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DESIGNING HUMAN-CENTERED 3D GIS INTERFACE AND INTERACTION MODEL TO SUPPORT AGRICULTURE COMMODITY SELECTION

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ABSTRACT

The purpose of this study is to design an interface and an interaction model using user-centered Design approach. The model-built first aim is to assist the development process of a 3-dimensional geographic information system (3D GIS). The second aim is to ensure that the system that is built meets the needs of the user. GIS has been applied in various fields. In the agriculture field, GIS is often used to assist land evaluation and commodity selection. 3D GIS can provide map visualizations that are similar to actual earth topography. This advantage can minimize the user's cognitive load when using the map. Developing 3D GIS requires more complex components than 2D GIS. This study proposes an interface and interaction model for 3D GIS in scope of agricultural commodities selections. This study has five main stages. The first stage is software requirements Analisys. The second stage is data and content analysis. At this stage, data analysis is carried out to then build a data model to manage geocontent. The third stage is User Interface design. At this stage, an interface model is created as guidelines to arrange the 3D map layout. The fourth stage is the development of the interaction model to analysis of potential user actions and feedback of the system. The last stage is prototype development and evaluation. The prototype is evaluated by involving farmers to measure the adequacy of the data. A heuristic evaluation focused on eight statements was carried out. Based on the evaluation process, in general, most users agree with the statements made. It means that the model built meets the needs of the user. This model is expected to make it easier for software developers to build 3D GIS and ensure the farmer’s need in the sistems are meets. It’s hoped that combining visual elements and interaction can increase the usability level of 3D GIS.

Keywords**:** 3D GIS, User Interface Model, Interaction Model, UCD, Commodity Selections.

INTRODUCTION

Geographical factors have a significant role in agriculture (Hassan et al., 2020). These factors are the crucial consideration factors in the land evaluation process. These factors also have a close relationship with the growth requirements of agriculture commodities (Finandhita and Maulana, 2019). It has a critical influence on the process of selecting agricultural commodities in a region. To carry out the process of land evaluation and commodity selection large amount of geographic data is required(Maulana and Kanai, 2020a). Complex mathematical calculations are also needed. All these processes can be handled effectively by GIS(Herzberg *et al.*, 2019). Geographical information systems (GIS) have to assist geospatial data processing in various fields. In the agriculture field, GIS usually is used for land evaluation and commodity selection. Unfortunately, GIS is used in large-scale agricultural companies. Gis is not used directly by farmers. It because not every farmer has the ability to use GIS. Spatial thinking skills are also needed to understand the information on the GIS(Nath *et al.*, 2000).

3D GIS is relatively easier to understand than 2D GIS (Noguera *et al.*, 2012). 3D GIS can provide visualizations that are similar to actual-earth topography. This advantage can minimize the user's cognitive load when using the map. Developing 3D GIS requires more components. The map processing process also requires a more complicated process(Noguera *et al.*, 2012). The development of models and frameworks continues to be carried out to make it easier to build GIS applications. Luong develop a framework and model to make it easier for developers to design a web-based GIS (Luong et al., 2011). Research on 3D map development was also carried out by Laksono et.al. In that study, the prototype 3D topographic map was developed using a game engine. In that study also state that 3D maps are more interactive than 2D maps(Laksono and Aditya, 2019). So, that users can better understand the information presented.

This study proposes an interface and interaction model for 3D GIS for the selection of agricultural commodities. The built model that is focuses on a combination of content and user interaction. This combination can help developers to understand and manage information when build the 3D GIS. This study describes the process of defining software requirements, identifying and analyzing data, how data is represented in the user interface, and explains how users will interact with data. The method used in this study is a User-centered design (UCD). UCD is a problem-solving method involving a human perspective (Wardhana *et al.*, 2017; Mushthofa, Sabariah and Effendy, 2018). The data used in this study is the output of preliminary research on the determination of agricultural commodities using multi-criteria decision-making (MCDM)(Maulana and Kanai, 2020b). This study also builds a 3D GIS prototype to implement the model. This model is expected to make it easier for software developers to build 3D GIS. It's also hoped that combining visual elements and interaction can increase the usability level of 3D GIS.

RELATED WORKS

Advances in map service providers such as google maps and open street maps have made it easier for GIS developers to provide geospatial data. These service providers generate an Application Programming Interface (API) as an interface that connects between applications(Luong, Etcheverry and Marquesuzaá, 2011). API consists of several elements such as functions, protocols, and other tools. The use of the API aims to speed up the development process. The API provides separate modules so that developers do not need to build a similar feature. However, even though many APIs are available, making usable geographic information systems is still difficult(Luong, Laborie and Nodenot, 2011). Requirement’s analysis and a complex development process are needed to meet User needs. Besides, a large amount of spatial data is required. This large amount of data makes it difficult to process. Luong et al. (2011) design a framework with tools for developing a web-based geographic application. That research aims to make it easier for developers to create geographic information systems. This framework focuses on three complementary tasks. The task is identifying desired data, specifying the graphical layout, and defining potential end-user interaction. With that resulting framework, the Developer has a clear direction in system development.

A suitable user interface can increase the usability of GIS. To make a user interface, the designer must understand how people think and work. Designers must understand that users will not work with algorithms, data structures, functions, or procedures. Users will only work by pressing buttons, selecting options, typing input, and select the menus. For that reason, the correct placement of components on the screen is crucial. Lanter et al. (1991) conduct Research on User Interface design. In that research, Lanter describes that a Graphical User Interface can help GIS be easier to understand, learn and use. In that research, Lanter used a user-centered design (UCD) approach(Lanter and Essinger, 1991).

Interaction is one of the crucial things in GIS. It's important to consider how the user interacts with the system. Rauschert et al.(2002) using a variety of interaction methods to implement on GIS User interface(Rauschert *et al.*, 2002). To make it easier for users to operate GIS, Rauschert even uses human-based interactions. That research replaces computer-based interaction tools with a combination of face and palm detection as an interaction tool with GIS applications(Rauschert *et al.*, 2002). That study shows that users can understand the information presented in a GIS better with appropriate interaction tools.

Unlike 2D Maps, 3D Maps require more data. The interactive side of the 3D map is an essential advantage and is a standard feature for 3D data visualization. Most of this interactive side of 3D maps is usually using the webGL framework. Another advantage is that the software developer can add animation effects and motion effects to the 3D platform. Unfortunately, realizing a GIS development in 3D is not an easy thing. Laksono et al. (2019) utilizing A game engine for interactive 3D Topographic. In that study, a topographic visualization of an area is presently using a game engine. The research explained that the construction of topographic maps in 3D provides many advantages. One of the advantages is that a game engine can handle the large scale of topographic data(Laksono and Aditya, 2019).

RESEARCH FRAMEWORK

This study proposes a framework for designing a 3D GIS application by adopting the UCD method. This framework focuses on two things. The first thing to focus on is what the user will see in the application. The second focus is what the user can do with what is available on the screen. Figure 1 describes the proposed framework. This framework consists of five working steps.

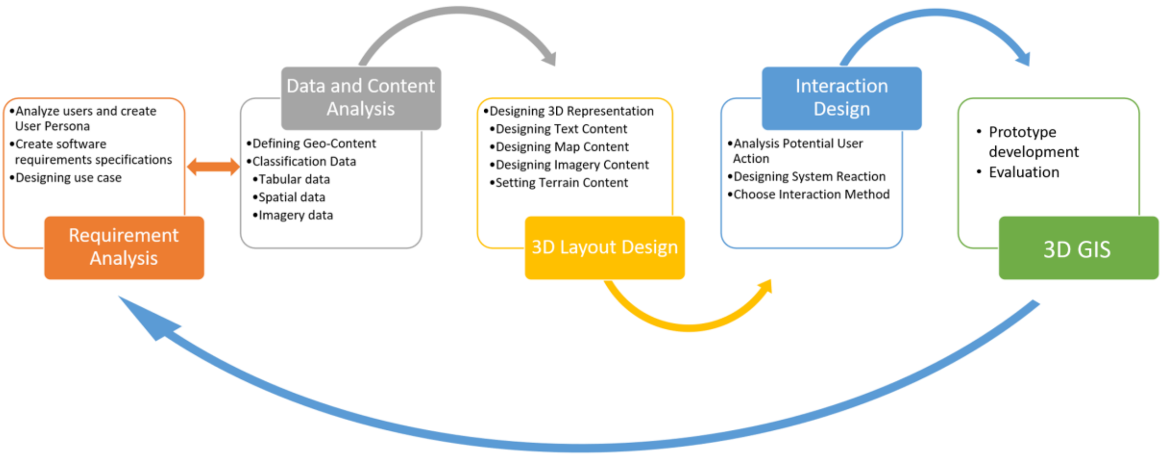

FIGURE 1. Proposed framework for designing 3D GIS

The first stage is Analyst requirements. At this stage, an analysis of the user is carried out. The user personas use to describe the user. In a user-centered design, a user persona is a fictional character that illustrates the user's characteristics. At this stage, the software requirements specifications are also determined. The final process of this stage is designing a use case.

The second stage is Data and Content analysis. This stage describes the data that will be able to manage on the geographic information system. Data can also be referred to as multimedia content. It can be textual data, images, 3D objects, etc.

The third stage is 3D layout design. The placement of objects and content of information on the User interface is a critical factor in GIS. At this stage, various representations are arranged as content on the map. Then, these representations are combined into a complete 3D map. The data Representation in GIS generally consists of two. The first is a textual representation containing textual content derived from tabular data. The other one is a spatial representation that contains geo-content. In 3D GIS, the altitude attribute is mandatory to create a 3D map.

The fourth stage is Interaction model design. At this stage, an analysis of potential user actions is carried out. Then, designing the interaction method. In this stage, the system reaction is designed. The system's reactions are feedback from the user's actions.

The last stage is the process of evaluating the interface and interaction models built. To evaluate the model, this stage develops a prototype based on the results of user analysis. This stage aims to ensure that the information contained in the model meets user needs.

RESULT

User characteristics are a crucial aspect of system development(Kujala and Kauppinen, 2004). This study uses two approach methods to analyze the user characteristics. The first method is using an online questioner. The second method is a literature study by studying research and books related to system development in agriculture. This study uses a user persona to identify the characteristics, attributes, and behavior of farmers. User Persona is a requirement definition technique that applies the human-computer interactions (HCI) method. The questionnaire is divided into deep and iterative questions. The questionnaire method can reduce the pressure on the subject. So that it can be considered as an effective method in obtaining accurate information on user needs. (Kikuchi et al., 2010; Mushthofa, Sabariah and Effendy, 2018). Thirty farmers were involved and filled out the questionnaire. In the Persona user, there is general information such as age, marital status, educational level, and other informations. In user persona's, the user motivation, applications used, and farmers hope is also presented. Figure 3. Describes the example of the defined user persona.

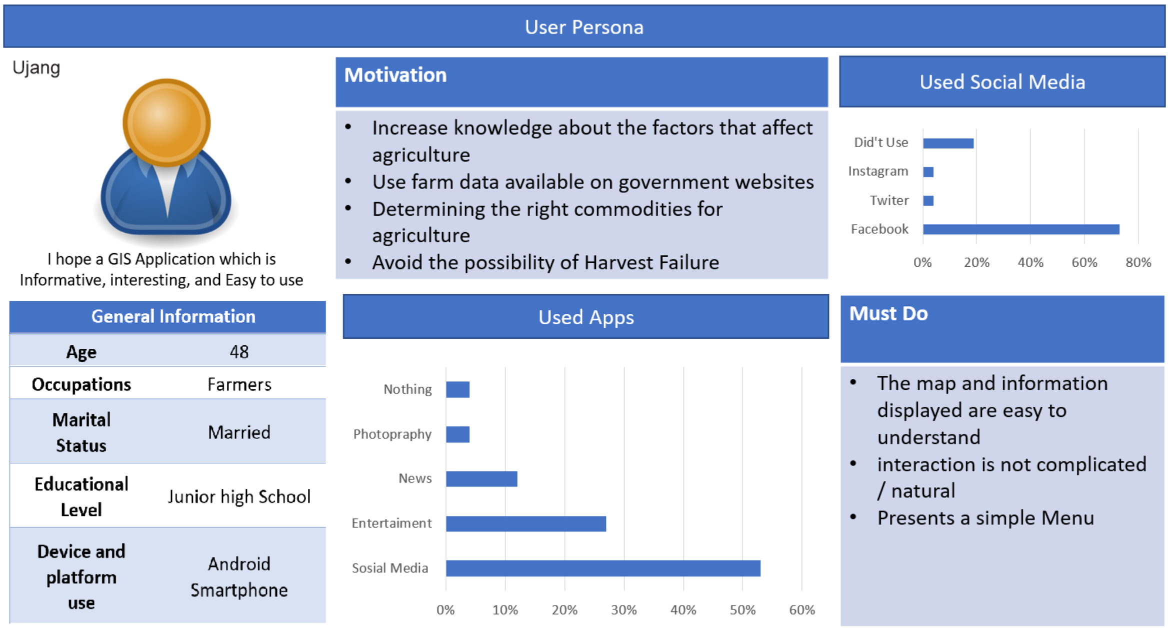

FIGURE 2. User Persona

Persona is one of the techniques used to define user characteristics. The application of the user persona aims to determine the system requirements from the perspective of the relevant stakeholders. The results of the analysis on the user personas are used for designing software requirements specifications. The software requirements specification is defined so that the system can meet the needs of Users(Pressman, 2005; Suryn, 2014; Oshana and Kraeling, 2019). The software requirements specification consists of two parts. First is the functional software requirement specification (SRS-F). The second is the non-functional software requirements specification (SRS-NF). Table 1 describes the functional software requirements specifications, and Table 2 explains the non-functional software requirements specifications.

TABLE 1. The functional software requirements specifications

No	Requirement code	Functional Requirement Specifications
1	SRS-F-001	User can choose the Base map
2	SRS-F-002	Display Information about Agriculture product
3	SRS-F-003	Displays Plant/Crop Commodity Information
4	SRS-F-004	View Criteria Map Layer
5	SRS-F-005	View Commodity Distribution map
6	SRS-F-006	Provide information about Annual Crop yield rate
7	SRS-F-007	Give a view about Land Suitability map
8	SRS-F-008	Give a recommendation to farmer about commodity Selection
9	SRS-F-009	Do calculation for Recommendation Selection Using MCDA
10	SRS-F-010	Provide Augemented Maps

TABLE 2. The non-functional software requirements specifications

No	Requirement code	Non-Functional Requirement Specifications
1	SRS-NF-001	Required high performance of GPU to display map on 3D
2	SRS-NF-002	System users is farmer
3	SRS-NF-003	Required high-speed internet acess
4	SRS-NF-004	The system must be multi-platform

Usecase is made based on the Software requirements specification(Pressman, 2005). It describes the interaction between actors and systems. Usecase also illustrates all the functions that exist in the system. Figure 3. describes the use case.

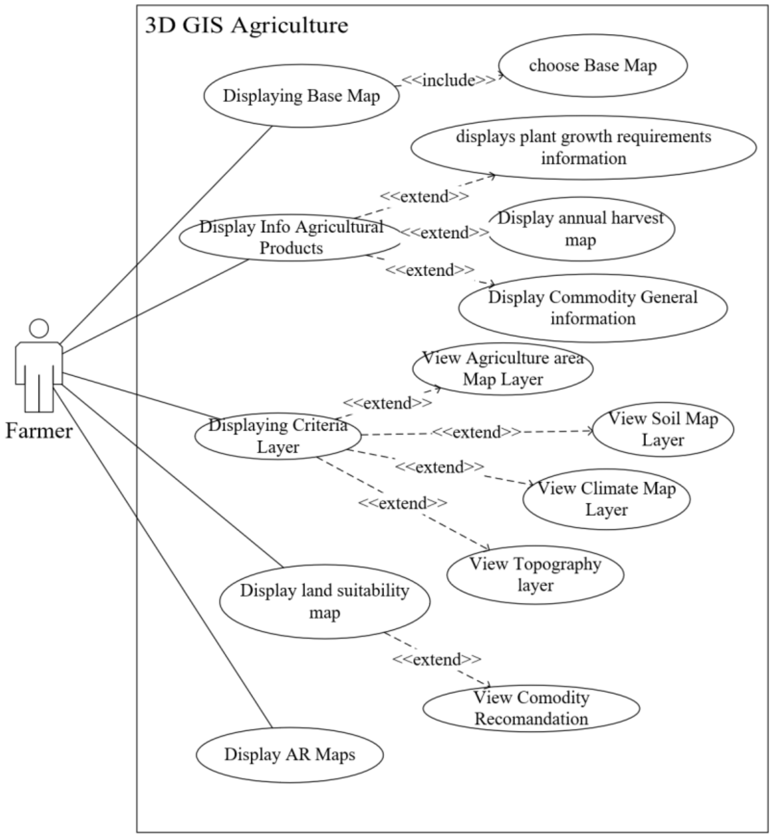

FIGURE 3. The use case

The data for the 3D map is gathered from the analysis of paper-based maps and data obtained from the Indonesian open geospatial data site. The map content analyst is conducted to compile and sort textual data, geo-content data, and data that require emphasis. Textual data comes from tabular / non-spatial data. Geospatial data contains data relating to geographic conditions. Emphasis on data aims to highlight map content. With the highlight, the map will be more interactive. The data is stored in a GIS database for later display in a 3D GIS. Figure 4 illustrates the data transformation process used in creating a 3D GIS.

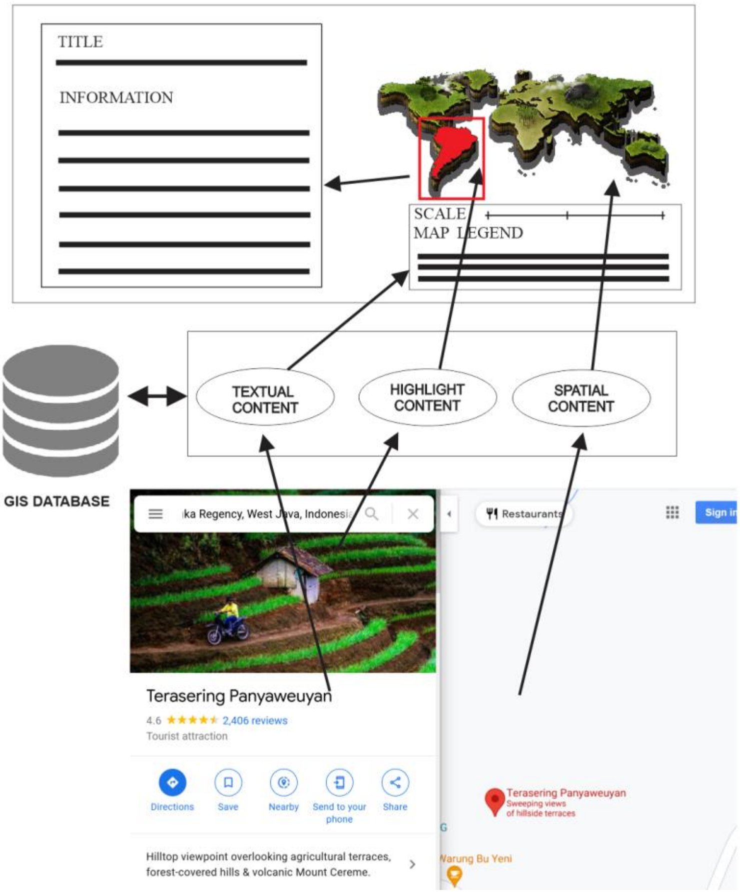

FIGURE 4. The data transformation process scheme of 3D GIS

The user interface model is used to describe the system interface components. This model has described the assembly process of several interface components. Different from 2D maps witch only have spatial and non-spatial representations, 3D maps have more data representations. Figure 5 describes a 3D GIS interface model.

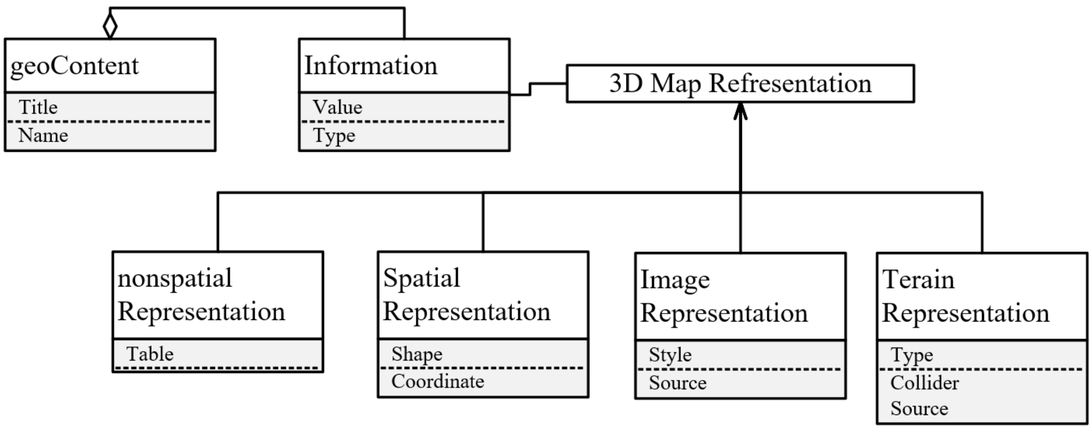

FIGURE 5. 3D GIS interface model

Non-spatial representation is the textual value of geo-content(Luong, Etcheverry and Marquesuzaá, 2011). The textual value is present as a data string (Example: "Bandung" "Jawa Barat"). Spatial representation in the form of data related to geographic coordinates on the map. The spatial representation can be in the form of point (point), line (polyline), and area (polygon). The representation image is a layer that covers the map. Image representation is sometimes called a base map. Several types of base maps that are familiar in GIS are satellite images, satellite streets, etc. The terrain representation is a map that has an altitude attribute so that it creates a 3D topographic map.

The interaction model aims to make it easier to describe the interaction between components in 3D GIS. This model presents the reaction/system response to the activities/actions performed by the user. User actions are activities that are related to user-initiated events(Mustafa, Flores and Cotos, 2018). In 3D GIS, user actions correspond to events on the collider. System reaction is the feedback from the system that responds to user action. In a 3D GIS, there are two types of system reactions. The first is an interactive visual reaction, for example, a highlight object. The second is the data reaction, which is feedback to display non-spatial information. Data reaction is the result of tabular data operation. These operations consist of selection, calculation, or classification of tabular data. The selection operation allows the user to designate a specific counter on the map. The selection operation process starts by selecting a subset of the content displayed on the screen. Then, the map will display information based on the process. One example of this operation is to select one of the polygons among all the polygons displayed on the screen. The second operation is the calculation operation. This operation can create new content by applying the calculation process to existing content. The map designer provides several calculations for displaying content related to agriculture. This calculation process uses land suitability assessment guidelines issued by the Indonesian Ministry of Agriculture. This operation can also be performed by GIS users. Examples of this operation are 1. the operation of determining land suitability for agricultural commodities. 2. calculate the distance from one point to another. And 3. calculate the total area of a polygon. The classification operation is the process of compiling content that has the same value. An example of this operation is selecting a polygon that has similar attribute such as soil type or soil texture. Figure 6 describes 3D GIS interaction model.

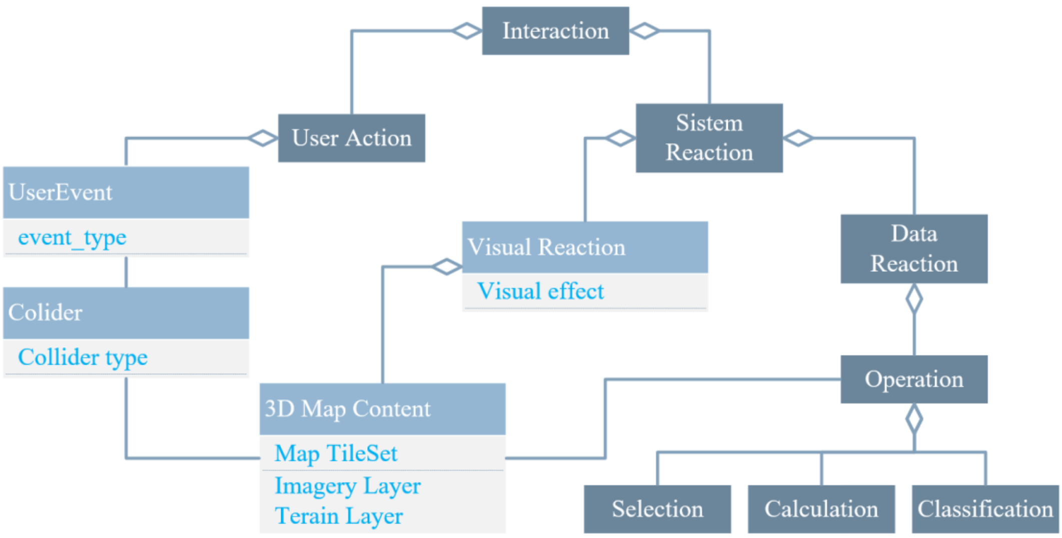

FIGURE 6. 3D GIS interaction model.

User Interface flow design explains the logic flow of the user interface in 3D GIS(Laksono and Aditya, 2019). It describes interface components and user actions. User Interface Flow Design also describes the script placement for each interface and user action. Figure 7 describes the user interface flow design.

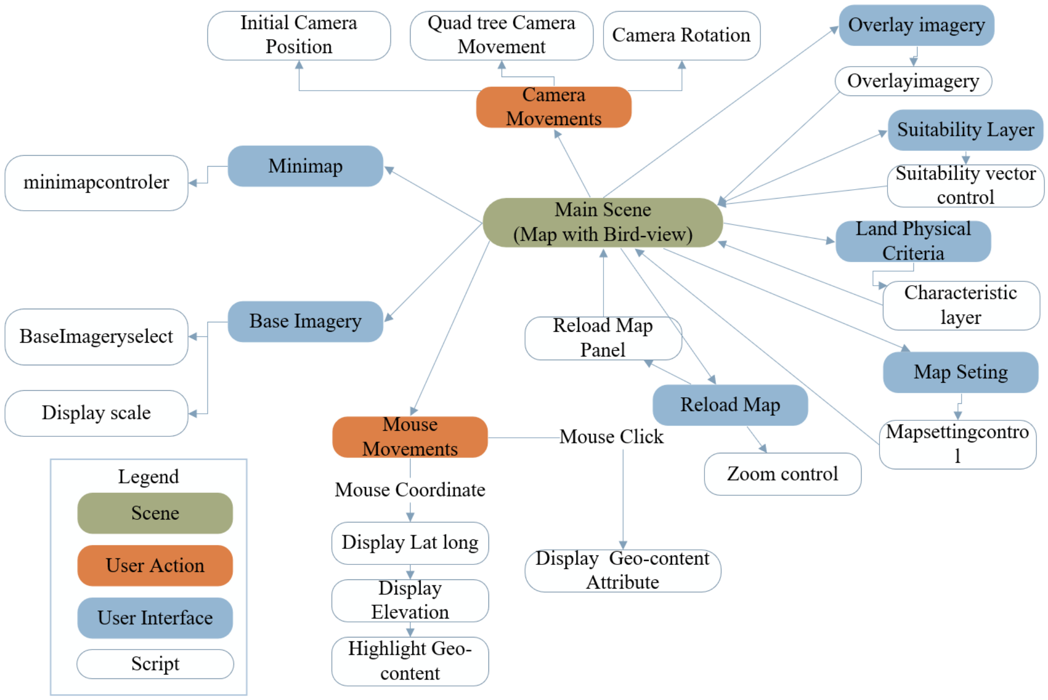

FIGURE 7. The user interface flow design

Concerning commodity selection, there is map management to compile the Map layer. Figure 8 describes the map settings of the 3D GIS for commodity selections (Kaur and Anjum, 2013; Maulana and Kanai, 2020b).

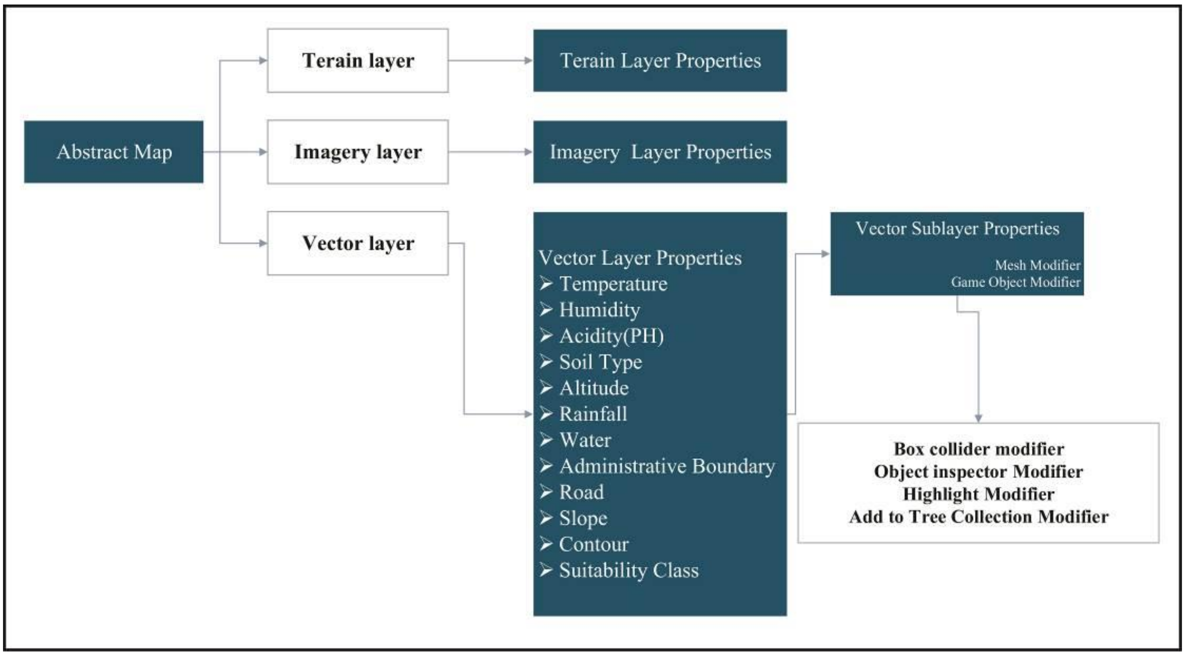

FIGURE 8. The Map Settings of the 3D GIS for Commodity Selections

This research develops a prototype to implement the built model. The prototype development process utilizes the visualization capabilities of the unity3D game engine. Unity3D's advantages in visualizing data and providing interactive interaction are the reasons for choosing the game engine. At first, Unity3D was not able to process geospatial data properly because it did not have a projection system. The projection system is crucial in GIS.

This is because GIS requires data that is accurate base on real-world coordinates. Currently, this weakness has been overcome with the implementation of Mapbox for unity extension. With this extension, Unity can process spatial data well. Figure 9 describes the main interface of 3D GIS. To make this extension work properly, the map is processed using GIS software. The processing results are stored in Mapbox cloud storage. Map management on cloud storage utilizing Mapbox studio. Mapbox cloud converts maps into tilesets. This tileset is what will be integrated with the scene in Unity3D.

FIGURE 9. The main interface of 3D GIS

The navigation menu on the user interface makes it easy for users to interact with the map. We place the main menu on the left side of the user interface. in the main menu, we provide a minimap, search function, and a feature to adjust the zoom level of the map. For interaction, Unity 3D provides standard navigation features to interact with user interface components. However, to make it more interactive, it is necessary to make adjustments using custom C#. Unity3D also supports building a multi-platform system. Mouse and touch screens are alternative tools for interacting with the system. Figure 10 describes the functionality implemented in the interaction tools using custom C# scripts.

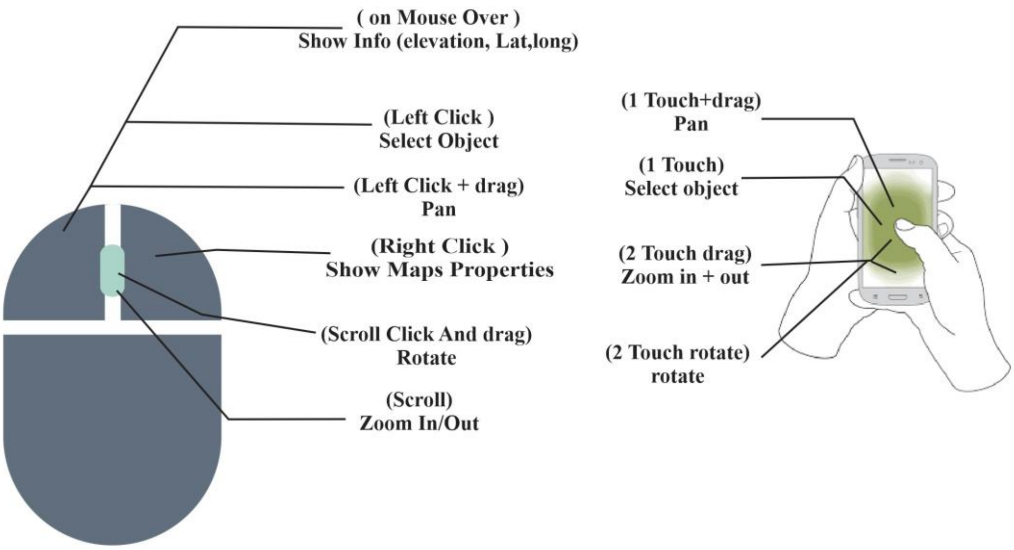

FIGURE 10. The functions assigned to the mouse button and touch screen

The models are evaluated trough prototypes by involving farmers to measure the adequacy of the data. This evaluation also aims to measure the level of system usability(Kikuchi *et al.*, 2010; Mushthofa, Sabariah and Effendy, 2018). In this study, a heuristic evaluation focused on eight statements was carried out. These statements are mostly adopted from Nielsen's usability testing (Gonzalez-Holland, E. 2017). Table 3 describes the statements made for the heuristic evaluation.

TABLE 3. The Statements Made for the Heuristic Evaluation

No	Statement
1	The information for commodity selection is defined in software Specification Requirement and implemented in the prototype
2	The information on software Specification Requirement is sufficient to make decision
3	The maps setting in model are accordance with the land Suitability Guidelines
4	Each parameter is represented by a map layer
5	Interaction flow can be understood and the system always give a feedback
6	User interface flow design is understandable
7	Screen control design is easy to remember
8	Map hierarchy describes map usage

The evaluation process is carried out using a questionnaire with the farmer as the target. Due to limited activities amid the COVID-19 pandemic, to explain the prototype to farmers, we made a video containing the explanation of the screen layout and interaction and how it works. Then, the questionnaire is prepared based on the statements that have been defined. The demos video and questioner were distributed through several agricultural forums in Indonesia. Thirty farmers filled out the questionnaire. To analyze the results of the questionnaire this study used a likert scale. Based on the evaluation process, in general, most users agree with the statements made. The most positive responses are in the seventh and sixth statements, these two points are related to the user interface and system interaction. This positive result indicates that the system is easy to use. Unfortunately, the results are not good in statement number three. Only 40% gave a positive result, 50% chose to give a neutral response and 10 percent gave a negative response. After analyzing the respondents' answers, the differences in farmers' knowledge regarding land evaluation guidelines led to misperceptions. Some farmers still use the 2011 revised edition of the guideline, while this study uses the latest edition of the guideline issued in 2016. However, because only ≤ 10% gave a negative response, this result can still be tolerated (Kikuchi et al., 2010). Figure 11 describes the overall presentation of the evaluation results.

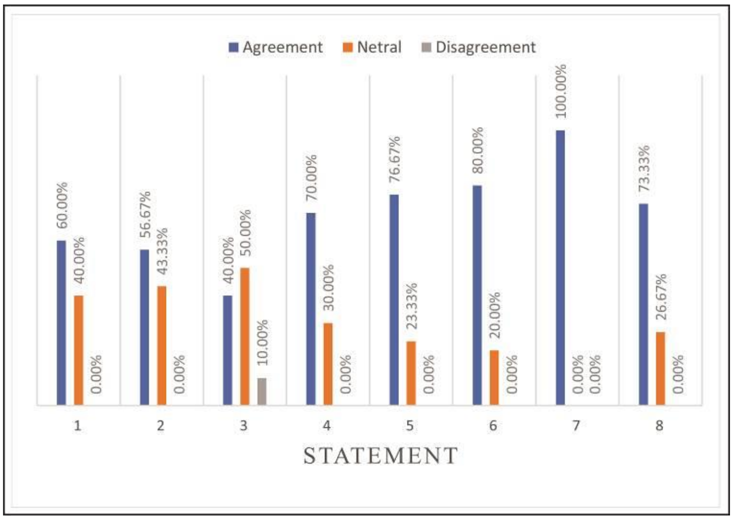

FIGURE 11. The Overall Presentation of the Evaluation Results.

DISCUSSION

GIS has been implemented in the agriculture field for a long time. However, not every farmer has the ability to read maps. This ability is needed to understand the information provided by the map. The 3D GIS makes it easier for farmers to understand the information provided. So that it can reduce the cognitive load when using GIS. 3D map visualizes elevation and slope so that the map is easier to interpret by map readers. This statement is in line with the research conducted by Noguera et al. (2011) that study states that 3D maps are easier to understand than 2D maps However, building a 3D GIS requires more components than 2D GIS (Noguera *et al.*, 2012). The 3D GIS also has a more complicated process. This study proposes models with a framework that adopts a user-centered design (UCD) approach. The development of this model has two side advantages. For developers, this model provides the workflow to facilitate the software design process. For users, they are directly involved in the requirements definition process and prototype evaluation process. They can read and ensure their needs are described in the Software Requirement Specification and implemented on the prototype. These results are in line with Luong et al.(2011) research. That research states by the making of the model and framework have a Crucial role in the development of GIS(Luong, Etcheverry and Marquesuzaá, 2011; Luong, Laborie and Nodenot, 2011). With the system requirements described, the model can make it easier for developers to build 3D GIS. This model is also expected to increase the usability level of 3D GIS in the future. This increase in useability level is obtained because the system is built based on user needs.

CONCLUSION

This study proposes a human-centered 3D GIS interface and interaction models to support the selection of agriculture commodities. The method used in this study is a user-centered design (UCD) approach. This study proposes a framework, data and content model, user interface model, and interaction model. This study consists of 5 main stages. The first stage is software requirements Analisys. The second stage is data and content analysis. At this stage, data analysis is carried out to then build a data model to manage geocontent. The third stage is User Interface design. At this stage, an interface model is created as guidelines to arrange the 3D map layout. The fourth stage is the development of the interaction model to analysis of potential user actions and feedback of the system. The last stage is prototype development and evaluation. This study also describes the map settings and layers used in commodity selection. The heuristic method is applied to evaluate the model built. It focuses on eight statements related to requirement specifications. Based on the evaluation process, it can be concluded that the information presented in the model meets the farmers' needs. the prototype that was built provides an overview of the models. The development of this model has two side advantages. For developers, this model provides the workflow to facilitate the software design process. For users, they are directly involved in the requirements definition process and prototype evaluation process. The farmers can read and ensure their needs are described in the Software Requirement Specification and implemented on the prototype. With proper visual content placement on the user interface, the information provided will become more organized and easier to understand. Also, with the best combination between content and its interaction in this model, it is expected that the usability level of 3D GIS will increase.

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