DOI: 10.38027/ICCAUA2021139N7

Graph Database Modelling on Malay Architecture IFC Data

*M.Kom. **Muhammad Ariful Furqon** [1], M.Sc. **Gun Faisal** [2] **and** M.Kom. **Nina Fadilah Najwa** [3]
Universitas Jember, Department of Information System, Jember, Indonesia [1]
Universitas Riau, Department of Architecture, Riau, Indonesia [2]
Politeknik Caltex Riau, Department of Information System, Riau, Indonesia [3]
E-mail [1]: ariful.furqon26@gmail.com, E-mail [2]: gunfaisal@eng.unri.ac.id, E-mail[3]: nina@pcr.ac.id

Abstract
Architecture is the manifestation of society and its cultural practice. Preserving the architecture is an important thing that must be done both physically and digitally. One of the architectural cultures that must be preserved is Malay architecture. A method to preserve Malay architecture is to model it in the form of a graph database. Graph databases have shown excellent capabilities in understanding and accessing complex and rich datasets in many different domains. In this study, a graph database was modelled on the Malay architecture's Industry Foundation Classes (IFC) data. The methodologies used in this study were: (1) generate Malay architecture's IFC from Building information modelling (BIM) software; (2) Parse IFC; (3) IFC meta-data graph modelling; and (4) IFC object graph modelling. The expected result of this research is a graph database modelling which will be developed further by defining queries to solve problems of Malay architectural models.
Keywords: Graph Database; Malay Architecture; Industry Foundation Classes (IFC); Building information modelling (BIM), Preserving Cultural Architecture.

1. Introduction

Malay architecture is a part of the architecture that puts forward cultural elements both physically and cosmic. It puts forward functions and philosophies that describe the meaning and symbols of life. Malay architecture has many typologies based on geographical conditions based on the location of the Malay settlement. The Malay house has a typology based on rivers and coastal areas as a path and source of life for the local community. Besides, acculturation and cultural mixing resulted in a typology separation. Typologies of Malay houses include the Limas Malay house in Pekanbaru, the Lontiak house in Kampar, the Begonjong house on Mount Toar, rumah beratap Layar dan Bersayap (the Screen and Winged house) in Sentajo, and the Malay Peranakan (mixed ethnic Chinese) house in Bagan Siapiapi and Selat Panjang (Faisal, 2019).
The decreasing of Malay houses' existence which part of Malay architecture indicates that the artifacts of Malay culture were diminishing. The advancement of information technology and new materials resulted in the erasure of Malay architecture as part of the culture. According to (Lodson et al., 2018) vernacular architecture has undergone several changes over the years as a result of the influence of modernity. Architectural heritage can be preserved tangible and intangible in the form of materials that reveal the details of where the ancestors lived and the connectivity of world cultures (Khafioza, 2018). The knowledge of Malay architecture itself is only used as research material without any concrete implementation to maintain and preserve Malay architecture. Malay architecture as part of the design reference was only limited to ornaments from interesting shapes and beautiful carvings. In fact, behind it, all contain meaning and philosophy, which is very meaningful in learning life. The Effort to preserve Malay architecture was carried out by documenting, which can be used as learning material for the next generation. This documentation effort will be better if it is supported by good information technology. Information technology becomes a tool in conservation efforts to be accessed and studied for all people, not only in the field of architecture but also in other fields.
Regarding the development of information technology (IT), the concept of conservation can "adjust" to advances in information technology without losing its purpose (Bani Noor Muchamad & Ira Mentayani, 2004). The preservation of traditional buildings such as the Malay house can be done with various efforts. One of the efforts we can make is to use information technology that is currently developing. The process of documenting a model or building form into a digital form no longer uses manual tools. However, close-range photogrammetry (CRP) overs architecture efficiency in the time process and gave alternative and valuable methods in obtaining a complete exterior of an architectural model (Firzal, 2021). Using this CRP makes it easy to document heritage buildings. Photogrammetry also opens to develop and combine with other BIM software (Sun & Zhang, 2018). Data mining, cloud storage, databases, and big data can provide ornamental references for architects in building modern houses but still provide

traditional elements (Faisal et al., 2021). Big Data application also improves reaction time promptly and provides correct data in managing the quality of the data (Fadiya, 2017). Furthermore, using web GIS in cloud users can access the full power of desktop GIS which allows for activities such as geospatial analysis, spatial intelligence, creation of customized mapping reports, and publishing geographic analysis on the Web by leveraging data stored online and shared (Handayani et al., 2016). Information Technology facilitates all of these conservation activities, such as using BIM in Architecture, remote sensing, CRP, drones, and processing data.

The evolution of the Web and the explosive growth of big data have placed new demands on database technology, bringing the relational model to its limits. What worked well for many years for structured data is not well suited for the unstructured, massive amounts of data. An approaches used to solve this problem is a graph database. A graph database is closely related to data interconnection, which has many data relations. Graph database consists of nodes and relations. Nodes and relations have labels and have properties/attributes. Graph databases do not have a schema, so they are more flexible in representing data (Roy-Hubara et al., 2017). Graphs can show capabilities in understanding and accessing complex data sets in various domains (Ismail et al., 2017). Graph applications are an essential technique in describing various types of data set scenarios so that they are easy to understand.

In architecture, the graph model is beneficial for representing and describing the relationship between building components and the data in the Building Information Modelling (BIM) (Isaac et al., 2013). The graph database schema can help build semantic information for extracting, analyzing, and displaying topological relationships in 3D objects and process queries quickly (Ismail et al., 2017). Various graphs can be used to model buildings using GIS and BIM, such as property graphs. Property graph provides a visual example representing the relationship between people and objects (Hor et al., 2018). The Industry Foundation Classes (IFC) defines a set of objects to describe and divide the building model. A pointer structure represents building component modelling. Thus, the graph database will be tested for its ability to store efficiently from the IFC model (Hor et al., 2018; Ismail et al., 2017). Research conducted by (Nguyen & Kolbe, 2020) proposes a conceptual model for a multi-perspective approach to interpreting semantic changes in CityGML using a graph database. This graph represents an urban model that is also stored. In connection with the different expectations and needs of various stakeholders, this study provides a multi-perspective that aims to make the system easy to use.

The application of graph databases in architecture is one of the latest innovations in the last few years. A graph database can be used to model various domains; thus, it can be implemented in the architectural field. Graph database modelling is expected to be able to solve various problems in the architectural domain. This study aims to model a graph database from the Malay architecture IFC data that was built using BIM. The novelty of this study is the graph database modelling in the Malay architecture domain. The modelling was conducted by extracting IFC data to create a graph model using Neo4J. The expected result of this research is a graph database modelling which will be developed further by defining queries to solve various problems of Malay architectural models.

2. Materials and Methods

This section discusses the problem of knowledge extraction from Malay house architecture. The approach used in this study refers to a study conducted by (Ismail et al., 2017). The workflow used to develop and build the IFC-based graph model starts with generating Malay house architecture using Google SketchUp. This study developed several Malay house models using Google SketchUp Pro 2015. However, not all Malay house models can be shown in the results and discussions of this research paper. Thus, this paper only presents and discusses one Malay house to represent the development and construction of the IFC-based graph model. The method used in IFC-based graph modelling is presented in Figure 1.

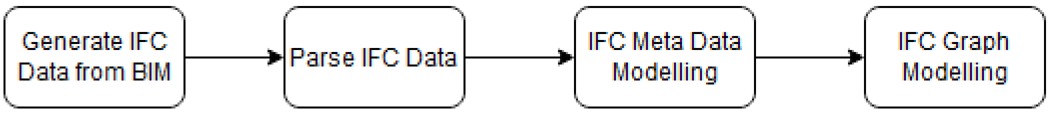


Figure 1. An IFC-based graph modelling method

The first step in this study was to generate IFC Data from BIM. As previously discussed, this study used Google Sketchup to model Malay houses. IFC data was obtained by exporting the designed Malay house model into *.ifc file format. IFC Data provides a comprehensive and standardized data format for digital building models as a basis for all data exchange operations (Borrmann et al., 2018). Thus, IFC data can model a graph database to solve problems related to Malay architectural modelling by querying those data exchange operations (Khalili & Chua, 2016). IFC data obtained from BIM was extracted to obtain information for modelling the graph database. The data extraction process was performed in the second stage by parsing the IFC data. In this study, the parsing process was performed using IFCModelParser, a tool to generate data from IFC Model in a human-friendly format (Dhillon et al., 2014). By parsing the IFC data, the information about the Malay house obtained from BIM will be easier to understand. Thus, the information generated can be modelled further in graph database form.

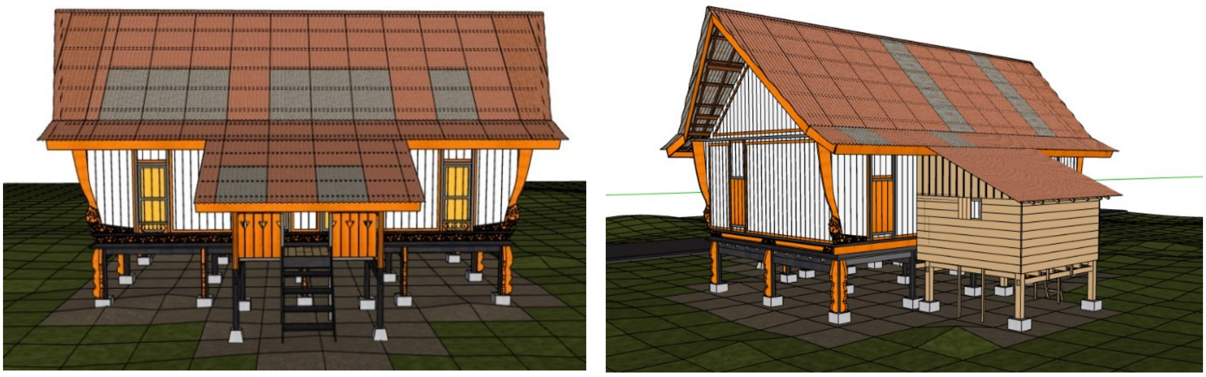
The next stage after parsing the IFC data was modelling the IFC metadata. Metadata was obtained from the results of the Malay house modelling. Metadata provides insight in the form of relevant information related to developing a Malay house architectural model. Thus, the meta-data is required to be well organized so that it is ready to be used for modelling the graph database (Ismail et al., 2017). The final stage in this study is the development of the IFC-based graph model. The IFC-based graph was built using metadata that was modelled in the previous stage. The IFC-based graph modelling was conducted by extracting meta-data to create a graph model using Neo4J. The expected result of this study is a graph database modelling which will be developed further by defining queries to solve various problems of Malay architectural models.

3. Results

The Malay house design used in this study was rumah melayu Rokan IV Koto. Rumah Melayu Rokan IV Koto is a traditional Malay settlement located in the royal area of Rokan IV Koto, in Rokan IV Koto District, Rokan Hulu (Faisal & Firzal, 2020). This house is usually found on the banks of the Rokan Kiri river, which is an essential part of the Rokan IV Koto Malay civilization and kingdom. Figure 2 is a photograph of the Malay house of Rokan IV Koto.

Figure 2. Malay house Rokan IV Koto

Based on the photograph of the Rokan IV Koto Malay house, it was further designed using BIM software. The design of the Malay house model was made using Google Sketchup Pro 2015. The design of the Rokan IV Koto house is presented in Figure 3.



(a) **(b)**

Figure 3. The Malay Rokan IV Koto House design was viewed from **(a)** front view and **(b)** side and rearview.

Based on the Malay house model that has been designed, the IFC data generated from the Google Sketchup software in the form of a *.ifc file format. IFC is a file format that has been standardized with ISO 10303-21 as a digital description of the built environment, including buildings and civil infrastructure (Geiger et al., 2015). The IFC file is script generated automatically by BIM. IFC is a structured building model file format that has attributes and properties. Thus, information related to building modelling is extracted using the IFC data parse process. The output from the IFC data parses process was a JavaScript Object Notation (JSON) file. Table 1 describes the IFC data, and table 2 describes the JSON data parsed from IFC data.

Table 1. IFC data generated from BIM

Lines	IFC data codes
1	ISO-10303-21;
2	HEADER;
3	FILE_NAME ('', '2021-03-30T06:18:30', (''), (''), '', 'SketchUp Pro 2015', '');
4	DATA;
5	#1 = IFCPROJECT('1NJfbNMBrBMQImlAgp8aGA', #2, 'Default Project', 'Description of Default Project', $,
6	$, $, (#20), #7);
7	#2 = IFCOWNERHISTORY(#3, #6, $, .ADDED., $, $, $, 1617059910);
8	#3 = IFCPERSONANDORGANIZATION(#4, #5, $);
9	#4 = IFCPERSON($, '', '', $, $, $, $, $);
10	#5 = IFCORGANIZATION($, 'SketchUp', '', $, $);
11	...
12	#2294511 = IFCCOLOURRGB($, 8.196078431372549E-1, 6.784313725490196E-1, 4.980392156862745E-
12	1);
13	END-ISO-10303-21;

Table 2. JSON data parsed from IFC data

Lines	JSON data codes
1	"{\"entities\": [{\"idx\": 1, \"entity\": {\"rtype\": \"IFCPROJECT\", \"GlobalId\": \"574e9957-58bd-4b59-
2	a4b0-bcaab322440a\", \"OwnerHistory\": {\"ref\": 2}, \"Name\": \"Default Project\", \"Description\":
3	\"Description of Default Project\", \"ObjectType\": null, \"LongName\": null, \"Phase\": null,
4	\"RepresentationContexts\": [{\"ref\": 20}], \"UnitsInContext\": {\"ref\": 7}}}, {\"idx\": 2, \"entity\":
5	{\"rtype\": \"IFCOWNERHISTORY\", \"OwningUser\": {\"ref\": 3}, \"OwningApplication\": {\"ref\": 6},
6	\"State\": null, \"ChangeAction\": \"ADDED\", \"LastModifiedDate\": null, \"LastModifyingUser\": null,
7	...
8	{\"idx\": 2294511, \"entity\": {\"rtype\": \"IFCCOLOURRGB\", \"Name\": null, \"Red\":
9	0.8196078431372549, \"Green\": 0.6784313725490196, \"Blue\": 0.4980392156862745}}], \"header\":
10	{\"rtype\": \"STEPHeader\"}}"

The IFC file is script generated automatically by BIM. However, the IFC data cannot be implemented directly into the graph database modelling, so it is necessary to parse the IFC file into JSON form shown in table 2. The final stage in this study is to model the IFC in JSON form into a graph database. In this study, Neo4J is used to model the graph database so that the model is presented in Figure 4.

Figure 4. Graph database Model of Rokan IV Koto Malay house

4. Discussions

IFC is a standard file format that defines the building object model and various design software (SketchUp, Autodesk Revit, etc.) can generate IFC files for BIM. Some relationships can be described in a structured manner between components at IFC. Because its structure is heterogeneous and cannot be mapped to the relational database model, another approach is needed. Therefore, a graph database was developed to map the relationships in the IFC model efficiently. The IFC model was composed of IFC entities built up in a hierarchical order. Each IFC entity includes a fixed number of IFC attributes, with any number of additional IFC properties. The IFC data schema has three fundamental entities, namely : (1) objects, (2) relations, and (3) properties (Hor et al., 2018). In this study, IFC data was obtained from BIM; thus, it could be modelled in graph form. The graph can allow users to model complex data that represents a real-life scenario. So that by using a graph database that Malay architecture can be modelled, in this case, is Malay Rokan IV Koto House.

Malay Rokan IV Koto House was designed using Google Sketchup Pro 2015, and the design results were shown in Figure 3. Google Sketchup has a feature to export the design into an IFC file automatically. IFC is a file format that has been standardized with ISO 10303-21 as a digital description of the built environment, including buildings and civil infrastructure(Geiger et al., 2015). If the IFC file is opened using a code editor or an integrated development environment (IDE), there was a script shown in table 1. The script has a structured format that shows the properties of the architectural model design using SketchUp. All information regarding properties and metadata is available in IFC files, such as project name, project owner, and organization. In addition, IFC data also records all information about the form and space of a building. However, the IFC data cannot be implemented directly into the graph database modelling, so it is necessary to parse the IFC file into JSON form shown in table 2. JavaScript object notation (JSON) is a format used to store and transfer data. Unlike XML (extensive markup language) and other formats that have similar functions, JSON has a data structure that is simple and easy to understand. So that is why it is necessary to parse the IFC file into JSON form.

After obtaining IFC data in JSON format, the next step is modelling the metadata model graph. The IFC Metadata Graph Model is used to create and examine the relationships between IFC entities and validate the IFC model. In addition, metadata is also used to run filters and information retrieval queries to understand the IFC schema better and analyze its complex data connectivity. The final step in graph modelling was converting the IFC model into an IFC Object Graph. Each entity and IFC relationship will be represented as a node and store information about the entity class and its underlying attributes and be linked to other entities through named relationships. The results of graph modelling in the Malay Rokan IV Koto House were shown in Figure 4. In the graph model, three fundamental parts compile a graph, namely: (1) node; (2) relationship; and (3) properties. Nodes are central entities in the graph that contain labels and properties. Their respective names uniquely identified nodes. There were no more than two nodes has the same name in a relationship. A relationship connects one or more nodes. Each relationship has a type (such as a node) and contains several properties.

In general, the use of graph database modelling helps the building preservation process. Information technology simplifies and speeds up the process so that fears of damage or loss of old buildings can quickly be saved. In addition, graph database modelling also creates accurate information, both in terms of the form and space of the building and the location of the building, and other supporting data. These data are knowledge that can be passed down from generation to generation without worrying about losing them. Apart from being a conservation effort, this data can also be used as other reference materials, in the research process, in the design process, or in planning. These preserved data can then be used together across time and place. So the hope is that its use will have a positive impact in efforts to preserve buildings, especially Malay architecture.

5. Conclusion and Future Works

In this research paper, we have discussed and presented graph database modelling on Malay architecture IFC data. IFC is a standard file format that defines the building object model and various design software (SketchUp, Autodesk Revit, etc.) can generate IFC files for BIM. Some relationships can be described in a structured manner between components at IFC. Because its structure is heterogeneous and cannot be mapped to the relational database model, another approach is needed. However, the IFC data cannot be implemented directly into the graph database modelling, so it is necessary to parse the IFC file into JSON format. The final stage of graph database modelling is modelling metadata and objects to obtain a graph representing knowledge of IFC data. These preserved data can then be used together across time and place. The use of graph hopefully will have a positive impact in efforts to preserve buildings, especially Malay architecture. However, this study still has some limitations that can be carried out a further study in the future. The future research opportunity is to validate this graph database model so that the knowledge extracted is genuinely valid. In addition, query testing can also be done to obtain accurate knowledge from a graph database. Lastly, the research opportunity in the future is to make comparisons of different IFC models so that new knowledge insights can be obtained.

Acknowledgment
We would like to thank LP2M Universitas Jember, LPPM Universitas Riau, and BP2M Politeknik Caltex Riau for the support in financing this research paper.

Conflict of interests
The authors declare no conflict of interest.

References
Bani Noor Muchamad, & Ira Mentayani. (2004). Model Pelestarian Arsitektur Berbasis Teknologi Informasi Studi Kasus: Arsitektur Tradisional Suku Banjar [Information Technology based Architecture Preservation Model Case Study: Traditional Architecture of the Banjar Tribe]. *DIMENSI (Jurnal Teknik Arsitektur)*, *32*(2), 95–101. http://puslit2.petra.ac.id/ejournal/index.php/ars/article/view/16180

Borrmann, A., König, M., Koch, C., & Beetz, J. (2018). Building information modeling: Technology foundations and industry practice. In *Building Information Modeling: Technology Foundations and Industry Practice*. https://doi.org/10.1007/978-3-319-92862-3

Dhillon, R. K., Jethwa, M., & Rai, H. S. (2014). Extracting Building Data from BIM with IFC. *International Journal on Recent Trends in Engineering and Technology*, *11*(1), 202–210.

Fadiya, S. O. (2017). Analyzing a large amount of data as a decision support systems tool in Nigeria organization. *International Journal of Cognitive Research in Science, Engineering and Education*, *5*(1), 121–130. https://doi.org/10.5937/IJCRSEE1701121F

Faisal, G. (2019). Arsitektur Melayu: Identifikasi Rumah Melayu Lontiak Suku Majo Kampar [Malay Architecture: Identification of the Lontiak Malay House of the Majo Kampar Tribe]. *Jurnal Arsitektur*, *6*(1), 1–12.

Faisal, G., & Firzal, Y. (2020). *Arsitektur Melayu: Rumah Tradisional dalam Sketsa dan Lensa [Malay Architecture: Traditional Houses in Sketch and Lens]*. UR Press.

Faisal, G., Najwa, N. F., & Furqon, M. A. (2021). IT - Architecture Study Literature Research Collaboration: Malay Architecture Context. *JOIV : International Journal on Informatics Visualization*, *5*(2).

Firzal, Y. (2021). Architectural Photogrammetry: a Low-Cost Image Acquisition Method in Documenting Built Environment. *International Journal of GEOMATE*, *20*(81), 100–105. https://doi.org/10.21660/2021.81.6263

Geiger, A., Benner, J., & Haefele, K. H. (2015). Generalization of 3D IFC building models. *Lecture Notes in Geoinformation and Cartography*, *PartF3*, 19–35. https://doi.org/10.1007/978-3-319-12181-9_2

Handayani, D., Ningsih, U., & Santoso, D. B. (2016). *Model Arsitektur Komputasi Awan E-Heritage Semarang [Semarang E-Heritage Cloud Computing Architecture Model]*. *21*(2), 84–93.

Hor, A. E. H., Sohn, G., Claudio, P., Jadidi, M., & Afnan, A. (2018). A semantic graph database for BIM-GIS integrated information model for an intelligent urban mobility web application. *ISPRS Annals of the Photogrammetry, Remote Sensing and Spatial Information Sciences*, *4*(4), 89–96. https://doi.org/10.5194/isprs-annals-IV-4-89-2018

Isaac, S., Sadeghpour, F., & Navon, R. (2013). Analyzing Building Information using Graph Theory. International Association for Automation and Robotics in Construction (IAARC). *30th ISARC, (S. 1013-1020). Montreal.)*.

Ismail, A., Nahar, A., & Scherer, R. (2017). Application of graph databases and graph theory concepts for advanced analyzing of BIM models based on IFC standard. *Digital Proceedings of the 24th EG-ICE International Workshop on Intelligent Computing in Engineering 2017*, 146–157.

Khafioza, A. (2018). Vernacular Architectural Preservation of Material and Spiritual Interconnected Cultural Heritage. *Journal of Contemporary Urban Affairs*, *2*(3), 10–19. https://doi.org/10.25034/1762.ijcua.3643

Khalili, A., & Chua, D. K. H. (2016). Generic BIM queries based on the IFC object model using graph theory. *Journal of Computing in Civil Engineering*, *29*(3), 04014046. http://ascelibrary.org/doi/10.1061/%28ASCE%29CP.1943-5487.0000331

Lodson, J., Ogbeba, J. E., & Elinwa, U. K. (2018). A Lesson from Vernacular Architecture in Nigeria. *Journal of Contemporary Urban Affairs*, *2*(1), 84–95. https://doi.org/10.25034/ijcua.2018.3664

Nguyen, S. H., & Kolbe, T. H. (2020). A Multi-Perspective Approach to Interpreting Spatio-Semantic Changes of Large 3D City Models in Citygml Using a Graph Database. *ISPRS Annals of the Photogrammetry, Remote Sensing and Spatial Information Sciences*, *6*(4/W1), 143–150. https://doi.org/10.5194/isprs-annals-VI-4-W1-2020-143-2020

Roy-Hubara, N., Rokach, L., Shapira, B., & Shoval, P. (2017). Modeling Graph Database Schema. *IT Professional*, *19*(6), 34–43. https://doi.org/10.1109/MITP.2017.4241458

Sun, Z., & Zhang, Y. (2018). Using drones and 3D modeling to survey Tibetan architectural heritage: A case study with the multi-door stupa. *Sustainability (Switzerland)*, *10*(7). https://doi.org/10.3390/su10072259