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Application Of Genetic Algorithm Classification Approach to Study Urban Streets Morphology at Neighborhood Scale

* Dr. **Mariame CHAHBI** [1],
International University of Rabat (UIR), Center for global studies/ ESAR/ College of Engineering and Architecture, Rabat, Morocco [1]
E-mail [1]*: mariame.chahbi@uir.ac.ma*

Abstract
Today's cities worldwide are facing several new challenges with the spread of advanced digitalization and information technologies. As science and innovation are going digital, urban planning is highly concerned and should follow up with this global numerical transition. Urban planners should make use of the potential of new technologies to develop better and smarter urban forms responding to the new challenges and issues. The study uses artificial intelligence techniques based on genetic algorithms and supported by statistical data upon 20 indicators applied on 450 street segments in different urban fabrics in Fez city aiming to classify and simulate urban streets morphology. Machine learning can have the power of solving complex issues that humans alone cannot. The results using the potential of Machine Learning techniques can be a framework for decision makers to help them thinking about an intelligent planning process matching today challenges while taking advantages of new technologies.
Keywords: Machine Learning; Genetic Algorithm; Urban Street Morphology.

1. Introduction

The colonial urban model is a founding model both historically and technically of many ex- colonized cities in the world. The French colonialism in Morocco has been a major catalysis that has drastically affected both social and spatial characteristics of Moroccan space and has gradually affected the local lifestyle following a long transformation process. Being the main catalyst of the shift from the traditional enclosure and closeness to the extreme exposure and openness, colonialism has used planning as a tool to reinforce centralization of power, increase social segregation, expressing superiority, strength and control over local people.
Street space is the essence that gives strength and vitality to urban communities and the basis of developing and growing economies (Amen,2022; LUU, 2021). Therefore, planning pleasant and convenient street space is a matter of uttermost significance. Streets in Moroccan cities are suffocating, facing increasing stress and pressure. This study focuses on a particular city in Morocco, Fez, a patchwork piece of art, hosting completely divergent urban fabrics and structures being the old city, which is unique in terms of its urban fabric, spatial form, ornaments and details on both architectural and urban level and the new town, which is rival and exotic, introduced during the colonization of Morocco between 1912 and 1956 based on the French urban style and vision. Other fabrics are presented as post-colonial urban extensions, either informal settlements or planned new districts, highly influenced by the French urban principles and planning solutions introducing new street arrangements that were mostly incompatible with the local context.
This research is aiming to define, through a comparison analysis of colonial and post-colonial streets spaces, how colonialism and western urban inspired solutions have affected today's urban space and planning practices in Moroccan dual cities especially at street level in order to help think about an innovative development of streets that match the local atmosphere and today's socio-economic reality of Moroccan post-colonial cities while subscribing to the modern context benefiting from the added value of the new technologies.
The nature of this research is both qualitative and quantitative focusing on the empirical data analysis studying the spatial components putting forward the importance of new technologies and computational tools such as Artificial Neural Network and Genetic Algorithm in studying urban streets morphology for classification at neighborhood scale automatically tracing the similarities and contrasts between different urban areas. This can help decision makers to reveal several interpretations of planning dysfunctions and predict relevant planning solutions in a way to create vibrant and liveable Streets.

1.1 Research Background and Cases Studies

This study focuses on the city of Fez in Morocco, a patchwork piece of art hosting completely divergent urban fabrics. Before the French occupation to Morocco in 1912, only the old Medina existed, constituting a single homogeneous urban core. After the independence in 1956, the city of Fez had a huge urban expansion especially in the neighbouring rural communes and along the mains axis connecting Fez to the other regions.
Fez is hosting divergent urban fabrics being:

- The Medina: which is founded twelve hundred years ago, one of the most conserved historical towns, listed as World heritage sites by the UNESCO (1981). with about 3000 historic monuments a high number of historic buildings.
- The new town "la Ville Nouvelle", which is rival and exotic, introduced during the colonial period between nineteen twelve (1912) and nineteen fifty-six (1956) based on the French urban principles and vision.
- Other fabrics are manifested as postcolonial urban extensions mostly residential, generated after the independence as the city of Fez had a huge expansion especially coming from the neighbouring rural regions.

Statistical analyses are based upon 20 indicators applied on 450 street segments in three different urban fabrics between the colonial and post-colonial districts in the city of Fez:

- *The first Case study* is called Agdal- the ex-colonial center which is hosting only 16% of the total population with the highest concentration of public facilities, attracting more and more pressure from its surroundings.
- *The second case study:* Narjis district, recently planned according to a grid as an extension to the city, with 10% of the total population relatively placed in a dense built frame.
- *The third Case study:* Bensouda district, post-colonial district that was developed in a very short time without a prior planning, hosting 28% of the total population, highly dense, located at the edge of the city suffering from major urban issues, being disconnected, segregated from the other entities.

Table1. Streets segments selection in the three studied cases.

Data collection	Street segments	Selected segments after selecting	percentage
Case I - Agdal	253	224	88.53%
Case II- Narjis	100	95	95%
Case III -Bensouda	135	134	99,25%
Total	488	**453**	92.82%

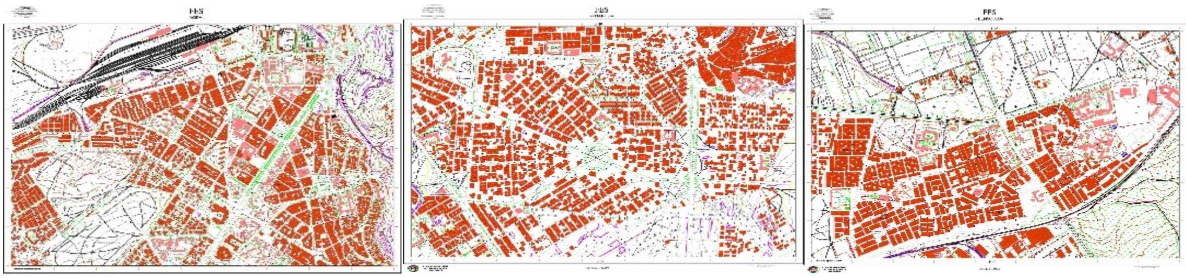


Figure 1. Fig. Fez- Cases studies (1) Agdal- the ex-colonial center, (2) Narjis, recently planned according to a grid as an extension to the city, (3) Bensouda, post-colonial district, developed in a very short time without a prior planning.

1.2 Research Aim

This research is aiming to define, the duality of Fez Street space and how colonialism has affected today's urban space and planning practices in Moroccan dual cities via a comparative study of three major districts between the ex-colonial center and two different post-colonial districts in terms of urban form targeting accessibility mobility and connectivity at neighbourhood scale and urban design qualities and physical features at street scale. The contrast and similarities between the areas are clearly traced and will reveal several planning dysfunctions.

2. Materials and Methods

2.1 Data sources

Data sources are hybrid. Up to 10000 data were collected based on surveys, Satellite data using OpenStreetMap's, axial maps Data using space syntax tools and then on-site observations permitted the acquisition of accurate information regarding the following indicators:

Table 2. Indicators used for this classification study

Street connectivity	Connectivity Nodes counts Integration

Physical features of the street	Street Width Street Length Sidewalk Number of lanes Building height
Qualitative Measurements	Street Planting Usage
Land use	Small business Coffeeshops Education Religious On street-Parking Other facilities
Transportation	Bus stations Number of lines Bicycles lanes

2.3 Machine Learning methods for Data classification, clustering, and prediction: Overview

In urban planning, the computational models have been used with co-occurrence with the geospatial analysis in several means such as classification, clustering, and prediction.

- **Classification** to recognise land-use patterns extracting green areas from satellite images by machine learning that can be easily used to perform any spatial analysis.
- **Clustering** techniques which are frequently adopted to generate model indicators of urban forms. A clustering analysis aims to split up a data set into different groups (clusters) that should be meaningful for the study under a supervised or unsupervised learning methods. This can be related to multiclass classification as well, for the fact that, the cluster labels are not given for learning, and the computer should understand the data itself, interpret and classify into different clusters (Barlow, 1989). In urban planning, clustering techniques are frequently adopted to generate model indicators of urban forms, for instance urban land use, urban tenure, and urban fabrics (Li. X, 2020).
- **Prediction** is frequently using spatial regression algorithms to help to predict future change and model future urban development.

This research is both qualitative and quantitative, based on secondary and primary data, surveys, satellite data, using computational tools such as ANN, Genetic Algorithms classification approach in studying urban streets for classification that help us think about adequate planning solutions in a way to create adaptive and liveable cities. Genetic algorithms are bio-inspired computational algorithms seeking to solve complex problems using models of biology providing efficient operation in flexible and mutating environments. The model of this study is inspired from the “Fisher’s Iris data set using both R and Python languages illustrating usages and visualizing the model results.

Above ten thousand (10 000) Statistical data are collected, filtered, to be prepared for classification and clustering analysis. Today, Urban data collection and structuring is an area of high demand, especially for ML-based applications (Amen,2021). *“Without the data, ML models can neither be trained nor calibrated”* (Al-Garadi et al., 2020; Jordan and Mitchell, 2015). According to Tekouabou S.C.K, Diop. El, Azmi.R, Jaligot.R, Chenal.J(2021), Models needs careful adjustment, and a quiet big amount of data to give accurate results. Both the computational model used and the volume of the data matter to reach the best performance. The computational models are progressing day by day due to the rapid digital transformation all over and the huge amount of data. Models are increasingly becoming complex to be more performant.

The methodology followed is based first on Space syntax tools to compare the level of integration and streets connectivity of the three cases. Depthmap is used to generate axial maps and graph analysis of both macro and micro scale of the city components. Processing and analyzing the numeric collected data are based on statistical computational tools such as R studio using R language and Spyder (IDE) in Phyton included in “Anaconda” which is open source and accessible for all. Data classification is based on Genetic Algorithm inspired from the code of Iris flower data set on python.

Satellite imagery is also a powerful tool that provides a big amount of data based on an accurate representation of the ground reality. It comes up with precise data at high resolution and recently became more and more available. The AI computational models are progressing day by day, increasingly becoming complex and more performant.

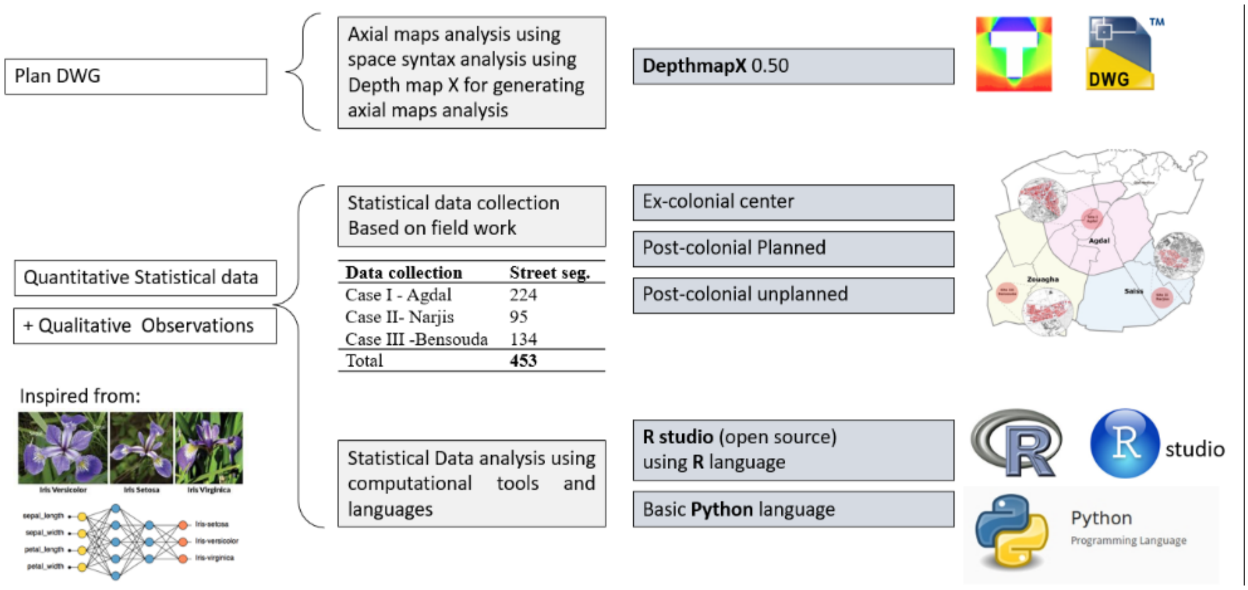


Figure 2. structure and methodology of the study (Developed by Author).

3. Data Analysis and Results

Data analysis is organized in several steps using computational tools to analyse the similarities and differences of the selected districts. Applying quantitative analytical methods on these areas will show similarities and analogies between colonial and post-colonial areas and will demonstrate how street network integration level is related to their liveability and success in a continuous changing process. Beside axial map analysis, on field qualitative observations complete data to reach a comprehensive analysis result.

Using of DepthmapX, various macro scale spatial variables can be calculated and visualized. Studying the integration help to predict how streets are used by pedestrians based on how it is accessible to them, a well-integrated and easily accessible street should be in theory highly frequented (Hiller, 2003). The ex-colonial center 'Agdal', scores the highest connectivity and integration values with a shallow urban structure, followed by the second post-colonial planned district then the third unplanned is the most isolated network with relatively the highest depth. Based on nodes counts of axes, we calculate how the axial lines are connected to each other. It also computes the street network measures and the plan according to the level of correlation of these street spaces.

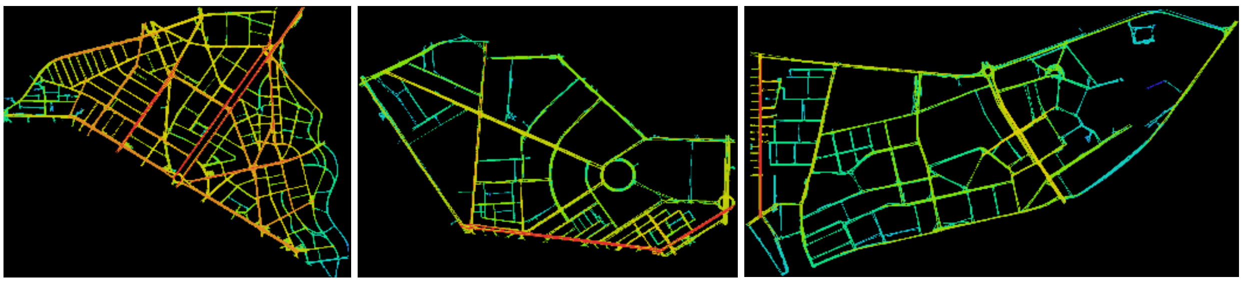


Figure 3. Integration level of the 3 cases studies based on DepthmapX tool (site 1: Agdal, Site 2: Narjis and site 3: Bensouda)

Comparing the Local and global integration values of Bensouda, one can note that the highest integration value R3 (7,44762) in Bensouda quarter is much higher than its global integration at radius n (3,7245). This shows that the quarter is poorly intelligible. In the previous cases the difference between R3 and Rn is less obvious. The higher the correlation between local R3 and Rn in an area, the more it is intelligible. According to axial map analysis, Agdal (site1) as well as Narjis (site 2) are more intelligible than Bensouda (Site 3).

Analysing axial maps generates the integration values of each district based on number of segments', their length, and intersections with other lines. Combining these data, axial maps reveal integration level and intelligibility with other spatial features. The city segments are shown as axial lines sorted from the shortest to the longest assigning a range of colours from red to blue, where red is the most integrated segment and blue is the most isolated one. Based on the data generated from these maps, the comparison of the street's length and integration level of the three case studies have been done using Spyder(python3.5) software27, based on a test after 1000 iterations. The result of this test is showing a similarity in terms of integration between Narjis and Agdal while Bensouda is contrasted from both with lower integration and a deeper urban grid can be similar to the traditional structure. The shallow urban structures such as ex-colonial center, "Agdal" have high street network integration rate.

3.1 Mapping Street Frontage

Mapping the street frontage use and relating it to the integration analysis above, shows how streets are used. well integrated and easily accessible streets in the three cases are hosting the most of economic activities and are thus highly frequented. We also note that Agdal (Site 1) scoring the highest concentration of public facilities, administrations, and commercial activities. site 2 is less active than site 1, while -Site 3- is ranking in the last position and extremely dependent on the city center.

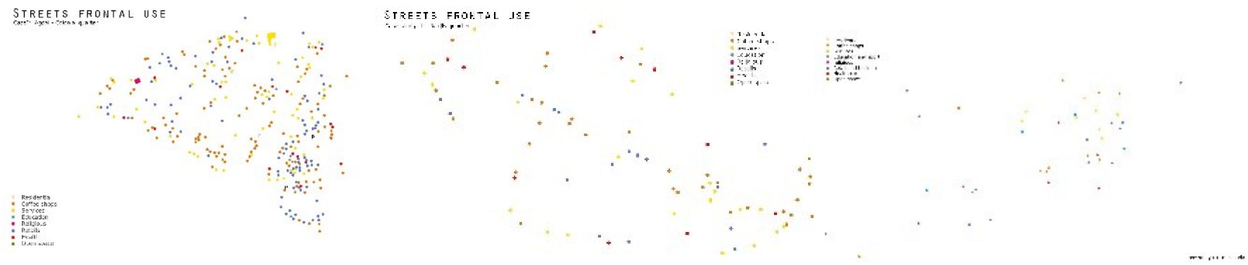


Figure4. Mapping Street frontage use in the 3 cases studies (site 1: Agdal, Site 2: Narjis and site 3: Bensouda)

Summary of the analogies and differences between the 3 cases shows a failure of urban planning is reflected in several aspects, based on a mono-centric system while other entities are spatially segregated with a poor access to facilities with a considerable dependence on the center.

3.2 Mapping Street Planting

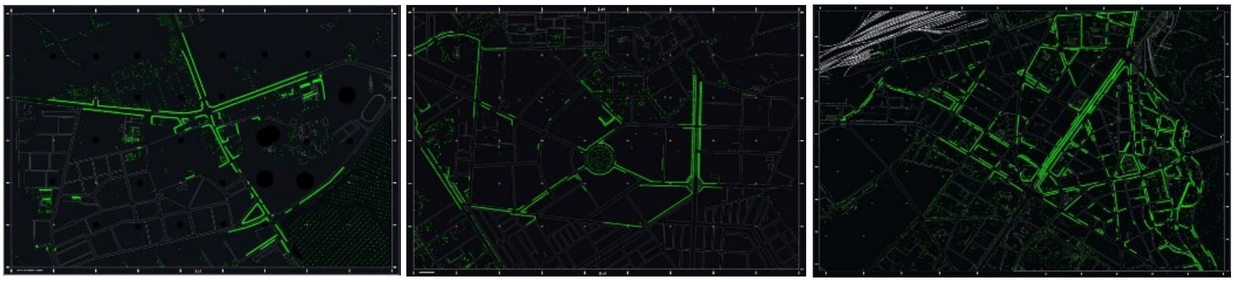


Figure 5. Mapping Street planting in the three studied areas (site 1: Agdal, Site 2: Narjis and site 3: Bensouda)

Mapping street tree planting, using satellite data shows a significant gap also between ex-colonial site streets canopy planting and the post-colonial ones with a percentage of 58% in site 1, Meanwhile, 34% in site 2 and 9% only in site 3 (Bensouda).

Table 3. Summary of statistical Data Site 1 (Agdal, ex-colonial center)

Categories	variables	Max.	Min.	Mean	Std.
Street connectivity	Connectivity (Con)	22	1	5.667	4.162638
Physical features of the street	Street Width (SW)	45	4	8.748	4.309221
	Street Length (SL)	1426,24	18,28	223.28	199.9758
	Sidewalk (SS)	66	3	7.7768	5.443855
	Number of lanes(NL)	6	1	2.341	0.7416158
	Building height (BH)	23	0	12.76	5.074634
Qualitative Measurements	Street Planting (SP)	1	0	0.583	0.860063
	Cycling infrastructure	0	0	0	--
Land use	Small business (SsB)	36	0	4.735	6.43449
	Coffee shops (Cof)	24	0	1.179	2.528063

	Education (Edu)	4	0	0.2398	0.6310423
	Religious (Rel)	1	0	0.09545	0.2927227
	Other facilities (Ser)	11	0	0.9775	1.840288
	On street-Parking (PA)	1	0	0.7578	0.4293498
Transportation	Bus stations (Bus)	4	0	0.1883	0.6080899
	Number of lines (BusL)	11	0	0.3587sd	1.374315

Table 4. Summary of statistical Data Site 2 (Narjis, Post-colonial, recently built quarter)

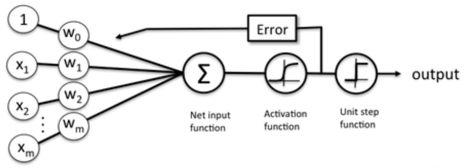
Categories	variables	Max	Min.	Mean	Std.
Street connectivity	Connectivity (Con)	17	1	4.606	2.99181
Physical features of the street	Street Width (SW)	30	5	9.532	5.96892
	Street Length (SL)	1018.29	37.24	214.94	193.027
	Sidewalk (SS)	15	2	5.074	2.775621
	Number of Lanes(NL)	4	1	1,84	0.9075927
	Building height (BH)	18	8	13.2	2.498621
Qualitative Measurements	Street Planting (SP)	1 (yes)	0 (no)	0.3404	0.4763931
	Cycling infrastructure	0	0	0	--
Land use	Small business (SsB)	42	0	3.34	6.168866
	Coffee shops (Cof)	9	0	0.8936	1.925874
	Education (Edu)	1	0	0.1064	0.3099804
	Religious (Rel)	1	0	0.6383	0.2457602
	Other facilities (Ser)	5	0	0.3723	1.126266
	On street-Parking (PA)	1(yes)	0(no)	0.5106	0.5025672
Transportation	Bus stations (Bus)	3	0	0.2021	0.6148658
	Number of lines (BusL)	8	0	0.4574	1.493102

Table.**5** Summary of statistical Data Site 3 (Bensouda, Post-colonial- Unplanned district)

Categories	**variables**	**Max**	**Min.**	**Mean**	**Std.**
Street connectivity	Connectivity (Con)	14	1	4.173	2.2378
Physical features of the street	Street Width (SW)	867.91	27.08	188.20	3.404174
	Street Length (SL)	24	4	7.609	145.8871
	Sidewalk (SS)	23	0	5.564	4.19479
	Number of lanes (NL)	4	1	1,925	0.6230918
	Building height (BH)	15	0	10.12	3.455425
Qualitative Measurements	Street Planting (SP)	1(yes)	0(no)	0.09023	0.2875878
	Cycling infrastructure	0	0	0	--
Land use	Small business (SsB)	30	0	0.2256	3.498055
	Coffee shops (Cof)	14	0	0.2256	1.306258
	Education (Edu)	1	0	0.1278	0.3351511
	Religious (Rel)	1	0	0.07519	0.2646914
	Other facilities (Ser)	4	0	0.1888	0.6758875
	On street-Parking (PA)	1(yes)	0(no)	0.8346	0.3729581
Transportation	Bus stations (Bus)	2	0	0.03759	0.2271702
	Number of lines (BusL)	1	0	0.03008	0.17144

Clustering analysis based on machine learning studies the design of algorithms that can learn based on artificial neural network tasks. *(This research has used as a reference, genetic algorithm on iris flower data set python).* These tasks are learned via available data of Site 1,2,3, (supervised learning) that were observed and collected from satellite-based sources, axial maps and surveys.

The clustering analysis and the comparison of the streets' physical features and integration level of the three case studies are done using computational coding language python based on a test after 1000 iterations. (72 entries, 10 for testing)



Schematic of a logistic regression classifier.

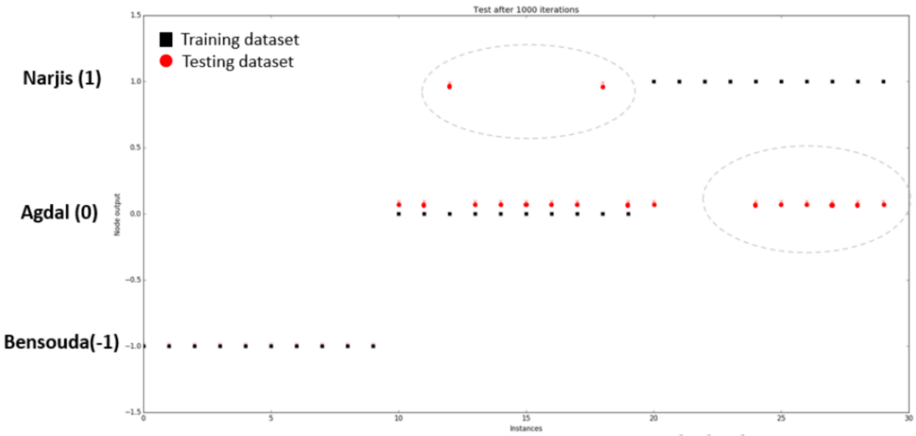


Figure 6. Result after testing and comparing variables in the three different sites: Agdal (0), Narjis (1) Bensouda (-1), (72 entries, from which 10 were for test) (Developed by Author).

$$\tanh x = \frac{e^{x}-e^{-x}}{e^{x}+e^{x-}} = \frac{e^{2x}-1}{e^{2x}+1} = \frac{1-e^{-2x}}{1+e^{-2x}}$$

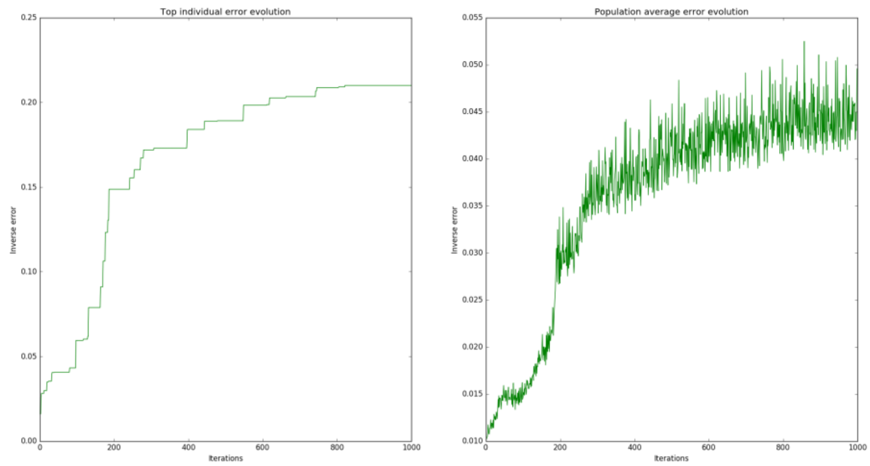


Figure 7. Inverse error - error correction by back propagation using python language

The result of this test, it is showing a similarity in terms of integration and physical features between (site 1) the colonial center and the post-colonial recently built quarter (site 2), while the post-colonial unplanned spontaneous settlements (site 3) is contrasted from both with lower integration and a deeper urban grid which can interpreted also to be similar the traditional structure.

The newly developed extensions are similar in structure however depend on the center and generating a real break in the city following a policy that is still favouring the center and increasing the existing socio-spatial gap between different entities of the city. Interestingly, unplanned settlement is comparable to the traditional structure, might indicates the unconscious choice and willing of people of low- and middle-income class, of enclosure, privacy and togetherness while maximizing land efficiency to a large extent.

4. Conclusion

The rapid pace of digital transformation is setting every day's life activities with artificial intelligence. computer scientists have been putting countless efforts in making machines able to see and understand the world same as human do. Machine learning can help finding strong correlations among data that must be given more attention, having the potential of solving complex issues that humans alone cannot.

Modern planning should increasingly get inspired of the advantages of new technologies adopting artificial intelligence (AI) techniques to support liveability dimensions and secure vitality and sustainability. Urban planning can benefit from the advantage of new technologies to enhance spatial analysis quality. Using the computational tools to compare the ex-colonial urban fabric with the post-colonial districts in terms of connectivity and physical features; shows that recent planning is still highly influenced by the planning regulations elaborated during the colonial period generating several urban dysfunctions.

Machine Learning methods can help efficiently in simulation and classification studies that can improve the performance processes of today's urban planning and support decision makers in developing an intelligent process of planning turning today's challenges into tomorrow opportunities.

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Conflict of Interests

The authors declare no conflict of interest.

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