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Utilization of LiDAR and Big Data in Daylight Concept Design Process Integrated with a Parametric Approach

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Abstract:

Indonesia is presently in the era of the Industrial Revolution 4.0 where data and information are important in the architectural design process, specifically for the daylight design at the initial observation stage. This is considered necessary because architecture students generally have problems obtaining accurate and measurable data for sunlight, wind direction, road patterns around the site, and others. Therefore, this study focuses on considering the quality of sunlight in the design of high-rise

I. INTRODUCTION

Indonesia is currently in the era of Industrial Revolution 4.0 where data and information are an important part of human life. The Internet of Things has been used to integrate every activity of humans through different devices. Moreover, social media, digital messaging services, lectures, and online meetings have become part of everyday life, specifically during the COVID-19 pandemic. Therefore, this has caused higher information traffic and accumulated into a large dataset known as Big Data. An example of the different types of information circulating is geospatial information which can be used in architectural education, specifically in relation to early design activities such as site analysis usually conducted to obtain initial information needed for the design process and building simulation. Furthermore, the development of open source-based applications such as OpenStreetMap has provided current opportunities for designers to obtain and contribute to enriching geospatial information in cyberspace. Furthermore, architecture learning technology using the simulation method has been developed and is currently being used officially by architectural education institutions as well as architects in the design process. The simulation results are believed to be fairly accurate and widely accepted, but the process requires fairly a variety of preliminary data such as climate data, surrounding buildings, vehicle traffic, and others which are very difficult to obtain manually due to several reasons. However, there are different kinds of engineering-related services available on the Internet such as the OpenStreetMap (OSM) which is a free-to-edit world map creation platform. The app was inspired by the success of Wikipedia and the availability of map data and is observed to have a contributory number of 1.6 million registered users that collect data using self surveys, GPS devices, aerial photography, and other free sources. This crowdsourced data is released under the Open Database License and the site is supported by the OpenStreetMap Foundation which is a non-profit organization based in the UK. It is important to note that the data being collected are getting bigger, wider, and more diverse, and this means this is a better time for the community, specifically architecture students, to make maximum use of this platform for various design purposes.

II. BACKGROUND AND PURPOSE

An Indonesia has entered the era of the Industrial Revolution 4.0 where data and information are important in the architectural design process, specifically at the initial observation phase which requires designing the daylighting concept. However, architecture students are faced with the problem of lack of physical data which match field measurements such as the direction of sunlight, wind direction, road patterns around the site, and others. It has been discovered that there is presently a significant increase in the demand for high-rise buildings and this was confirmed by the statistics which showed more than 100% increase in the construction of these buildings since 2011 (CTBUH,

2009). This phenomenon triggers the use of massive energy to fulfill the needs of artificial lighting and artificial ventilation with the need for artificial lighting observed to have increased by 10-25% (Al Kodmany, 2012). Moreover, daylight calculation requires considering the amount of solar radiation captured by the building, the level of glare affecting the visual quality of the occupants, the availability of lighting in the building, and the amount of solar intensity entering the building (Ander, 1995). Therefore, a strategy is needed to optimize each parameter observed to be affecting daylight quality, but there are difficulties in obtaining data and getting access to high-rise buildings considered to have fulfilled the green building criteria, thereby making it difficult to prepare supporting data. This means the problems previously highlighted to be facing architecture students also include data collection and modeling processes which are different from the simulation. Therefore, this study aims to integrate the process of collecting spatial data, exploring building models, and developing simulation processes in a series of works to be presented in the form of visual scripting.

LITERATURE REVIEW AND THEORY FRAMEWORK

Architects need to consider passive design strategies to reduce the heat received by the building (Dewi et al., 2018). Therefore, this section describes previous study that supports passive design strategies which involve using building simulation software to adapt to climatic conditions outside the building (Mufidah and Purwanto, 2021). Asim Ahmada et al. explained that daytime lighting and its influencing factors can be calculated using simulation software such as MATLAB, Energy Plus, Velux, Relux, and DIALux which can also be used to calculate energy utilization in buildings (Ahmad et al., 2020). However, it is important to note that this innovative software is not only available for the modern building alone as indicated by Nermine Abdel Galil M et al. that Ecotect can also be used to calculate the typical Egyptian “sheesh” shading tool (Gelil and Badawi, 2015). Moreover, it is also possible to apply them to determine tropical conditions as well as to analyze 1-story buildings such as residential houses (Dabe and Adane, 2020). Meanwhile, Javier González and Francesco Fiorito emphasized a few obstacles with the use of the software such as the high dependence on working time and a certain number of iterations to produce an accurate solution. This means that there is a need for an integrated workflow to rectify this problem (González and Fiorito, 2015). Therefore, this study discusses the use of simulation software which is not limited to the design phase, but is also applicable in the site analysis stage.

BUILDING MODELING SIMULATION IN ARCHITECTURE

The simulation process in the discipline of Architecture is divided into drawings, photography, and building models, but the focus of this present study was on simulation through building models. The process involved obtaining different types of simulation results from the calculation of the model’s parameters. It is also important to note that the model is categorized into physical and virtual with the building orientation, sunlight, wind movement, and others usually determined based on the physical test process. An example of this is the wind tunnel which is normally used to test the movement of the wind against the building. Meanwhile, an example of the virtual aspect is the BESTEST (Building Energy Simulation Test) which is mostly applied to calculate the quantity of energy consumption in a building to provide optimization solutions. It is also important to note that software such as “Design Builders” and “Ecotect Software Analysis” have the ability to simplify the process involved in identifying different variables in building models such as DBT (Dry Bulb Temperature) and WBT (Wet Bulb Temperature). Moreover, the designer can change the parameters during the research process and also check the modeling results to select the best from probabilities offered to be directly applied to the building design.

THE SPECIFIC PLAN FOR HIGH-RISE BUILDINGS

The planning of high-rise buildings is not much influenced by variations in microclimate such as vegetation and surface conditions on the site, but by different external vertical conditions due to its

height as well as the density of the surrounding buildings. Moreover, the level of exposure to the sunlight varies based on the height of the building such that a higher building has more sunlight entering. It is also important to consider the effect of heat reflected by the surrounding buildings in the design process (6).

INFORMATION TECHNOLOGY AND DATA OF THE CITY IN RELATION TO ARCHITECTURAL NEEDS

Advancement in information technology has changed people's lifestyles, specifically their socialization and behavioral patterns, thereby leading to the formation of a new habit for the community (Oulasvirta et al., 2012). The technology was also observed to have created new opportunities such as the development of a new reality which involves the integration of the environmental and digital media in everyday life (Bower et al., 2010). Moreover, students and the current generation of Architecture Practitioners are known as Digital Natives (margaryan et al., 2011) due to their familiarity with technology, specifically digital technology. It is also important to note that the use of technology in the works of architects is previously limited to applications such as CAD (Computer-Aided Design) and BIM (Building Information Modeling) which are only used for visualizations. However, some other software have been developed in line with the advancement of Virtual and Augmented Reality as well as Geo-Referencing technology to create new and wider skills for the design process (Valls et al., 2018).

SITE ANALYSIS

Site analysis is the initial part of the design process which is usually based on empirical facts to explain the existing condition of a site. The purpose is to ensure their design object adapts to the conditions of the area by proposing several alternative designs (White, 1983).

OPENSTREETMAP

OpenStreetMap is a large geographic information service crowdfunding project which was originally started in 2004 to provide geographic information that can be utilized by everyone through crowdfunding. It is a database distributed through the Open Database License (ODbL) which allows contributors to build actual information and makes them freely accessible to others (Minghini and Frassinelli, 2019).

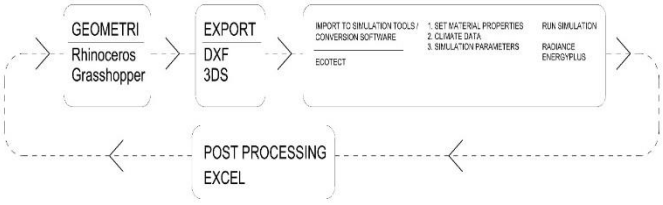
PARAMETRIC APPROACH

The parametric approach in digital architecture produces different design solutions in a digital model through visual scripting (Tedeschi, 2014). However, it requires some parameters such as initial formation, numerical variables, and operational relationships which are packaged into a visual formula to produce the solutions and methods needed (Abdullah and kamara, 2013). Therefore, this study used the process of simulating building performance design with a parametric approach to produce a diverse and optimal design solution using Rhinoceros and Grasshopper as the main software.

WORKFLOWS

Several applications were used to support the experimentation process which involved converting data from object modeling software to simulation engines, but the process was observed to be fragmentary as indicated in the following workflow chart.

Diagram 1. Commonly used workflows
Source : (Buildings and Performance, 2016)



This study discusses the use of visual scripting to integrate workflows with the process observed to have started from site mapping using LiDAR technology and its subsequent integration into the vector data obtained from the OpenStreetMap website followed by the modeling and simulation processes in a complete series.

IMPLEMENTATION METHOD AND STEP

This study used experimental methods which involved modeling strategies and simulation processes using Rhinoceros, Grasshopper, Elk, and Diva software in preparing the daylight planning concepts. The steps generally involved mapping, marking, and documenting the site using LiDAR technology. The first step was the mapping conducted to produce the point cloud which was converted into an .OBJ file as shown in Figure 1. Moreover, the data were completed and validated using the LiDAR drone presented in Figure 2, after which the vector data were retrieved from the OpenStreetMap website in OSM format.

Figure 1. Pointcloud mapping results from LiDAR Drones
Source: Author

Figure 2. LiDAR Drone Device
Source: Author

The second step was to combine the results of the LiDAR mapping which is in the form of an .OBJ file with vector data obtained from the OpenStreetMap website as shown in Figure 3. These files were compiled in Rhinoceros Grasshopper software using Elk plugins to produce the vector objects in Figure 4. This process was used to filter the imported .OSM files to ensure they were visualized based on the needs of the user with the focus on the data for the buildings, roads, locations of public facilities, rivers, and others. Meanwhile, the data from OpenStreetMap include those related to the site boundaries, highways, and surrounding buildings.

Figure 3. Map of the area in OpenStreetMap website
Source: Author

Figure 4. Regional Map in the form of vector converted by Elk plugins
Source: Author

The third step was the combination of the vector and pointcloud data with the climate data in the form of EPW or Energy Plus Weather Data files which were converted using the climatestudio plugins. The EPW data were used to determine the traces of the sun's movement as presented in Figure 5, wind direction in Figure 6, air temperature in Figure 7, as well as the psychrometric chart and map of solar radiation throughout the year as shown in Figure 8.

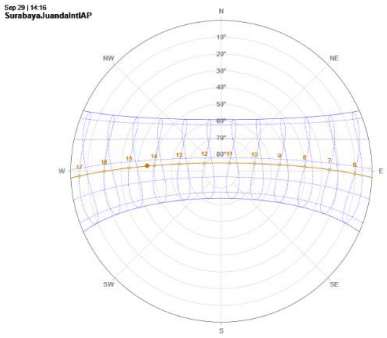


Figure 5. Traces of the sun's movement (Sunpath)
Source: author

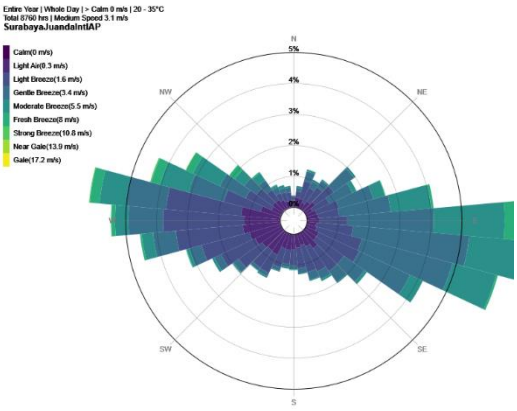


Figure 6. Windrose
Source: Author

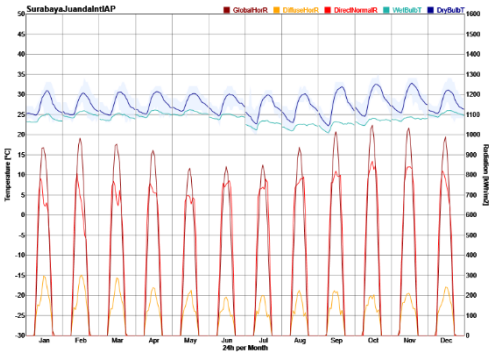


Figure 7. Diurnal Averages
Source: Author

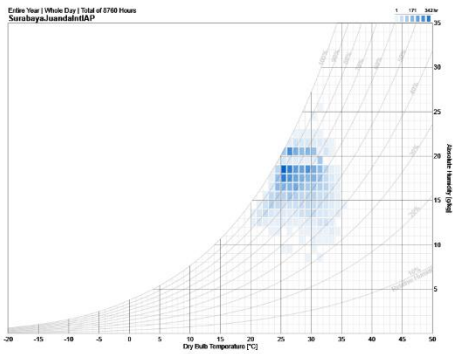


Figure 8. Psychrometric Chart
Source: Author

The last step involved using the data obtained to analyze and plan the early daylighting concept using Rhinoceros and Grasshopper software which have the ability to integrate a series of components such as Elk and Ladybug in the form of visual scripting. This was followed by the selection of the 16th floor which functions as studios and classrooms for regular lectures as the case study. The position of the floor is presented in light blue as indicated in Figures 9 and 10.

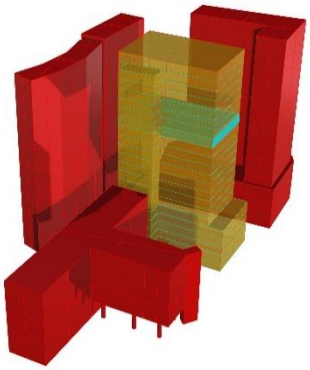


Figure 9. The position of the floor used as a study object
Source: Author

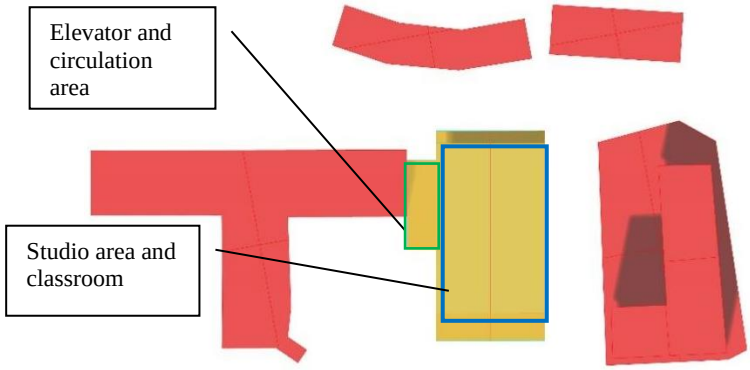


Figure 10. The study object involves the studio and classroom area
Source: Author

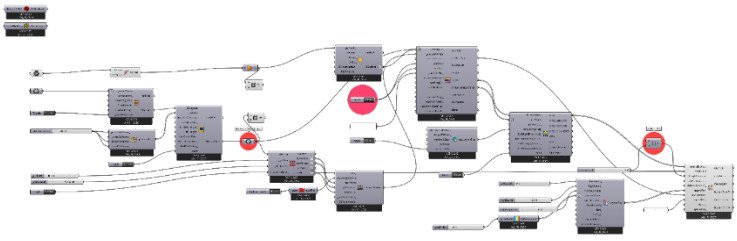


Figure 13. Visual Scripting made on Grasshopper for simulating natural lighting (daylight)
Source: Author

RESULT

These activities lead to the arrangement of the workflow as follows:

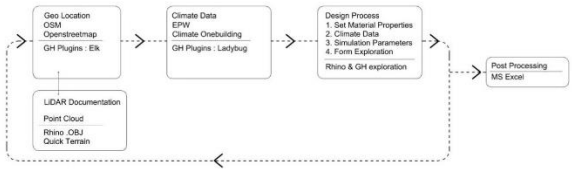


Figure ?. Structured workflow using a parametric approach
Source: Author

This study showed that the geographic and climate data processed through a parametric approach were directly visualized on the same platform - Rhinoceros software. It is important to note that this visualization can be in the form of site conditions, diagrams, or dynamic building simulations. Meanwhile, the high-rise buildings studied showed the factors that often significantly affect each other include the orientation of the building which affects the amount of sunlight entering the building, and the amount of sunlight entering which is needed to be matched with the number of openings in the building, and other factors. Moreover, several aspects also need to be considered at the design stage and this means there is a need for a site analysis process with accurate data. The parametric approach was observed to accommodate a dynamic design process and this allows the integration of the simulation of environmental impact analysis on the site with the design process. However, this process was greatly influenced by the designer's understanding and experience of external environmental data, therefore, it is not recommended to be used by elementary-level students. Furthermore, from the perspective of software usage, it is also necessary to have a fairly good understanding of parametric-based workflows considering the need to interpret the behavior of data in visual scripts such as the translation of environmental parameters into a series of data lists. Practically, the process of reading external input data such as OSM and EPW requires a long time when they are all simulated at the same time. Therefore, the users need to separate certain sections to avoid crashes during the process. In conclusion, architects, designers, and students can take advantage of the prevalence of Big Data in cyberspace by using the parametric approach to shorten and integrate the initial design process with the site analysis. However, it is important to note that this process requires knowledge of environmental simulation, sufficient experience in operating software on a parametric basis, and the complexity is strongly influenced by the capabilities of the user and the device.

CONCLUSION

The parametric design allows architects to create design concepts that involve the use of geospatial data and climate data in an integrated workflow. Of course, this makes the work process more practical because there is no need to export and import to different software. Users can also take advantage of data taken from OpenStreetMap. On the other hand, users can also contribute to completing the data by crowdsourcing. However, this process requires sufficient knowledge of the knowledge and use of the software. However, this process allows the designer to select data or software that suits the specific design and research needs.

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Refrences

1. n.a. (2009) n.t, *CTBUH J. 2009*, no I p 60
2. Abdullah H.K., and Kamara J.M. (2013). Parametric design procedures: A new approach to generative-form in the conceptual design phase, *AEI 2013 Build. Solut. Archit. Eng. - Proc. 2013 Archit. Eng. Natl. Conf.*, No. April, pp. 333–342. DOI: 10.1061/9780784412909.032.
3. Ahmad A., Kumar A., Prakash O., and Aman A. (2020) Daylight availability assessment and the application of energy simulation software – A literature review, *Mater. Sci. Energy Technol.*, Vol. 3, pp. 679–689. DOI: 10.1016/j.mset.2020.07.002.

4. Al Kodmany K. (2012). Sustainable tall buildings: toward a comprehensive design approach, *Int. J. Sustain. Des.*, Vol 2, No 1, p 1 DOI: 10.1504/ijsdes.2012.051470.
5. Ander G.D. (1995) *Daylighting Performance and Design*. Van Nostrand Reinhold
6. Bower M., Cram A., and Groom D. (2010). Blended reality: Issues and potentials in combining virtual worlds and face-to-face classes, *ASCILITE 2010 - Australas. Soc. Comput. Learn. Tert. Educ.*, pp. 129–140.
7. Buildings T., and Performance D. (2016). Study on Integrated Workflow for Designing Sustainable Tall Building - With Parametric method using Rhino Grasshopper and DIVA for Daylight Optimization, Vol. 16, No. 5, pp. 21–28.
8. Dabe T.J., and Adane V.S. (2020). Evaluation of Daylight Parameters on the Basis Simulation Model for the Tropical Climate, *J. Archit. Environ. Struct. Eng. Res.*, Vol. 3, No. 2, pp. 22–28. DOI: 10.30564/jaeser.v3i2.598.
9. Dewi C.P., Utomo J.B., and Choirotin I. (2018). Optimalisasi Kinerja Solar Shading Sebagai Usaha Menurunkan Solar Gain pada Bangunan, *Rev. Urban. Archit. Stud.*, Vol 16, No 2, pp 42–48 DOI: 10.21776/ub.ruas.2018.016.02.4.
10. Gelil M.N.A. andBadawy N.M. (2015). Simulated comparative investigation of the daylight and airflow of the conventional Egyptian shutter 'sheesh' and a proposed latticework device 'new mashrabiyya, *Indoor Built Environ.*, Vol. 24, No. 5, pp. 583–596. DOI: 10.1177/1420326X13516656.
11. González J., and Fiorito F. (2015). Daylight design of office buildings: Optimisation of external solar shadings by using combined simulation methods. *Buildings*, Vol. 5, No. 2, pp. 560–580. DOI: 10.3390/buildings5020560.
12. Margaryan A., Littlejohn A., andVojt G. (2011). Are digital natives a myth or reality? University students' use of digital technologies, *Comput. Educ.*, Vol. 56, No. 2, pp. 429–440. DOI: 10.1016/j.compedu.2010.09.004.
13. Minghini M., and Frassinelli F. (2019). OpenStreetMap history for intrinsic quality assessment: Is OSM up-to-date? *Open Geospatial Data, Softw. Stand.*, Vol. 4, No. 1. DOI: 10.1186/s40965-019-0067-x.
14. Mufidah L., and Purwanto. (2021). Adaptasi Kinerja Bangunan Rumah Tinggal dengan Ventilasi Atap Responsif, *RUAS (Review Urban. Archit. Stud.*, Vol 19, No 1, pp. 80–91.
15. Oulasvirta A., Rattenbury T., Ma L., and Raita E. (2012). Habits make smartphone use more pervasive," *Pers. Ubiquitous Comput.*, vol. 16, no. 1, pp. 105–114, 2012, DOI: 10.1007/s00779-011-0412-2.
16. Tedeschi A. (2014). *AAD Algorithms-Aided Design : Parametric Strategies Using Grasshopper / Arturo Tedeschi ; Foreword: Fulvio Wirz*.
17. Valls F., Redondo E., Fonseca D., Torres-Kompen R., Villagrasa S., and Martí N. (2018). Urban data and urban design: A data mining approach to architecture education, *Telemat. Informatics*, Vol. 35, No. 4, pp. 1039–1052. DOI: 10.1016/j.tele.2017.09.015.
18. White E.T. (1983). *Site Analysis: Diagramming Information for Architectural Design*, Architectural Media.