structure, it is possible to formulate a methodology of simulating the self-adapting behavior of the network of urban public spaces.

Since many of the research topics for strategies for urban interventions aim at the treatment of the public spaces of Athens as a coherent whole and not as a sum of sparse entities scattered at the urban environment, the study of the connections between public spaces contributes at the enrichment of the criteria for the prioritization of urban interventions on public spaces (nodes-public spaces and their interconnections).

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