Exploring Reciprocal Relationships of Land-Uses in a Historical Mixed-Use Quarter of Istanbul

Measuring mixed-use patterns of Cihangir

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Abstract. *In this paper we explore the land-use patterns of a historical mixed-use quarter of Istanbul by focusing on the reciprocal relationships of housing and commercial uses. We are concerned with the distribution of land-use patterns based on spatial adjacency and land-use patterns within the buildings. We measure reciprocal relationships of housing and commercial uses by using GIS and Data Mining in a complementary way and we test if we can re-generate these relationships by evolutionary computation to further support land-use allocation in inner city regenerations or new urban developments.*
Keywords. *Mixed-use patterns; land-use allocation; GIS; data mining; evolutionary computation.*

INTRODUCTION

In this paper we explore the land-use patterns of a historical mixed-use quarter of Istanbul by focusing on the reciprocal relationships of housing and commercial uses. We are concerned with two types of relationships; the distribution of land-use patterns based on spatial adjacency and land-use patterns within the buildings. Our aim is to measure reciprocal relationships of housing and commercial uses within Cihangir and to test if these relationships can be re-generated to further support land-use allocation in inner city regenerations or new urban developments.

MIXED-USE CONCEPT

Developing future land-use scenarios and land-allocation plans is one of the main tasks in urban planning. Land-use planning starts by gathering and analysing information on existing land-use.

Land is a rich concept which goes far beyond the basic classifications to include many other associated characteristics and components such as (Berke, et al., 2006)

- Land as a functional space
- Land as a setting for activities
- Land as a part of an environmental system
- Land as a real estate exchange commodity
- Land as a publicly planned, serviced and regulated space
- Land as a visual feature orientation and social symbolism

These attributes of land makes it a dynamic concept changing with the dynamics of community growth, economic growth, public-private decisions and actions. Therefore land-use analysis has many dimensions and perspectives such as understanding the forces active in land-use decisions, measur-

ing land supply, land capacity, land suitability and identifying land use indicators. Land-use indicators are key factors that are used to benchmark existing conditions of land-use (Berke, et al., 2006) Analysing land use indicators is identifying relationships of land-use distribution with factors such as demographic conditions, environmental aspects, economic indicators, spatial and morphological aspects of urban settings and so on. Land-use in the scope of this paper refers to "how land is put to use' (Chapin and Kaiser, 1979). We take land as a functional space such as housing (residential), commercial and working (business-shopping), amenities, infrastructure and so on.

On the other hand, the concept of mixed-use is one of the hot topics of land-use studies dealing with the diversity of land-uses in an urban setting. Since 1960's, especially with Jane Jacobs's highly influential book - The Death and Life of Great American Cities - mixed-use has become a very important concept; *"a fine-grain mixing of diverse uses creates vibrant and successful neighborhoods."* Jacobs (1961) defines mixed-use as one of the conditions to generate diversity in a city district. According to Jacobs (1961), a balanced mix of working, service and living activities provides urban vitality. Jacobs (1961) defines mixed primary uses and mixed secondary uses. Primary uses are residential and major employment or service functions producing the demand for secondary uses such as shops, restaurants, bars and other small-scale facilities for people who are living or moving through an urban area.

Since Jacobs (1961), during the last few decades mixed-use development has become an important planning paradigm in various European and North American cities. The recognition of the long-term environmental benefits of maintaining and improving existing urban districts let to the adoption of strategies emphasizing mixed-use and high-density development (Couch, Frazer and Percy, 2003; Ravetz, 2000; Stouten, 2011). However, the concept of mixed-use is ambiguous in both theory and practice. (Hoppenbrouwer and Louw 2005). Re-appreciation and implementation of mixed-use is rather an empirical and practical matter and by no means positioned within the academic or theoretical debate (Van den Hoek, 2008). Economics of multi-functional land-use and its operationalization (Rodenburg and Nijkamp, 2002) and defining a Mixed-use Index to measure mixed-use intensity (Van den Hoek, 2008) are among recent interesting academic works focusing on mixed-use concept from different perspectives.

MIXED-USE IN CIHANGIR

Within this background, our main interest is to research mixed-use patterns of a historical neighbourhood of Istanbul; Cihangir, by means of computational methods. Cihangir dating back to 17th century, has a rich historical housing stock and a great variety of uses such as shops, restaurant-cafes, hotels, offices, is a very distinctive mixed-use quarter. Beside many other factors (historical, economical, social, and cultural factors), having a mixed-use distribution plays an important role in the highly vital urban life of Cihangir quarter. We assume that the variety of land-uses in Cihangir in terms of their intensity, spatial organization and compatibility with each other, is both an indicator and a facilitator/provider of urban vitality.

Due to the fact that Cihangir is a very good example of a diverse live urban quarter with a variety of uses distributed along, our hypothesis is that if we can identify land-use patterns of Cihangir in terms of their intensity and reciprocal relationships based on spatial adjacency we can extract some valuable results that can support mixed-use development projects.

There are three main reasons why we acknowledge Cihangir's mixed land-use patterns as a potentially valuable input to support mixed-use planning:

- Vibrant urban life in Cihangir
- Diversity of land-use present in Cihangir
- Self-organized nature of Cihangir's land-use patterns (because governmental auditing of urban planning in Turkey is very weak, the actual land-use organization in Cihangir is mostly formed in a historical process continuously shaped by dynamic processes created by eco-

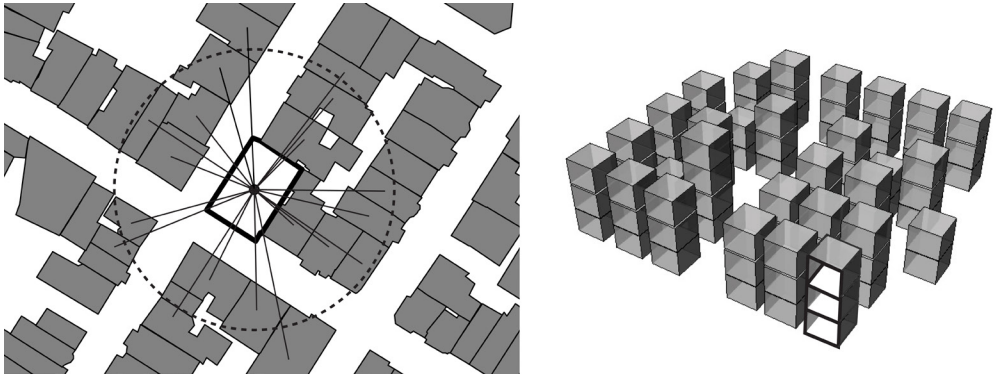


Figure 1
Land-use patterns between "closer/spatially adjacent" buildings within a certain distance; horizontal mixed-use patterns (on the left), land-use patterns within the buildings; vertical mixed-use patterns (on the right).

nomical, social and cultural forces. Therefore we can think of Cihangir as a mostly "self-organized quarter".)

METHODOLOGY

In the scope of this paper we identify two types of relationships among land-uses:

- Land-use patterns between buildings in terms of their spatial adjacency within a certain distance (horizontal mixed-use patterns) (also applied by Rowley, 1996)
- Land-use patterns within the buildings (vertical mixed-use patterns) (also applied by Hoppenbrouwer and Louwe, 2005)

Schematic description of horizontal and vertical mixed-use patterns is depicted in Figure 1.

After analysing horizontal and vertical mixed-use patterns by means of Data Mining methods, further on we will test if the findings of the analysis process in the form of frequent mixed-use patterns can re-generated by means of evolutionary computation.

The basic resource of this study is a GIS based database consisting of Cihangir buildings' land-use information. In this database, there are 1821 buildings and their land-use information from ground floor up to 10th floor, which is constructed, based on the conventional land-use analysis maps of 2008 Master Plan of Preservation of Beyoglu published by Istanbul Metropolitan Municipality. Within the scope of this study we partially use this database by including two types of attributes; Land-use Ground Floor, Land-use 1st Floor. In addition to that, we calculate a third attribute; Dominant Neighbor Land-use by GIS analysis. Attributes and their properties are described in Table 1.

The process of the study is divided in two parts:

- **Identification of mixed-use patterns:** We use GIS and Data Mining methods in a complementary way to conduct the analysis of the mixed-use patterns. Vertical land-use information is already included in the database. To collect the spatially adjacent buildings' land-use information (horizontal land-use information) we apply proximity buffer analysis in GIS. This way, land-use information of the adjacent buildings' is added into the database as new attributes for each building. We then process this database to identify frequent horizontal and vertical mixed-use patterns by applying Data Mining methodologies (Clustering and Association Rule Analysis)
- **Re-generating mixed-use patterns:** We implement an evolutionary algorithm that we developed to test if we can re-generate mixed-use patterns of Cihangir in order to further use them to support land-use allocation in inner city regenerations or new urban developments.

Attributes	Attribute Values and Amounts	Resource of Data
Land-use Ground Floor	Other (108), Residential (979), Business-Shopping (440), Sociocultural Infrastructure (132), Accomodation (16), Technical Infrastructure (6), Empty (113), Open Space (27)	constructed based on the conventional land-use analysis maps of 2008 Master Plan of Preservation of Beyoglu provided by Istanbul Metropolitan Municipality
Land-use 1st Floor	No 1st Floor (263), Business-Shopping (188), Other (28), Residential (1155), Empty (97), Accomodation (16), Sociocultural Infrastructure (46), Technical Infrastructure (2), Open Space (26)	constructed based on the conventional land-use analysis maps of 2008 Master Plan of Preservation of Beyoglu provided by Istanbul Metropolitan Municipality
Dominant Neighbor Land-use	Residential (1273), Business-Shopping (418), Sociocultural Infrastructure (56), Other (23), Empty (17), No neighbor (22), Open Space (4), Accomodation (7), Technical Infrastructure (1)	calculated by meand of GIS proximity analysis

Table 1
Cihangir Land-use Database, Attributes and their properties.

IDENTIFICATION OF VERTICAL MIXED-USE PATTERNS

To identify the vertical mixed-use patterns we export the GIS based database containing the vertical land-use information of the buildings into an open source Data Mining platform where we apply;

1. Clustering Analysis to identify the frequent building clusters based on their land-use distribution
2. Association Rule Analysis to identify attribute-value conditions within those clusters

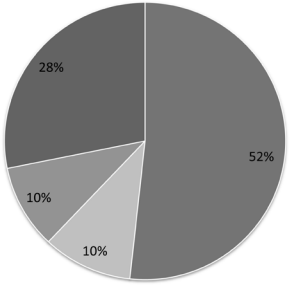
Clustering Analysis

We apply clustering analysis performing clustering with a density-based clustering algorithm named DBSCAN. The clustering algorithm identifies three main clusters in terms of land-use ground floor and 1st floor, which are described in Figure 2 where we see a pie chart visualizing the amount of buildings within each cluster in the whole Cihangir.

The results of the clustering analysis to identify the frequent building clusters based on their ground floor and 1st floor land-use values is also visualized in the form of a histogram in Figure 3 where we see the clusters' properties and the frequency of the buildings within each cluster.

As seen in Figures 2, 3 and 4 the main three clusters are described as follows:

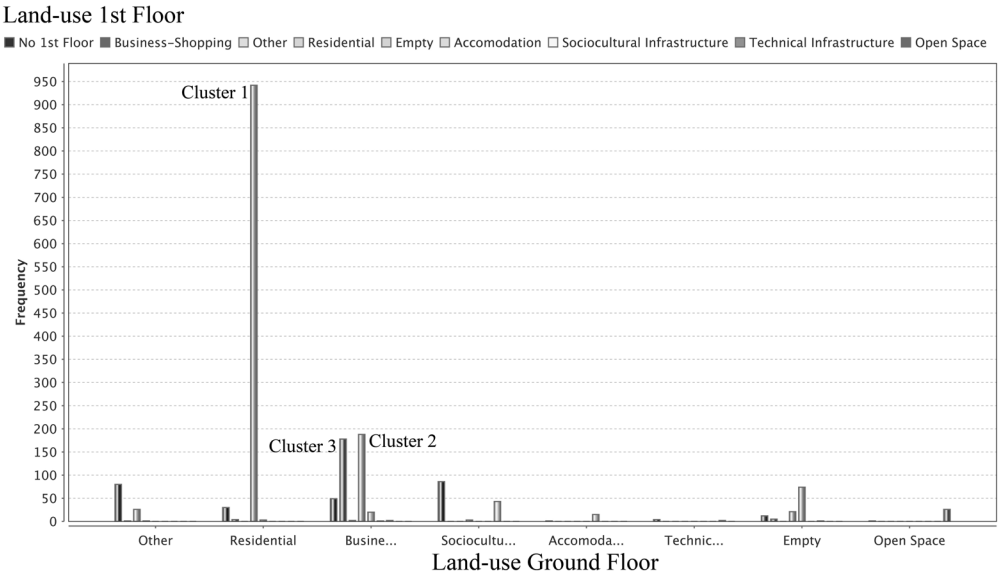
- *Cluster 1:* Land-use Ground Floor; Residential, Dominant Neighbor Land-use; Residential, cluster found in 52% of the whole Cihangir
- *Cluster 2*: Land-use Ground Floor; Business-Shopping, Dominant Neighbor Land-use; Residential, cluster found in 10% of the whole Cihangir
- *Cluster 3:* Land-use Ground Floor; Business-



Clusters	Land-use Ground Floor	Land-use 1st Floor	Nbr of Bldgs	Percentage
Cluster 1:	Residential	Residential	942	52%
Cluster 2:	Business-Shopping	Residential	188	10%
Cluster 3:	Business-Shopping	Business-Shopping	178	10%
Other Clusters (12 clusters)			513	28%

Figure 2
Cihangir Vertical Land-use clusters' description.

Figure 3
Cihangir Vertical Land-use clusters' frequency.



Shopping, Dominant Neighbor Land-use; Business-Shopping, cluster found in 10% of the whole Cihangir

Association Rule Analysis

As a further step in the analysis we apply Association Rule Analysis to identify the frequency of the attribute-value conditions within those three clusters. This process consists of applying a FPGrowth Learner algorithm to calculate all frequent items sets from the given Cihangir Land-use Database and to apply an operator of Association Rule Generator to generate a set of association rules for a given set of frequent item sets. Support and confidence are two important basic measures for association rules. Support of an association rule is defined as the percentage/fraction of records that contain X and Y together to the total number of records in the database. Confidence of an association rule is defined as the percentage/fraction of the number of transactions that contain X and Y together to the total number of records that contain X. Confidence is a measure of strength of

Figure 4
Cihangir Vertical Land-use clusters' maps prepared in GIS.

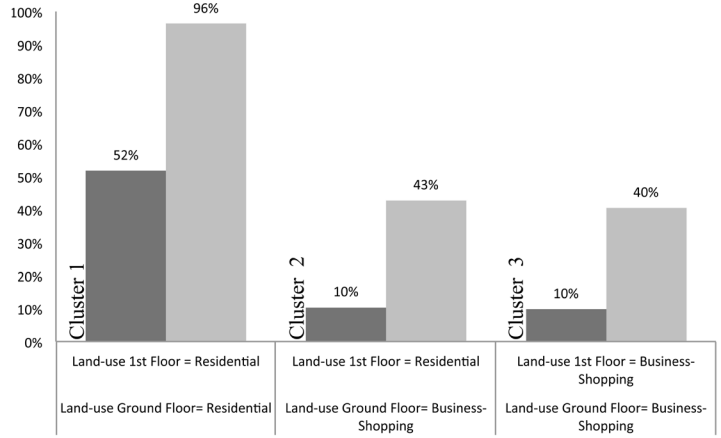


Figure 5
Cihangir Vertical Land-use Association Rule Descriptions.

	Rule Premise	Rule Conclusion	Support	Confidence
Cluster 1:	Land-use Ground Floor= Residential	Land-use 1st Floor = Residential	52%	96%
Cluster 2:	Land-use Ground Floor= Business-Shopping	Land-use 1st Floor = Residential	10%	43%
Cluster 3:	Land-use Ground Floor= Business-Shopping	Land-use 1st Floor = Business-Shopping	10%	40%

the association rules. (Kotsiantis and Kanellopoulos, 2006) We already calculated the amount of buildings within the clusters in the previous analysis, which is defined as *support value* in association rule analysis. Therefore by means of Association Rule Analysis we are interested in calculating the percentage/fraction of the number of buildings that contain rule premise and rule conclusion together to the total number of records that contain rule premise, which is defined as confidence of the association rules. The results of the Association Rule analysis are given in Figure 5.

As seen in Figure 5 the confidence values for the main three clusters are described as follows:

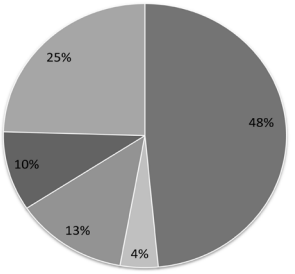
- *Cluster 1:* If the ground floor is Residential then the 1st floor is Residential for 96% probability
- *Cluster 2*: If the ground floor is Business-Shopping then the 1st floor is Residential for 43% probability
- *Cluster 3:* If the ground floor is Business-Shopping then the 1st floor is Business-Shopping for 40% probability

IDENTIFICATION OF HORIZONTAL MIXED-USE PATTERNS

To identify the horizontal mixed-use patterns we apply:

1. Proximity (Buffer) analysis in GIS to collect the spatially adjacent buildings' land-use information (horizontal land-use information) within a 30 m. buffer distance. This way, land-use information of the adjacent buildings' is added into the database as new attributes for each building.
2. Python coding to automatically identify the most dominant land-use within a 30 m. buffer distance for each building in the database. We then export this new database into Data Mining platform where we apply clustering and association rule analysis.
3. Clustering Analysis to identify the frequent building clusters based on their ground floor and dominant neighbor land-use distribution
4. Association Rule Analysis to identify attribute-value conditions within those clusters

Figure 6
Cihangir Horizontal Land-use clusters' description.



Clusters	Land-use Ground Floor	Dominant Neighbor Land-use	Nbr of Bldgs	Percentage
Cluster 1:	Residential	Residential	883	48%
Cluster 2:	Residential	Business-Shopping	79	4%
Cluster 3:	Business-Shopping	Business-Shopping	235	13%
Cluster 4:	Business-Shopping	Residential	177	10%
Other Clusters (10 clusters)			447	25%

Clustering Analysis

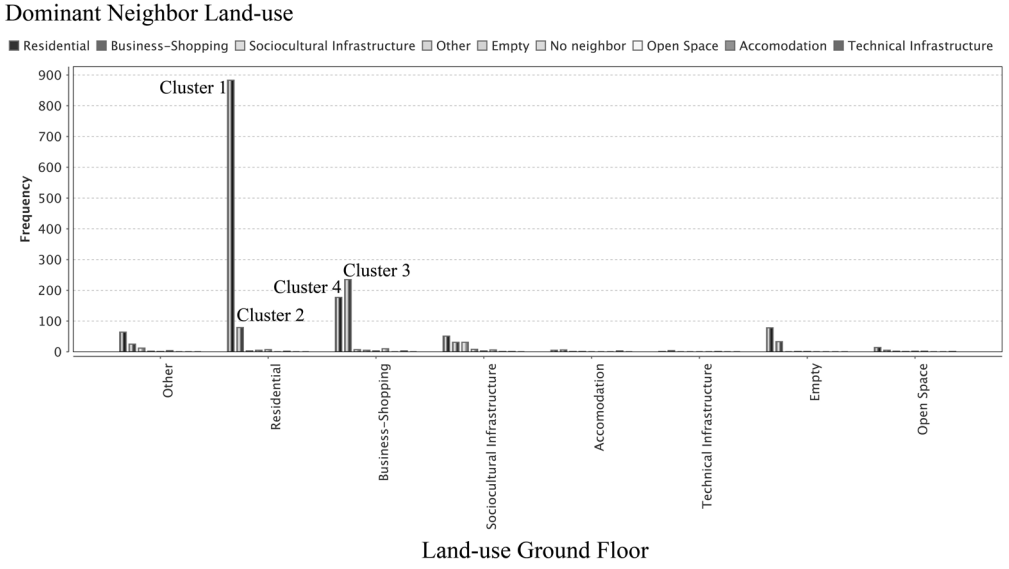
The clustering algorithm identifies four main clusters in terms of land-use ground floor and dominant neighbor land-use which are described in Figure 6 where we see a pie chart visualizing the amount of buildings within each cluster in the whole Cihangir.

The results of the clustering analysis to identify the frequent building clusters based on their ground floor and dominant neighbor land-use values is also visualized in the form of a histogram in Figure 7 where we see the clusters' properties and the frequency of the buildings within each cluster.

As seen in Figures 6 and 7 the main four clusters are described as follows:

- *Cluster 1:* Land-use Ground Floor; Residential, Dominant Neighbor Land-use; Residential, cluster found in 48% of the whole Cihangir
- *Cluster 2*: Land-use Ground Floor; Residential, Dominant Neighbor Land-use; Business-Shopping, cluster found in 4% of the whole Cihangir
- *Cluster 3:* Land-use Ground Floor; Business-Shopping, Dominant Neighbor Land-use; Business-Shopping, cluster found in 13% of the whole Cihangir

Figure 7
Cihangir Horizontal Land-use clusters' frequency.



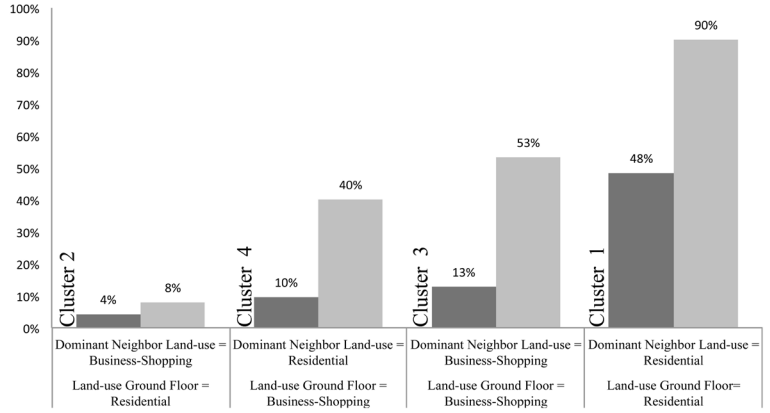


Figure 8
Cihangir Horizontal Land-use Association Rule Descriptions.

	Rule Premise	Rule Conclusion	Support	Confidence
Cluster 1:	Land-use Ground Floor = Residential	Dominant Neighbor Land-use = Residential	48%	90%
Cluster 2:	Land-use Ground Floor = Residential	Dominant Neighbor Land-use = Business-Shopping	4%	8%
Cluster 3:	Land-use Ground Floor = Business-Shopping	Dominant Neighbor Land-use = Business-Shopping	13%	53%
Cluster 4:	Land-use Ground Floor = Business-Shopping	Dominant Neighbor Land-use = Residential	10%	40%

- *Cluster 4:* Land-use Ground Floor; Business-Shopping, Dominant Neighbor Land-use; Business-Shopping, cluster found in 10% of the whole Cihangir

Association Rule Analysis

The results of the Association Rule analysis are given in Figure 8.

As seen in Figure 8 the confidence values for the main four clusters are described as follows:

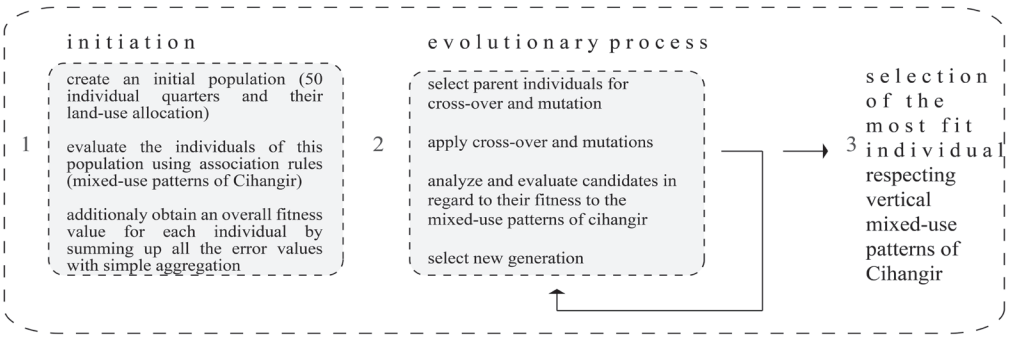
- *Cluster 1:* The dominant land-use surrounding the buildings with Residential Land-use on the ground floor is Residential for 90% probability
- *Cluster 2*: The dominant land-use surrounding the buildings with Residential Land-use on the ground floor is Business-Shopping for 8% probability
- *Cluster 3:* The dominant land-use surrounding the buildings with Business-Shopping Land-use on the ground floor is Business-Shopping for 53% probability
- *Cluster 4:* The dominant land-use surrounding the buildings with Business-Shopping Land-use on the ground floor is Residential for 40% probability

By means of these analyses we measured the reciprocal relationships of housing (residential) and commercial (business-shopping) uses in Cihangir and formulated them in terms of association rules. In the following section we will test if we can re-generate those rules by defining association rules as fitness functions of an evolutionary process.

RE-GENERATING MIXED-USE PATTERNS

As we previously mentioned, the main assumption that we make in this research is that the variety of land-uses in Cihangir in terms of their intensity, spatial organization and compatibility with each other, is both an indicator and a facilitator/provider of urban vitality. After measuring the reciprocal relationships of housing and commercial uses in Cihangir, we therefore focus to test if we can re-generate them. We claim that if we can re-generate those patterns based on this approach and methodology, by further work we can develop a new approach to support land-use allocation in inner city regenera-

Figure 9
Evolutionary process diagram.



tions or new urban developments.

We found out three clusters for the vertical land-use patterns and four clusters concerning the horizontal land use patterns in terms of housing/commercial land-use and we formulated them in the form of association rules given previously in Figures 5 and 8. We designed a multi-objective evolutionary algorithm to carry out an example re-generation process. We regenerated vertical land-use patterns by defining those association rules as fitness functions of an evolutionary process. As we only focus on housing/commercial patterns in this paper, we only implemented mutations to the relevant attributes (land-use ground, 1st and dominant neighbor) and their relevant values (residential and business-shopping).

The study of identifying vertical land-use patterns by means of Data Mining methods and re-generating these patterns by means of Evolutionary Computation has been tested successfully. The evolutionary process diagram is given in Figure 9.

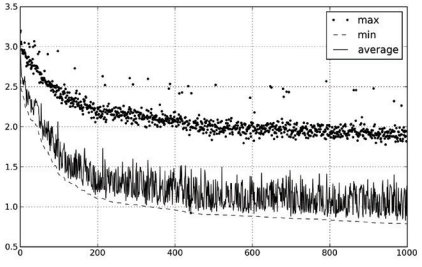
Overall fitness graph of the evolutionary process showing decrease of total error in each generation is given in Figure 10.

The final minimum error after 10.000 generations is below %10, therefore we evaluate that the multi-objective evolutionary algorithm that we implemented is successfully re-generating Cihangir's vertical mixed-use patterns given in Figure 1. Within the scope of this paper we only applied the re-generation of vertical land-use patterns and we aim to focus on the re-generation of horizontal land-use patterns (Figure 5) in the next phase of our research.

CONCLUSION

In this paper we implemented a methodology making use of GIS, Data Mining and evolutionary computation to measure and re-generate mixed-use

Figure 10
Fitness graph on the left side (y axis: error, x axis: generations. 10.000 generations, final minimum error: 0.788336), and visualization of the land-use allocation plans (ground and 1st floor land-use plans) of the most fit individual in respecting mixed-use patterns of Cihangir on the right side.



patterns of a real urban context. So far, we successfully demonstrated that the methodology is working but the research has not been completed yet. We are planning to enlarge our research by including the re-generation of horizontal land-use patterns and implementing a comparative study in order to compare Cihangir with other districts based on their housing/commercial patterns. A comparative study could reveal the real potentials and problems of the methodology we apply and provide clues about defining "better mixed-use balance" in reference to Jane Jacobs. This way we expect to contribute both to the theoretical research and practical applications of mixed-use concept by providing a methodology for measuring and re-generating mixed-use performance of any urban setting. The overall goal is to contribute to the general problem of how mixed-use performance can be defined, measured and operationalize in urban planning. We claim that the research of local knowledge in urban analysis is very critical and our approach has potentials to lead to a more general knowledge by providing a deeper understanding of the real urban contexts.

ACKNOWLEDGMENT

This work is dedicated to the people of Turkey peacefully protesting to protect Gezi Park in Taksim, our right to the city and democracy despite the excessive police brutality.

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