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TOWARDS COMPUTATIONAL ANALYSIS METHODS AND GRAPHICAL DISPLAYS IN URBAN DESIGN EDUCATION: CASE STUDY SITE ANALYSIS COURSE IN KAFRELSHEIKH UNIVERSITY

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ABSTRACT. A proper knowledge of computational methods is considered a key competence for future urban designers. But unfortunately, the integration of computational pedagogies in urban design education remains underexploited. This study aims to present an urban analysis course content that took place in the architectural department in the faculty of engineering in Kafrelsheikh University in 2020, applying computational analysis and graphical simulations of quantitative data. Through a selection of software tools for spatial and environmental analysis the course aided students to understand the challenges of the site in their graduation urban design project. The course exploited Geographic information system software (GIS), Space Syntax theory represented in DepthMap software, besides Ladybug plugin for Rhino Grasshopper. The course is presented though practical tasks and theoretical discourses. The paper concludes by developing a computational analysis tool-kit for urban studies education, with limitation only to the physical representation of urban morphology, rather than social/ cultural or economic studies.

KEYWORDS: Site analysis course; Computational analysis; GIS; Parametric environmental analysis; Space Syntax.

1. INTRODUCTION

Site analysis is one of the most important steps of urban design process.[1]. Urban studies concern both tangible and intangible attributes. The former is related to the geometric form of the built environment and its effect on the microclimates, functional patterns, open spaces, layouts of buildings. The latter engages the cultural, social and economic conditions. This paper focuses on the tangible form of the built environment, based on the figure–ground theory, and is related to spatial and environmental analysis. [2].

A proper knowledge of computational methods is considered a key competence for future urban designers. These smart methods acquire the ability to predict data as well as producing efficient analytical perspectives. Unfortunately, the integration of computational pedagogies in urban design education remains underexploited, most probably, because technology is advancing faster than education. This technological evolution enabled a better data control and the creation of innovative computer oriented design approaches [3] Moreover, it reduced the gap between the analytical studies and the final design output (Vanossi, 2018).

The paper is presenting the main computational analytical tools provided by the Site analysis studies course, carrying the code of ARC4x33. It is an elective course for the fourth year in architectural department - the faculty of engineering in Kafrelsheikh University. It is structured around 2 hours lectures per week besides 2 other hours of practical work. It takes place in parallel with the design graduation project. In this course students explore how to execute, analyze and interpret spatial configurations and environmental conditions with advanced computational methods, in order to achieve a better understanding for the contexts using simulation methods. The course was concerned of interpreting the conventional methods of collecting data (ex: surveys/ observations/ site visits), towards computational analytical methods for large data sets. Besides providing the capacity of data prediction utilizing software programs.

This study presents an integrated urban analysis course model, applying computational tools. It focuses on exploiting parametric analysis and geographic information system in order to achieve

urban sustainability [4]. The course exploited GIS (Geographic information system software, Ladybug plugin for Rhino grasshopper, Autodesk CFD (computational fluid design). According to literature, they are selected software's that proved their efficiency and accuracy in performing urban design analytical operations.

2. LITERATURE REVIEW

Traditional methods for urban analysis are becoming obsolete and not capable of facing the current urban complexities [4]. The Urban reality today requires tools that can capture, store, analyze and predict data. Comparing with conventional approaches, computational analytical methods for urban contexts offer visualised modelling interfaces to modify or update data. It facilitates urban analysis and contextual studies in aspects of efficiency, flexibility, and visualisation [2].

Geographic information system software (GIS) is one of the advanced tools that can carry out sophisticated operations to spatial information [5] While, Motta confirmed in 2011 that GIS surpassed over conventional methods in managing big data sets besides modeling and predicting unknown spatial information [6, 7]. Although Gil in 2010 stated that it is not widely adopted within creative design process [8]. Both Kempf [7] and Elsayed [9] in 2019 and 2021 respectively, affirmed that satellite imagery (SIM) is one of the basic data sources used by GIS for data extraction and prediction [7] and [9], which is an available and easy tool to be used for educational demands. The use of Satellite imagery in GIS facilitates further operations like Geo-referencing enabling users to obtain real measurements from images of non-spatial references. Consequently, geo-editing process for buildings, infrastructure, natural elements and resources, etc. could take place together with data querying. Moreover, Geo-referencing operation facilitates digital terrain modelling (DTM) which uses sample points in predicting unidentified values of geographic data such as the latitude in order to perform contour analysis [10] ("Contour Analysis," 2014).

Besides simulation models based on geographic information system, urban analysis education is concerned with investigating complex spatial relationships between urban spaces. Space syntax theory utilizing DepthMap is one of the recent computational tools developing this concept. It was developed at the Bartlett School of Architecture, University College London. According to Nes and Yamu [11] in 2021, it is capable of analyzing how space networks are related to functional patterns. They also affirmed that Space syntax theory using depthmap software is designed to measure street network connectivity and define the spatial integration of people with urban spaces [11]

Within the current urbanization and climate change challenges, model based computational methods derived from parametric systems are designed to investigate the interactions between urban form and their microclimate [12]. The term denotes the use of parameters to indicate geometric and environmental information. Knecht [13] mentioned in 2018 that parametric systems are more desirable to deal with complex urban phenomena more than to conventional analytical methods. It uses rule-based models that enable the exploration of a wide scope of simulation results by changing the parametric definitions or relationships. Parametric urban analysis can be used for both the assessment of existing urban areas or the development of new settlements through visualisations and quantification techniques. This leads to a better understanding for the site's environmental challenges and provides students with clearer visions towards their design approaches. Furthermore, it enhances the accountability of designers and design-decision makers [13].

Parametric analytical methods participate in reaching a comprehensive design approach towards site challenges from a technical perspective. It communicate through the manipulation and exploration of different spatial and environmental parameters, such as solar radiation, day lighting or airflow analysis [4]. Zhang and Liu [2] added in 2021 that parametric thinking participates in understanding the possible design approaches in terms of shaping urban areas and obtaining suitable sunlight, space, visibility and moderate wind. The also stated that successive iterations for environmental parametric model can promote the optimized performance of urban morphology. This method provide various result formats presented in numerical reports and analytical simulation 2D and 3D models, which facilitates the decision making process in urban design projects, in order to create environmentally friendly cities [2].

3. RESEARCH METHOD:

Following the previous literature, the research method is investigating the potentials of geo-spatial and parametric systems in obtaining efficient computational analytical methods for educational pedagogies.

The site analysis course is scheduled in the same semester of the graduation project in order to utilize the urban analytical studies in the designing tasks. The students' project site was in the New Cairo capital which is located 35 KM east of Cairo and of a total area of 170,000 Feddan. It lies between the regional ring road, the Cairo-Suez road and Cairo-El

Ain El Sokhna road. The new capital includes residential, commercial, business, and recreational activities. The study area of the project is located at the southwest border of the city along the green river. The new capital fits the research target of examining computational tools for spatial and environmental analysis in new urban development projects.

The course departed from a series of theoretical lectures highlighting the importance of computational analytical methods and their impacts in guiding the urban design processes. Referring to its potentials in predicting, analysing, and simulating data.

3.1. GEOGRAPHIC INFORMATION SYSTEM (GIS) SOFTWARE

The first tool introduced by the course concerned the Geographic information system analysis based on GIS software. The course adopted Al Shurouk city as a case study for the course's analytical simulations provided by the course coordinator. It is a new settlement in Cairo resembling the graduation project site. The course coordinator employed Google Earth's spatial resolution images leveraging Maxar technologies for extracting the required geo-data. The city of Al-Shurouk in Cairo is located at 36^0 08′ 23″ north and 31^0 38′ 19″ east, The geographical coordinates are retrieved from the Google Earth engine with an eye altitude set of 2.04 Km in April 2019.

3.1.1. GIS GEO-REFERENCING TOOLS

Geo-referencing is a process transforming aerial images to appear in place in GIS software, so as it fits other spatial data sets as shown in Fig. 1. The course introduces how to use a Google Earth image as a base map in ArcGIS Pro through the following steps. Open Google earth engine, select the exact location of the study area and save it as an image with Jpg file extension, which is currently an image of a non-spatial reference. Add at the corners four place marks representing the ground control points. Then save the place marks as a KML file extension, which is a file format used to display geographic data in Google earth engine. Consequently, open a blank Arc map file; create a *new personal geo-database* for storing all the spatial data for the study area. Choose from search engine a conversion from *KML to layer* in order to display the place marks as a feature class. Then upload the saved Jpg image file from *Add data* on Arc-Map. Finally, by using Geo-referencing tool, relate the place marks to their location on the saved image using *Add Control points* command. After this step students can obtain a Google earth image with a spatial reference as shown in Fig. 1.

Since their study area is in Cairo-Egypt the image was automatically set after Geo-referencing process to WGS_1984_UTM_Zone_36N. The coordinates of each place-mark could be visualized from displaying the view link table, which enable users to view and edit in any place-mark.

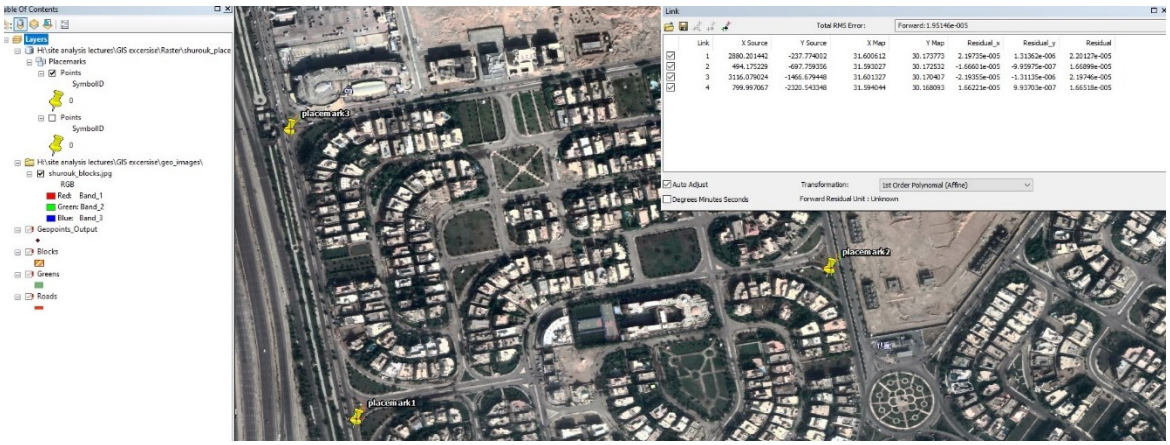

Fig. 1. shows the Place-marks location in map after Geo-referencing process, Source: Author

Link	X Source	Y Source	X Map	Y Map	Residual_x	Residual_y	Residual
1	2880.201442	-237.774002	31.600612	30.173773	2.19735e-005	1.31362e-006	2.20127e-005
2	494.175229	-697.759356	31.593027	30.172532	-1.66601e-005	-9.95975e-007	1.66899e-005
3	3116.079024	-1466.679448	31.601327	30.170407	-2.19355e-005	-1.31135e-006	2.19746e-005
4	799.997067	-2320.543348	31.594044	30.168093	1.66221e-005	9.93703e-007	1.66518e-005

Fig. 2. shows the Place-marks Coordinates in the source and on map the table is extracted from the view link table on Arc-Map (GIS), Source: Author

3.1.2. GIS-EDITING TOOLS

After obtaining a Google Earth image of a spatial reference, students are capable of editing, producing, modifying, updating or deleting feature classes or data sets stored on a specific geo-database. In this phase students are becoming familiar of creating feature classes and data sets to obtain roads, buildings, natural elements, infrastructures and so on so forth. Moreover, students are trained to upload data to feature classes using '' *Open attribute table*''. This step enabled students to store all data concerning, building conditions/ heights/ materials/ or year to buildings feature class, using text, numbers or Boolean values (yes/no). Similarly this could take place to other feature classes through add/Delete or edit fields and records. After this phase students are prepared for executing GIS-Querying process.

3.1.3. DATA-QUERYING EXPRESSIONS

Practicing data querying is essential for students learning GIS. It is a process enabling students to select spatial features using structured query language (SQL). Data Querying could take place through two methods. The former selects through attribute tables associated with features or stand-alone ones as shown in Fig. 3. Attributes can be numbers, text strings or decisive values based on true or false inputs. As shown below some expression examples using SQL used for GIS queries, proposed by the author during the course:

[Use] = 'residential' AND [construction_state] = 'constructed' AND [services] = 'available'

[Use] = 'residential' AND [construction_state] = 'constructed' OR 'not_constructed' AND [no_floors] > 4

The later concerns spatial queries selecting through location derived directly from drawn features on the map. Both attribute and spatial queries answer questions that would not be practical to answer using other conventional methods as shown in Fig. 4. More over, the course introduced statistical and mathematical operations related to data query like summation, mean, standard deviation, which are very useful in managing and analyzing big data.

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Fig. 3. shows the practiced example of attribute queries (Select by attribute), The query stated:

[Use] = 'residential' AND [construction_state] = 'constructed' OR 'not_constructed' AND [no_floors] > 4. Source: Author

Fig. 4. shows the practiced example of spatial queries (Select by location), The query states questions How many residential blocks located at a distance < or =100 m from the selected garden?, Source: Author

3.1.4. GEOMORPHOLOGICAL STUDIES

Geomorphological studies reflect the landform challenges and percentage change in a slope elevation over a certain distance. Geomorphological analysis can enable students to accomplish efficient spatial and environmental decisions for the urban form and infrastructure during the preliminary design phases. The course introduced the procedures of obtaining contour analysis, slope analysis besides topographical sections and reports. It supported students with data prediction tools in order to deal with uncertainties in complex urban and natural environments, which is entirely available in GIS software.

Accordingly, the course presented the technique of extracting geomorphological data from Google earth images, exploiting GPS online interface and finally performing the operation on ArcGIS software. Students used Google earth for creating a path forming a grid covering their study area. The path is saved as a KML file format. Using GPS visualizer online interface students were capable of obtaining the elevations (latitudes) of the geographic data uploaded through the KML file. The file is saved as a GPX format, which enables the storage and processing of geo-data. Consequently, students used Arc Map in GIS to convert the geodata (GPX file) to a feature class, then to a raster image using *IDW* (inverse distance weighted) *spatial analysis* command. Accordingly, they were capable of extracting contour lines and slopes through *Contour spatial analysis* and *Slope spatial analysis commands,* respectively as shown in Fig. 5. Furthermore, the course trained students to modify class and color of each contour through properties/symbology. Besides designing maps and 3D views using Arc Scene interface. After this phase, students were capable of presenting all the necessary maps concerning the geomorphological analysis of their study area

3.2. SPATIAL ANALYSIS USING SPACE SYNTAX THEORY AND DEPTHMAP SOFTWARE:

Space syntax theory was introduced theoretically by the course, aiming to develop the students' capacities of self-learning. Space syntax concept is considered a compulsory literature for urban studies and spatial analysis courses. The course opened up the opportunity for students to explore the online platform for learning depthmapX visual and spatial network analysis software and explore their capacities to use the software themselves. Space syntax enabled students to analyze street network connectivity and examine the spatial integration of people with space as shown in Fig. 6.

3.3. ENVIRONMENTAL STUDIES

The second phase of the course concerned the environmental analysis, which took place in Cairo. The city lies at latitude of 30.05^0 N and a longitude of 31.17^0 E, and located in a hot arid area. In this context, the environmental analysis is crucial to guide the students' new designs in order to achieve healthier urban microclimatic conditions. This phase adopted Ladybug plugin for Rhino grasshopper parametric software and Autodesk CFD (Computational fluid design) software.

3.3.1. ENVIRONMENTAL STUDIES USING LADYBUG PLUGIN FOR RHINO GRASSHOPPER

The general environmental analysis of the city was explianed using online energy plus weather data files (EPW file), which was uploaded on Ladybug plug-in for Grasshopper. Accordingly students were able to obtain data concerning location, dry bulb temperature, relative humidity, wind direction and speed, besides other weather data on grasshopper interface.

Accordingly, further environmental processes were executed, like wind rose analysis, which can combine both the wind speed and direction besides air temperature (if the dry bulb temperature data is plugged in the annual hourly data) using *Ladybug-Wind rose* component. Moreover, the course introduced sun path analysis, which enabled students to predict the daylight experience over their study area besides the sun's temperature, in different analysis period (Winter/summer). Students were also trained to simulate solar rose analysis using *Ladybug-Solar Rose* command. It enabled students to generate a graphical representation for the amount / direction and typology of solar radiation demonstrating total, direct and diffused radiation. Furthermore the course introduced the *Psychrometric analysis* tool, which helped students to explore the suitable passive heating and cooling strategies in their context. All scripts are generated on the Grasshopper canvas, while the graphical simulations are relatively generated on Rhinoceros interface as shown in Fig. 7 and Fig. 8 respectively.

Afterwards, the course focused on developing environmental analysis over a specific urban form. Measuring and modeling the urban context using Rhinoceros 3D software, was the first level of this phase. It helped in understanding the spatial configuration of the urban context and its effect on the urban microclimate of the area. Modeling enabled students to perform Solar radiation analysis, which is a component calculating the radiation falling on an input geometry using a selected sky matrix during a specific analysis period (Elsayed, 2021b). The selected test geometries could be the floor, the facades or the roof. Solar radiation analysis requires specifying as well the surrounding context, which indicates the

sunlight blocking buildings. While, the offset distance of the test point from the input geometry is set at 0.01 m as shown in Fig. 7. After running the simulation the results elucidated high solar radiation values in red color, while lower ones are represented in blue as shown in Fig. 8.

3.3.2. ENVIRONMENTAL STUDIES USING AUTODESK COMPUTATIONAL FLUID DESIGN SOFTWARE (CFD)

Finally, the course introduced the Airflow analysis utilizing computational fluid design (CFD) software supported by Autodesk. This analysis helped students to understand the urban design challenges related to aerodynamic performances presented in numerical and analytical solutions. In order to obtain airflow analysis users had to define wind speed, direction and space dimensions, besides the impact of the surrounding context. Exploiting the wind rose-ladybug analysis for Cairo city students were capable of calculating the wind speed in winter, which reached 7m/s and 5m/s in summer following a northwest direction. The course explained the procedures followed to set the boundary conditions of the model concerning materials, air velocity and pressure. In this context, air was assigned to the inflow box while; brick was assigned to the surrounding context. The velocity differed from winter to summer (5m/s, 7m/s respectively), while the gage pressure was set to its constant value for atmosphere, which is, equals to 0 (PG). After running 100 iterations the outputs illustrated the airflow and velocities at a distance of 1.5 m high from the ground level, and all values are measured in CM/s. High air velocities are highlighted in red, while lower ones are in blue color as shown in Fig. 8.

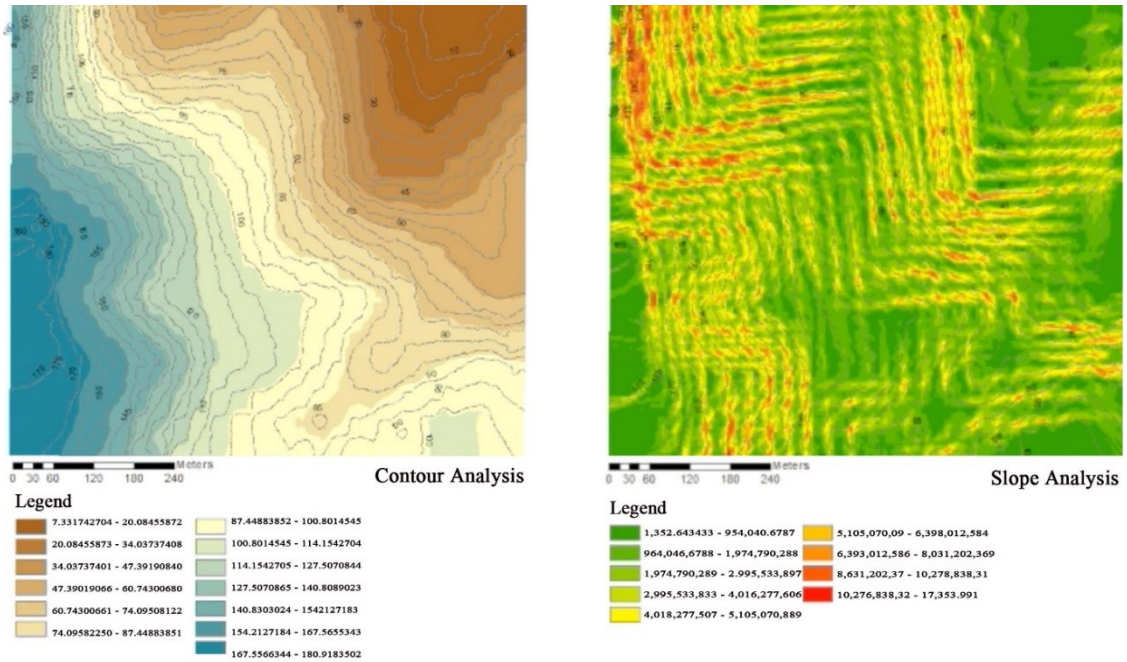

Fig. 5. shows contour analysis and slope analysis maps executed by the course coordinator during the course, Source: Author

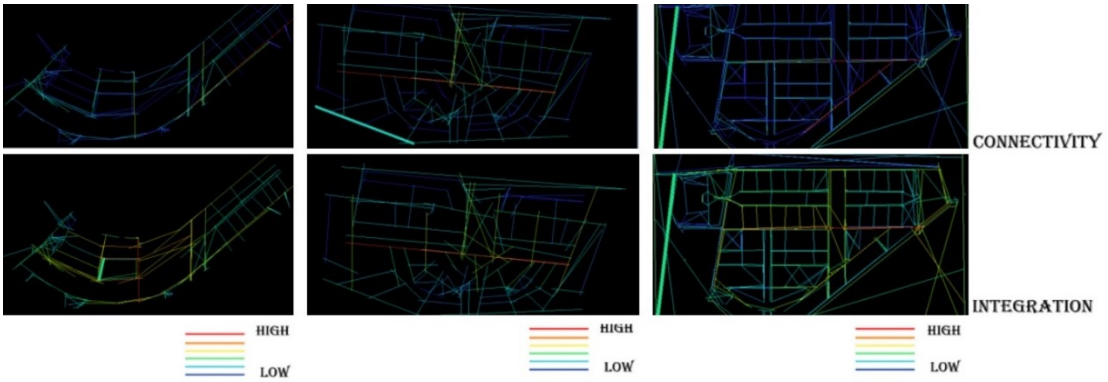

Fig. 6. shows: Space syntax analysis showing areas of connectivity and integration
Source: (students'work) Group members: eng. Hadeer gamal, Alyaa Abdella, Esraa Abdelnaser, Ola Salah, Aya Elsaid, Eman Ahmed, Amany Gwil

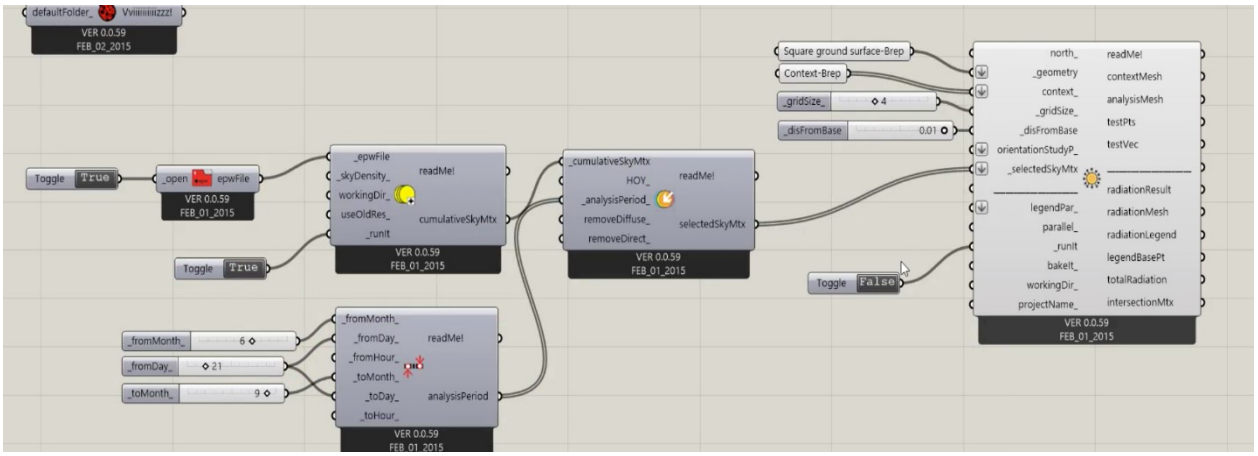

Fig. 7. shows the algorithmic script of solar radiation ladybug analysis executed using Rhino Grasshopper software, Source: Author

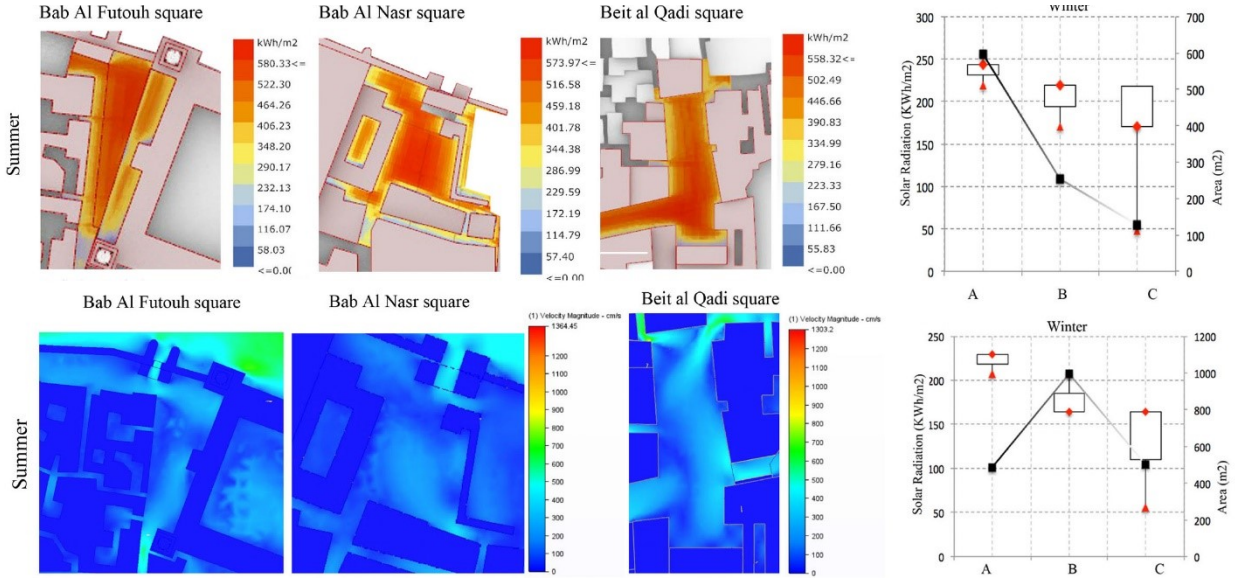

Fig. 8. shows a solar radiation ladybug analysis simulated for an urban space in old Cairo, in the upper figure and an airflow analysis in the lower figure. Source: The microclimatic impacts of urban spaces on the behaviour of pandemics between propagation and containment: Case study historic Cairo. Urban Climate, 36.

4. RESULTS AND DISCUSSIONS

The research outcomes are synthesised in computational analysis tool-kit for urban studies education, limited to the physical representation of urban morphology represented in Table 1 and Fig. 9. The table is illustrating the analysis concerning each typology of studies, related to geographical, Spatial or environmental topics. Furthermore, it highlights the most usable softwares for each sector, weather in educational process or professional practice. The analysis and softwares marked with (*) are the ones practiced during the site analysis course, while the others are possible softwares that could be introduced in the course's future developments.

The course demonstrated that the majority of students had developed their analytical and interpretational skills with the aid of computational methods. Where the adopted pedagogies supported the students to become disillusioned about Computational urban analysis methods. But students recommended a better-integrated pedagogical approach between site analysis and urban studio courses, in order to enable the optimum employment of the analysis during different design phases. Aiming to empower optimisation process between design scenarios to reach urban configuration with the optimum spatial and environmental performance. Moreover, Students were not efficiently capable of balancing the workflow and submission schedule between both courses. As, they preferred to learn the computational analytical methods in an earlier semester.

The course enhanced the intellectual and professional capacities of students related to self-learning. Some student groups were capable of

decoding the logic of computational analytical softwares and present it in their final reports. But they represented a minority between students. Apparently, the self-learning process regarding computer software is affected by previous programing experiences as well as adequate knowledge of mathematics and statistics. These aspects affected the general performance of students. Regarding future development of the course, it is recommended to include demographic studies concerning population, density, education, employment, labor force, birth and death rates, etc. Utilizing statistical analytical models IBM SPSS software. Besides the continuous upgrading of the course with the most advanced and wide spread softwares used in urban design analytical methods.

Table 1. shows a tool-kit for urban studies education based on computational analytical methods.

Geographical Studies*	**Geomorphological Analysis***	**Software**
	• Urban regulations* • Street networks* • Land use* • Building Heights* • Building Conditions • Infrastructure • Natural resources • Risk mapping	**GIS geographic information system*** • ArcMap* • ArcScene* **Rhinoceros 3D software*** Rhino_ Grasshopper *
	• Contour analysis* • Slope Analysis* • Topographical Profile sections • Cut and Fill	**Surfer software**
Spatial Studies	**Spatial analysis**	**Software**
	• Pedestrian Modeling • Connectivity • Integration	**DepthmapX (Space Syntax)***
	• 3D Analysis* • Isovist field analysis (Visual analysis)	**Autodesk AutoCAD (2D, 3D)*** **Autodesk Max** **Rhino Grasshopper***
Environmental studies*	**Environmental Analysis***	**Software**
	• Dry bulb temp* • Relative humidity* • Shadow analysis* • Wind Rose* • Solar Dome* • Sun Path Analysis* • Radiation Rose* • Psychronometric charts* • Solar Radiation analysis* • Daylight Analysis • Thermodynamic Analysis • Energy Modeling • Airflow Analysis* • Noise Mapping	**Rhinoceros 3D software*** • Grasshopper-Rhino 3D* • Ladybug plugin for Grasshopper* • Honeybee-Grasshopper • Climate Studio-Grasshopper • Dragon Fly _Grasshopper **Autodesk** • Ecotect • Computational fluid Design* CFD Autodesk * **ENVI-Met Microclimate simulation** **CadnaA Noise prediction software**

5. CONCLUSION

The paper represents the educational pedagogies practiced in the Site analysis elective course, code (ARC4x33) in the faculty of engineering in Kafrelsheikh University. The course adopted computational urban analysis methods based on geographical information and parametric systems. Through a selection of software tools for spatial and environmental analysis the course aided students to understand the challenges of the site in their graduation urban design project besides exploring their capacities in self-learning. The paper highlights the importance of establishing a better-integrated pedagogical approach between site analysis and urban studio courses. Furthermore, the study tackled the students' preference in learning computational analytical methods in earlier semesters. Finally, it concluded by a tool-kit guiding the education of computational urban analytical methods, updated with the most functional computational tools used in education and professional practice.

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