DATA EXTRACTION AS INPUT FOR THE ENERGY ANALYSIS OF AN URBAN DISTRICT WITH UMI

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Abstract. The energy usage of an urban district has become a major subject of study and interest since we observed a significant expansion of cities caused by the movement of inhabitants. Sustainability of urban areas is mainly related to interactions between street patterns and building distances. Monitoring these connections in terms of energy flows creates possibilities of optimizing building construction and retrofitting. There are many tools used to make this possible.In this paper, we want to demonstrate how it is possible to import the 3D structure of an urban area recorded in an SHP file into the Urban Modeling Interface software. The data extraction protocol we developed to this aim principally consists in approximating clusters of XYZ coordinates into a set of boxes with minimum loss in geometry, orientation, and position of buildings. Estimations of energy consumption and CO_2 are among the outcomes we were able to obtain from imported data into UMI. Using the developed data extraction strategy, we can potentially analyze the energy usage of an entire city.

1. Introduction

Energy saving has become a priority in this growing city. During the society development energy has always been a key factor of the growth starting from the ancient work until today. Energy in a certain way defines how we live. Currently the demand for energy use is increasing while the resources are decreasing. The energy saving takes an extremely important place this times.
Different studies have proved that by orienting the urban street pattern in accordance to the wind rose, having a dense urban texture, reducing the facade glazing, keeping an ideal proportion of building height increases the energy efficiency of the buildings.
Researches of Radhi and Sharples 2012 aimed at forecasting energy consumptions and CO_2 emissions in the residential sector of UAE..To develop their statistical model, they used indices related to the energy consumption in Abu Dhabi. According to them, buildings represent the sector that consume the biggest part of the total electric consumption in Abu Dhabi. This phenomenon is undoubtedly due to a strong usage of air-conditioning systemsas per Afshari et al. 2014.
The Building Performance Simulation Tools such as, Energy Plus, Design Builder, IES, consider in the simulations only the single building taken into study. UMI has developed the urban scale of energy simulation, in this case the energy of one building is effected from the surrounding environment, building, bringing the model closer to the real conditions.

Based on Rhino design environment, the Urban Modeling Interface (UMI) program was developed by MIT in order to propose an easy-to-use urban district analysis tool for architects and urban planners. From a simplified 3D structure of an urban area, information like energy use, walkability and daylighting can be assessed by UMI. Complex files imported from programs like ArcGIS, would simplify the design process of the architects and urban planners. Once they have the environment conditions and energy impacts in the area where a new building will be places or a new road will be added it will be more efficient and helpful in calculation the energetic behavior of the intervention in the early design phase.

In this paper, we defined a data extraction protocol which allows us to analyze an urban district stored in a SHP file with the UMI program. More than just consulting stored data, UMI can infer information related to energy consumption. While a dense urban area recorded in a SHP file can easily be imported into most of geographic information systems(GIS)like ArcGIS, UMI does not have any direct options that enables us to extract a complex urban structure and convert it into a simplified representation.

2. Data Extraction Process

To import a set of buildings recorded in a SHP file into UMI, we developed a data extraction protocol consisting of three basic steps. We first used the Shape Viewer software for generating an Excel file containing XYZ coordinates of each building. This Excel file was next imported into Matlab in order to proceed to a cubic approximation of each cluster of 3D points. The resulting cubic representation of the urban area was finally imported into the Rhino 5 environment using a Python script.

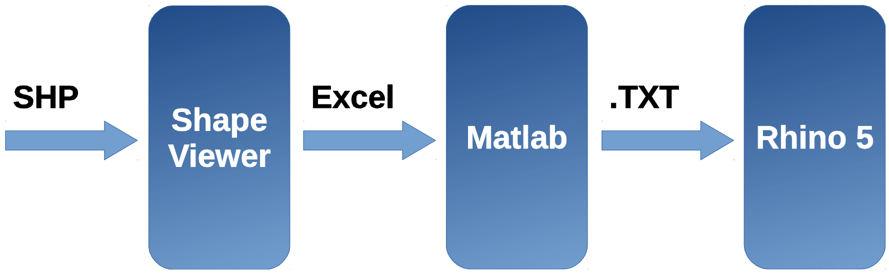


Figure 1. Data extraction process for importing a SHP file into Rhino 5 in order to be analyzed with UMI.

Shape Viewer is a free software that was developed for viewing SHP files. It exports the 3D structure stored inside the SHP file into an Excel file. Each row of the generated Excel file contains a building ID, a surface ID, a point ID, and XYZ coordinates. Consequently, it is possible to identify clusters of 3D points representing buildings of the urban area recorded in the SHP files.

This set of clusters can easily be imported and processed in Matlab. As we mentioned before, UMI only deals with simple shapes (i.e cubes) for analyzing urban districts. Therefore, we had to find a strategy for estimating all these clouds of 3D points by cubes. Using a minimum bounding box algorithm(Freeman and Shapira, 1975), we were able to define eight XYZ coordinates for each cluster corresponding to the most representative cube. The reduced number of XYZ coordinates associated to one cube (i.ethe estimated 3D structure of one building) was finally stored into a .txt file to be easily read and manipulated by any programing language.

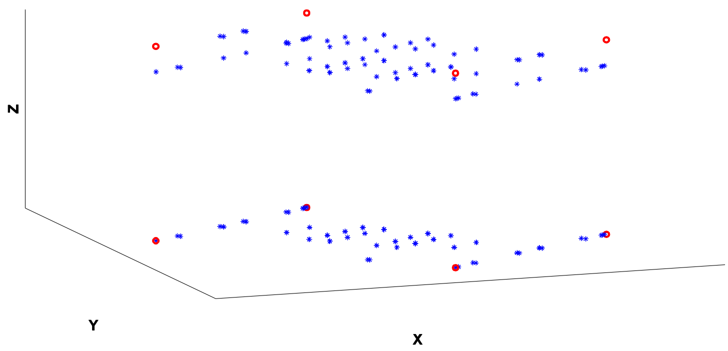


Figure 2. Cubic approximation of a cloud of 3D points (in blue) with height XYZ coordinates (in red).

The Python interpreter can be called from Rhino 5 for automatically generating 3D objects. Knowing this capability, we implemented a small Python script in the aim of importing cubes we created from Matlab. The resulting set of cubes can easily be processed with UMI in order to define properties of the urban area under study.

The above description is the input to UMI in order to provide the below output results. It basically analyses the electric consumption and CO2 emissions among other functions not considered in this paper.

3. Case Study

The case study we considered for testing the data extraction processwas taken from the main island of Abu Dhabi, framed from the streets of: Zayed the First Street, Sultan Bin Zayed the First Street, Fatima Bint Mubarak Street and 5th Street. It's a typical district with high rise residential, hotels and office buildings on the borders of the area and low rise residential buildings inside the area. There are also placed facilities such as small mall, a school, a mosque in the center of the district. The study of this zone was divided in three parts in order to facilitate the process of evaluating the glazing percentage on each building. The total number of buildings is 47, Fig. (3), divided as shown below in three tables. According to the data receives from previous studies, a continuous verification on site for each building, a confrontation with the principles of construction in Abu Dhabi it was possible to reassume the calculations of the glazing as shown in Tab. (1), Tab. (2), and Tab. (3).

Figure 3. District division.

TABLE 1. District division 1.

Building Analysis									
No.	Code	Building Type	No. Floors	No. App	South F.	North F.	Est F.	West F.	Tot % of Glazing
	A1	residential	24		90.44	90.44	90.44	90.44	**90.44**
	A2	residential	14		39.59	39.59	15.89	15.89	**27.74**
	A3	residential	14		49.22	49.22	15.89	15.89	**32.56**
	A4	residential	14		42.02	42.02	15.89	15.89	**28.95**
	A5	residential	14		39.58	39.58	15.89	15.89	**27.74**
	A6	residential	14		51.71	51.71	15.89	15.89	**33.80**
	A7	residential	14		27.30	27.30	15.89	15.89	**21.59**
	A8	residential	15		74.91	74.91	15.89	15.89	**45.40**
	A9	residential	14		42.42	42.42	15.89	15.89	**29.16**
	A10	residential	14		54.17	54.17	15.89	15.89	**35.03**
	A11	residential	14		56.67	56.67	15.89	15.89	**36.28**
	A12	residential	14		38.04	38.04	15.89	15.89	**26.96**
	A13	residential	14		73.73	73.73	15.89	15.89	**44.81**
	A14	residential	14		36.08	36.08	15.89	15.89	**25.98**
	A15	residential	14		86.25	86.25	15.89	15.89	**51.07**
	A16	residential	15		28.88	28.88	15.89	15.89	**22.39**
	A17	residential	14		64.95	64.95	15.89	15.89	**40.42**
	A18	residential	15		39.69	39.69	15.89	15.89	**27.79**

TABLE 2. District division 2.

Building Analysis									
No.	**Code**	**Building Type**	**No. Floors**	**No. App**	**South F.**	**North F.**	**Est F.**	**West F.**	**Tot % of Glazing**
	B1	residential	17		54.72	54.72	54.72	54.72	**54.72**
	B2	residential	18		60.68	60.68	60.68	60.68	**60.68**
	B3	residential	18		85.51	85.51	85.51	85.51	**85.51**
	B4	residential	18		78.09	78.09	79.09	79.09	**78.59**
	B5	residential							
	B6	residential	12		37.31	37.31	37.31	37.31	**37.31**
	B7	residential	13		42.12	42.12	42.12	42.12	**42.12**
	B8	residential	20		6.28	6.28	6.28	6.28	**6.28**
	C1	residential	13		84.83	84.83	84.83	84.83	**84.83**
	C2	residential	15		60.15	60.15	60.15	60.15	**60.15**
	C3	residential	14		32.58	32.58	32.58	32.58	**32.58**
	C4	residential	14		42.35	42.35	42.35	42.35	**42.35**
	D1	residential	19		44.51	44.51	44.51	44.51	**44.51**
	D2	residential	18		62.19	62.19	62.19	62.19	**62.19**
	D3	residential	17		72.22	72.22	72.22	72.22	**72.22**
	D4	residential	18		70.89	70.89	70.89	70.89	**70.89**

TABLE 3.District division 3.

Building Analysis									
No.	**Code**	**Building Type**	**No. Floors**	**No. App**	**South F.**	**North F.**	**Est F.**	**West F.**	**Tot % of Glazing**
	E1	residential	5		43.60	43.60465	38.8	38.8	**41.20**
	E2	residential	5		36.36	36.36364	38.8	38.8	**37.58**
	E3	residential	5		29.49	29.48905	38.8	38.8	**34.14**
	E4	residential	5		42.54	42.54144	38.8	38.8	**40.67**
	E5	residential	5		37.02	37.01657	38.8	38.8	**37.91**
	E6	residential	5						
	E7	residential	5						
	E8	residential	5		24.23	24.22611	38.8	38.8	**31.51**
	E9	residential	5		35.59	35.59322	38.8	38.8	**37.20**
	E10	residential	5		43.46	43.45679	38.8	38.8	**41.13**
	E11	residential	5		61.87	61.86557	38.8	38.8	**50.33**
	E12	residential	5		39.40	39.40182	38.8	38.8	**39.10**

F1	residential	5	39.64	39.63964	38.8	38.8	**39.22**
F2	residential	5	41.58	41.58004	38.8	38.8	**40.19**
F3	residential	5	41.51	41.50943	38.8	38.8	**40.15**
F4	residential	5	42.61	42.61438	38.8	38.8	**40.71**
F5	residential	5					
F6	residential	5	38.84	38.84409	38.8	38.8	**38.82**
F7	residential	5	40.68	40.68396	38.8	38.8	**39.74**
F8	residential	5	57.11	57.10956	38.8	38.8	**47.95**
F9	residential	5	39.29	39.29059	38.8	38.8	**39.05**
F10	residential	5	41.84	41.83536	38.8	38.8	**40.32**
F11	residential	5	51.37	51.36986	38.8	38.8	**45.08**
F12	residential	5	60.86	60.8642	38.8	38.8	**49.83**
F13	residential	5	40.83	40.83225	38.8	38.8	**39.82**
F14	residential	5	34.80	34.79769	38.8	38.8	**36.80**
F15	residential	5	24.30	24.29668	38.8	38.8	**31.55**
F16	residential	5	45.93	45.9279	38.8	38.8	**42.36**
F17	residential	5	42.90	42.89617	38.8	38.8	**40.85**
F18	residential	5					
F19	residential	5	44.94	44.94238	38.8	38.8	**41.87**
F20	residential	5	33.82	33.82022	38.8	38.8	**36.31**
F21	residential	5	42.63	42.63473	38.8	38.8	**40.72**
F22	residential	5					
F23	residential	5					
F24	residential	5	54.66	54.65839	38.8	38.8	**46.73**

4. Energy Consumption and CO_2 Emissions

Based on a SHP file received from the Municipality of Abu Dhabi, we imported all buildings of the case study into the UMI interface using the developed data extraction process. Then, we defined each building according to the number of floors and the glazing ratio specified in Tab. (1), Tab. (2), and Tab. (3). Finally, we run a UMI simulation in order to estimate energy consumption and CO_2 emissions.

Fig. (4) represents the electric energy consumption approximation of each building in the urban district under study. According to this result, all buildings consume between 503 and 640 kWh/m^2 of electricity on average over the year. While buildings with higher electric consumption are located in areas A, E, and F, urban areas B, C, and D is characterized by lower electric consumption.

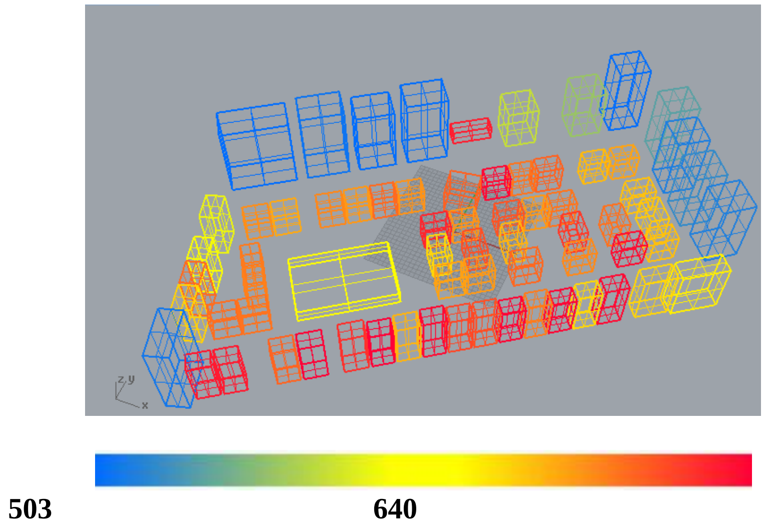
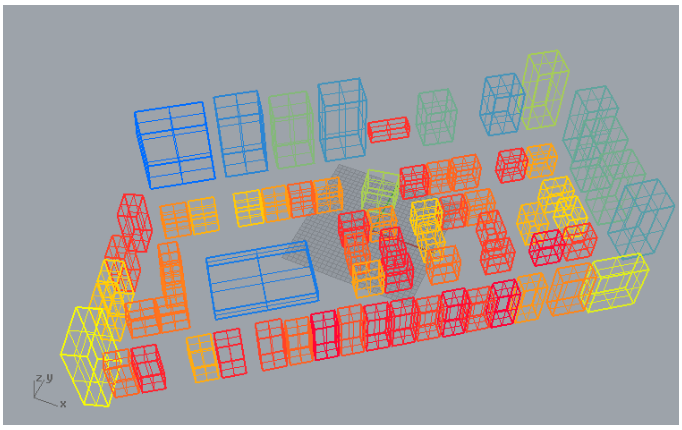


Figure 4. Electric energy consumption estimation (in kWh/m^2) for each building.

CO_2 emissions in the urban area under study are introduced in Fig. (5). The range of emitted CO_2 on average over the year in each building is approximated between 68 and 86 kg/m^2. Conforming to this observation, urban areas B and D are the ones with the lowest CO_2cost. These results are calculated based on the type of construction of the studied buildings, wall package and type of glazing defined the Abu Dhabi Municipality report (ref). The study is referred to Abu Dhabi weather data.



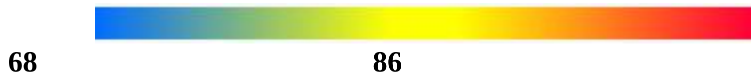


Figure 5. CO_2 estimation (in kg/m^2) for each building.

5. Conclusion

In this paper, we introduced a methodology for extracting an urban district stored in a SHP file in order to make its energy analysis possible with UMI. Based on a case study, we estimated the average electric consumption and CO_2 emissions over the year of an urban area imported into UMI employing the developed data extraction protocol.
The verification of the results with the real data is shown in Tab. (4). together with an estimated error percentage. As it can be seen, the error value is quite low that brings us to the conclusion of the efficiency of the estimation made in UMI.

TABLE 4.Comparison Table.

Comparison Table				
No	**Category**	**Estimation**	**Measured**	**Error%**
1	Blue	503.00	0	
2	Green	548.67		
3	Yellow	571.50		
4	Orange	594.33		
5	Red	640.00		

The capabilities of UMI in inferring information related to the energy consumption of the urban area under study are still limited. The implementation and analysis of the urban heat island effect in UMI would be an interesting challenge for a future study.

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