
Interactive Design of 3D-Tactile Map for Visual Impairment people

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Abstract. Blind people have the same rights as us in getting information, especially on maps. In general, the map can only be used by users who can see visually and blind people have difficulty reading the map because there is no map for the visual impairment in 3D. This map has the advantage of being printable so that it is easy to understand and use for blind users. Amid the development of the map, the authors developed a 3D interactive map design that can accommodate the needs of blind users. This development is generated from DSM data through aerial surveys using drones altered to produce a smoother surface so that it can be reconstructed into a 3D design and analysis of the level of texture density and the level of conformity to the real or original shape and reconstruction using aims to improve and model. Shape to fit the 3-dimensional printing process. The voice module is installed using the RFID Tag identification that is embedded in the 3D map and the RFID Reader in the user's hand, with voice data processing. This innovation that has been developed has the advantage of having a 3-dimensional shape that can be felt, texture, shape, and height equipped with braille-shaped markings that are specially made using Riglet for easy reading and sound as a support to improve the blind's people spatial understanding and spatial literacy.

Keyword: 3D Map, Visual Impaired Map, Spatial Map, Interactive 3D Map

1 Introduction

A map is the graphic visual that represents geographic objects on the earth's surface with certain symbols that are in precise spatial locations with a certain scale [1],[2]. Maps are presented in a number of different forms and ways, from traditional printed maps to digital maps that can be presented on mobile electronic devices and computers.

At this time, a 3D map has been developed which is presented in the form of images, lines, curves, and polygons having points that are connected to a 3D shape. Graphs on a 3-dimensional map have a drawing technique based on the x-axis (flat), y-axis (upright), and z-axis (sloping) [3]. The advantages of a 3D map can be printed so that it is easy to understand and use for visually impairment users.

Maps for blinds users are usually tactile and can help blind people find local information [4]. But unfortunately, tactile maps have limitations in presenting information because tactile maps are still in the form of embossed paper, and there is no map specifically designed for blind people with full vision limitations.

Therefore, it is necessary to have a 3D interactive map because it is touchable and easy to understand, and easily accessible to help blinds people find out more detailed information with shapes and sounds because most of the blind have difficulty knowing the surrounding information. So far tactile maps have proven efficient for the acquisition knowledge of spatial by the visually impaired. However, these maps have significant limitations and need development [5].

Based on the problems experienced by people with visual impairments, that is difficult to understand the map to determine the location and place to go and information on the surrounding environment. Because of the lack of data and information presented on the map or location plan, even blind users do not know the shape and description of information around them, for example, buildings and public facilities [6].

In the midst of 3D maps development, the authors develop a 3D interactive design that is able to accommodate the user's needs with visual distractions. The map that will be developed has the advantage of having a 3D shape that can be felt, texture, shape, and height equipped with braille letters and sound as a support to improve spatial understanding and spatial literacy for blind people.

Marking is a map component using braille letters and a voice module that will be developed to be identified with Radio Frequency Identification (RFID). Generally, this device technology is used for queuing and attendance parking systems or other signal-based IDs [7]. The RFID advantage is that it can identify accurately using sender and receiver signals so that it has high accuracy towards a predetermined object, for example building information or location or public facilities on a 3D interactive map which will help blind users identify.

This study aims to provide answers and solutions to the shortcomings of tactile maps with the design and use of interactive maps for users with visual impairment in 3D. This research will also carry out an empirical study related to the spatial understanding of users with visual impairments on 3D interactive maps, braille, and sound as well as good user understanding regarding the information on the surrounding environment.

2 Related Work

This section contains related research carried out before identifying the ideas of previous researchers in related fields, arguments, and areas of controversy to formulate questions that require further research on maps for the visually impaired [8]. Previous research by Brock's [5], states that interactive maps are a solution for presenting spatial information for the visually impaired. The researcher presented a prototype interactive multimodal map based on a tactile paper map. Draw and print tactile paper maps, multi-touch technology options, interaction technology, and software architecture. It then describes the methods used to assess user satisfaction, including satisfaction independent of the user's age, previous visual experience, or Braille experience. This prototype will be used as a platform for designing advanced interactions for spatial learning.

Blind friendly map courtesy by reference [9] tactile as an excellent source of mobility orientation for blind people to acquire spatial knowledge. But have the use of security in tactile maps by blind people, one of which is their accessibility, which is why researchers are opening up new perspectives in the use of tactile maps. Researchers have also developed a method that generates basic visual maps that can be optimized

using microcapsules paper. The main purpose of producing tactile maps is to help users develop their spatial abilities through maps and other graphic resources. Similar to reference [10], also studied the usefulness of tactile maps through the experimental technique of 3D printing with tactile symbols. The purpose of this study was to determine whether there is a difference in the use of tactile maps when using symbols that have different dimensions and to compare two-dimensional (2D flat relief) and three-dimensional (3D volumetric) characters. The technique is through microencapsulation and 3D printing. The methodology used is a prototype. The results in these two studies are that the use of 3D tactile symbols to increase the average time of certain tasks, localize certain symbols on the map.

Research by reference [11] analyzed route searching for blind people and the importance of tactile maps for blind people. The method used is the route method on a tactile map. The study also describes experiments through tactile maps to determine efficient strategies in the environment for blind people. The Braille presented on the map helps in understanding the tactile graphic representation. The researchers traced the map through the layout to find out about the environment and the route to take. There are two strategies that interfere with route planning and execution, namely regarding the space in the route tracking or the environment. It can be concluded that most of these studies tend to use the same strategy to understand tactile maps for blind people. The same case in reference [12]. The aim of this study was to examine structured spatial knowledge for studying audio haptic maps by visually impaired persons. This study also describes experiments using media, namely, Braille, TTS system, and recording materials. By carrying out the cognitive map method using a soundscape as a sound maker in the environment. Conclusions that audio haptic maps using multimodal applications can be used by blind individuals to study independent movement within the mapped area and the importance of supporting certain applications as an aid to constructing spatial knowledge and cognitive maps.

According to the author's knowledge, there is no comprehensive study dedicated to 3D interactive maps developed with braille as marker and RFID reader and tag as voice identification so the authors developed this innovation for 3D interactive maps for the visually impaired.

3 Research Method

The research methods are arranged so that the research process can be carried out systematically and planned also used to answer all research questions or problems regarding maps for the blind [13,14]. The steps used in this study are related to the design of interactive 3D maps for users with visual impairments, the flow of the methodology illustrated in flowchart Figure 1.

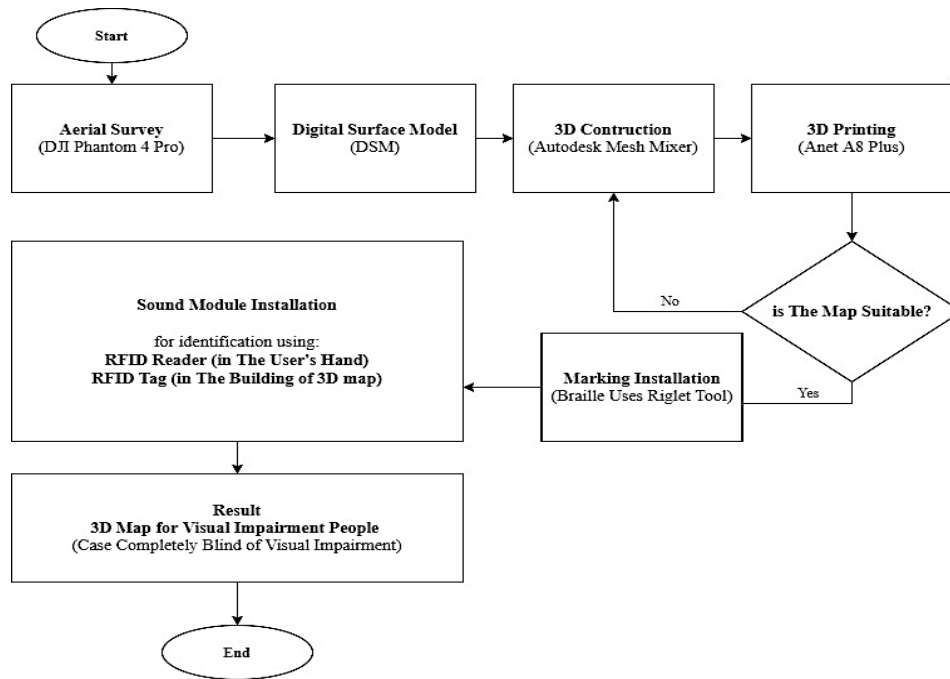


Figure 1. Research Method.

From an aerial survey using the DJI Phantom 4 Pro drone produces Digital Surface Model (DSM) data created using the 3D Agisoft Photoscan conversion technique to produce a smoother surface for DSM data. The reconstruction using Autodesk Meshmixer aims to refine and model 3D shapes to make them suitable for the printing process. The printing process uses the Anet 8 plus printer with a formation of 11 parts with a length = 15 cm, a width = 15 cm, and a height of 16 cm. if the map is in accordance then continue the marking installation, if not then go back to the reconstruction process to fix the part that is less than perfect. The marking on the map uses braille letters which are specially made using riglet tools commonly used to read and write braille. The sound module is installed on a 3D map using the identification of the RFID tag embedded in the building and the RFID Reader in the user's hand, with voice data processing on visual basic.net 2019. The result is a 3D interactive map ready to be tested on the user's spatial understanding and spatial literacy.

3.1 Study area

The study area of this research is located in the city of Malang, namely using the map of Brawijaya University, various buildings and strategic locations are easily accessible and understood [15]. The study area was chosen because it was a representative environment which had buildings with varying heights and characteristics, had 16 Faculties, and were equipped with adequate public facilities such as lecture buildings, mosques, sports buildings, cultural building, polyclinic [16], thus adding new knowledge for visual impairments people.

3.2 Design

Designing a 3D map for users with limited vision (Completely Blind) researchers propose an interactive 3D map design and full features among 3D shapes, markings, and sounds. 3D maps generated from DSM data generated through aerial surveys using the DJI Phantom 4 Pro drone were modified using Agisoft Photoscan to produce smoother surfaces so they can be reconstructed into 3D designs and analyzed in terms of texture density and degree of conformity with actual or original shapes[17]. From the aerial survey data, DSM is converted to the ASCII STL format using the QGIS plugin tools to generate 3D object data with height, depth, and density [18].

3.3 Construction

Reconstruction of object files in DSM data that has been processed produces 3D data in the form of Stl file which can be imported directly into Autodesk Meshmixer for analysis of the level of fragility of density and texture before printing in 3D form, this process is to adjust 3D conditions to match analysis and to this process is to adjust the 3D conditions to suit the analysis and minimize printing failures, thus saving filament usage. The editing process at this stage is very influential on the success of the printing process. Printing process can see in figure 2.

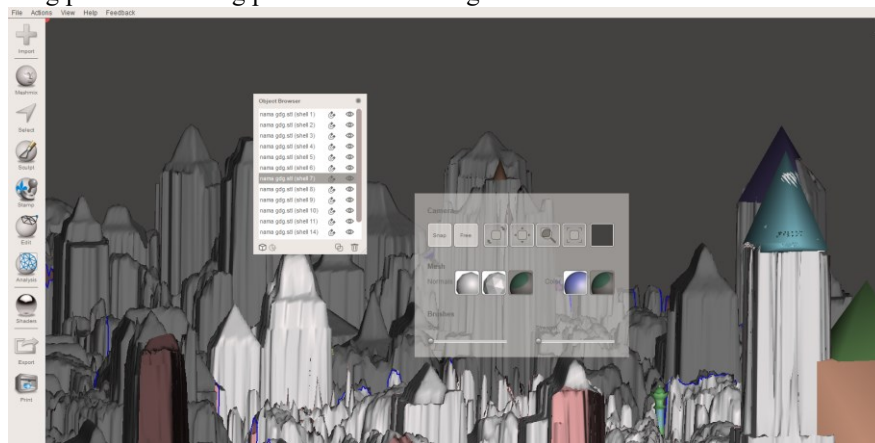


Figure2: Design construction 3D map

3.4 Printing Process

The printing process uses the Anet 8 plus printer with a formation of 11 sections/zones with a length = 15 cm, a width = 15 cm, and a height of 16 cm. using the Simplify 3D tool, where each level of density and analysis of the movement of the nozzle head can be indicated and the consumption of filaments, the duration of time can be adjusted as needed. Printing process show in figure 3.


```

Private Sub TextBox1_KeyDown(sender As Object, e As EventArgs)
Handles T1.KeyDown
    If T1.Text = "0001037710" AndAlso e.KeyCode = Keys.Enter Then

My.Computer.Audio.Play("C:\Users\ARIEF\Documents\wav\filkom.wav")
    Label1.Text = "Faculty of Computer Science"
    T1.Text = ""
    Label1.Text = setfocus
    End If
End
Sub

```

4 Result and Discussion

An overview of the system can be seen in the use of a map with a simulated 3D building image equipped with a 125 khz RFID Tag chip which will be identified by the reader with a short distance so that the sound output can come out according to the location where the reader detects the tag [24] The simulation of using maps can be seen in Figure 2.

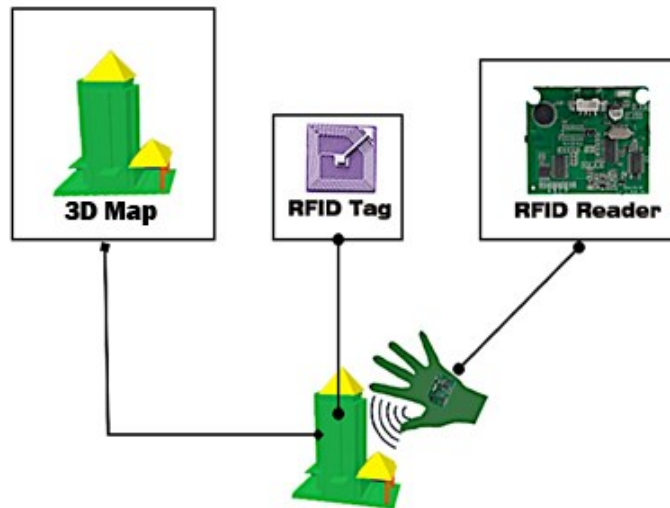


Figure 4. Simulation

4.1. 3D Map

After the printing process from digital data to 3D maps, it can be transformed into a real shape, tree buildings and others, as well as the shape and characteristics of the building, can be touched so that it makes it easier for the visual impairment to understand the map for the results image without having to guess the shape of the building and its printing location. 3D maps can be seen in Figure 3, and braille features in Figure 4.

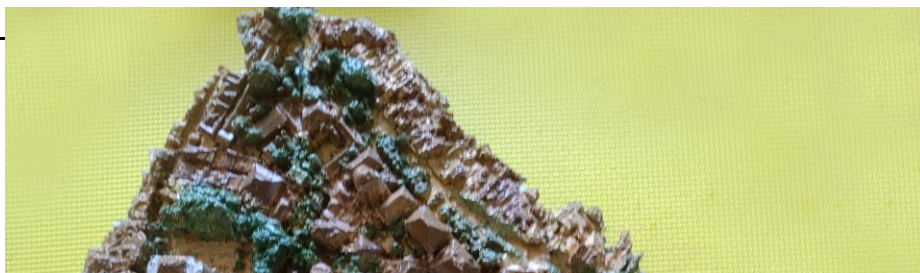


Figure 5: Interactive 3D map



Figure 6: Marking with Braille feature

4.2. Detection

After the coloring process and installation of the 3D interactive map sound module can be used by bringing the Reader module closer to the location you want to know when the reader detects a 3D building it will sound about the building information or location on the 3D map.

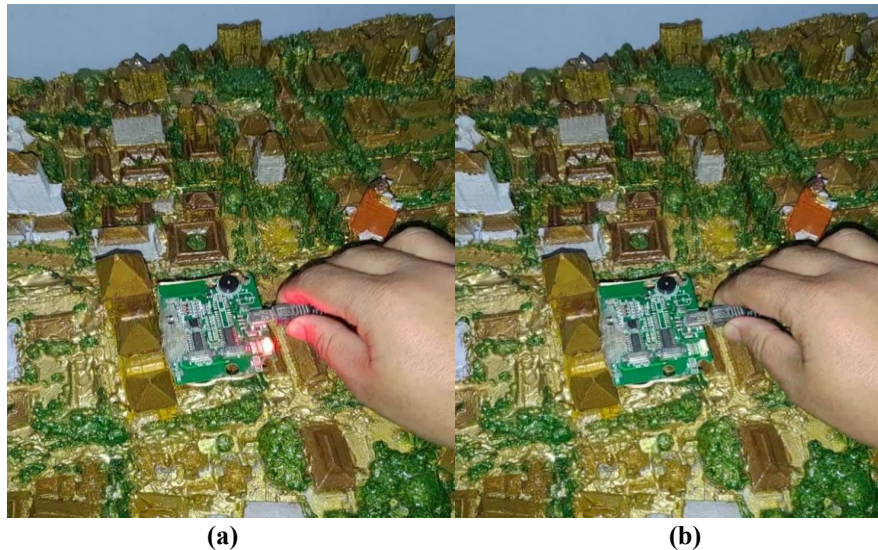


Figure 7: The red indicator light indicates the building has not been detected (a).
The blue indicator light indicates the building was detected (b).

This research shows that the advantages of this map are 3D according to the characteristics of the original shape and easily accepted by users. These maps were

superior to tactile maps embossed on paper [5]. Another advantage of this 3D map is that it has sensors on each building or location and information to make it easier for users to understand the shape of the building's size and surrounding information. In this case study, the role of 3D maps is more effective than web-based maps [26].

The RFID chip sensor found in the building effectively reacts when it comes close to touching after being tested 20 times at different id locations the detection is between 1-5 cm depending on the position of the chip (inside the building on the map or under the map). The user can feel the characteristic text and sound output that has been identified through a signal on any information embedded on the map, in touch the user can read the building information and the shape of the location. Braille letters with the ability to feel owned by blind users. for the RFID sensitivity test results using Guttman Scale, also known as cumulative scale analysis that measures the "Strength" of opinions. In other words, it determines how much positive or negative attitude towards a particular system [25]. That can be seen in Table 1 to Table 5.

Table 1. RFID Sensitivity test distance 1 cm.

| No | Tag ID | T1 | T2 | T3 | T4 |
|----------------|---------|-----------|-----------|-----------|-----------|
| 1 | 5743650 | 1 | 1 | 1 | 1 |
| 2 | 6213489 | 1 | 1 | 1 | 1 |
| 3 | 1598415 | 1 | 1 | 1 | 1 |
| 4 | 1493257 | 1 | 1 | 1 | 1 |
| 5 | 1588784 | 1 | 1 | 1 | 1 |
| 6 | 1512454 | 1 | 1 | 1 | 1 |
| 7 | 1555829 | 1 | 1 | 1 | 1 |
| 8 | 1446774 | 1 | 1 | 1 | 1 |
| 9 | 6180978 | 1 | 1 | 1 | 1 |
| 10 | 1651859 | 1 | 1 | 1 | 1 |
| 11 | 1609213 | 1 | 1 | 1 | 1 |
| 12 | 1529157 | 1 | 1 | 1 | 1 |
| 13 | 1637340 | 1 | 1 | 1 | 1 |
| 14 | 1480556 | 1 | 1 | 1 | 1 |
| 15 | 1593560 | 1 | 1 | 1 | 1 |
| 16 | 1657004 | 1 | 1 | 1 | 1 |
| 17 | 1619342 | 1 | 1 | 1 | 1 |
| Amount | | 17 | 17 | 17 | 17 |
| Average | | 17 | | | |

Table 2. RFID Sensitivity test distance 2 cm.

| No | Tag ID | T5 | T6 | T7 | T8 |
|----|---------|----|----|----|----|
| 1 | 5743650 | 1 | 1 | 1 | 1 |
| 2 | 6213489 | 1 | 1 | 1 | 1 |
| 3 | 1598415 | 1 | 1 | 1 | 1 |
| 4 | 1493257 | 1 | 1 | 1 | 1 |
| 5 | 1588784 | 1 | 1 | 1 | 1 |

| | | | | | |
|----------------|---------|-----------|-----------|-----------|-----------|
| 6 | 1512454 | 1 | 1 | 1 | 1 |
| 7 | 1555829 | 1 | 1 | 1 | 1 |
| 8 | 1446774 | 1 | 1 | 1 | 1 |
| 9 | 6180978 | 1 | 1 | 1 | 1 |
| 10 | 1651859 | 1 | 1 | 1 | 1 |
| 11 | 1609213 | 1 | 1 | 1 | 1 |
| 12 | 1529157 | 1 | 1 | 1 | 1 |
| 13 | 1637340 | 1 | 1 | 1 | 1 |
| 14 | 1480556 | 1 | 1 | 1 | 1 |
| 15 | 1593560 | 1 | 1 | 1 | 1 |
| 16 | 1657004 | 1 | 1 | 1 | 1 |
| 17 | 1619342 | 1 | 1 | 1 | 1 |
| Amount | | 17 | 17 | 17 | 17 |
| Average | | 17 | | | |

Table 3. RFID Sensitivity test distance 3 cm.

| No | Tag ID | T9 | T10 | T11 | T12 |
|----------------|---------|-------------|-----------|-----------|-----------|
| 1 | 5743650 | 1 | 1 | 1 | 1 |
| 2 | 6213489 | 1 | 1 | 1 | 1 |
| 3 | 1598415 | 1 | 1 | 1 | 1 |
| 4 | 1493257 | 1 | 1 | 1 | 1 |
| 5 | 1588784 | 1 | 1 | 1 | 1 |
| 6 | 1512454 | 1 | 1 | 1 | 1 |
| 7 | 1555829 | 1 | 1 | 1 | 1 |
| 8 | 1446774 | 1 | 1 | 1 | 1 |
| 9 | 6180978 | 1 | 1 | 1 | 1 |
| 10 | 1651859 | 1 | 1 | 1 | 1 |
| 11 | 1609213 | 1 | 1 | 1 | 1 |
| 12 | 1529157 | 1 | 1 | 1 | 1 |
| 13 | 1637340 | 1 | 1 | 1 | 1 |
| 14 | 1480556 | 1 | 1 | 0 | 0 |
| 15 | 1593560 | 1 | 1 | 1 | 1 |
| 16 | 1657004 | 1 | 1 | 1 | 1 |
| 17 | 1619342 | 1 | 1 | 1 | 1 |
| Amount | | 17 | 17 | 16 | 16 |
| Average | | 16,5 | | | |

Table 4. RFID Sensitivity test distance 4 cm.

| No | Tag ID | T13 | T14 | T15 | T16 |
|----|---------|-----|-----|-----|-----|
| 1 | 5743650 | 1 | 1 | 1 | 1 |
| 2 | 6213489 | 0 | 0 | 0 | 0 |
| 3 | 1598415 | 1 | 1 | 1 | 1 |
| 4 | 1493257 | 0 | 0 | 0 | 0 |
| 5 | 1588784 | 0 | 0 | 0 | 0 |

| | | | | | |
|----------------|---------|-------------|----------|----------|----------|
| 6 | 1512454 | 0 | 0 | 0 | 0 |
| 7 | 1555829 | 0 | 0 | 0 | 0 |
| 8 | 1446774 | 1 | 1 | 1 | 1 |
| 9 | 6180978 | 1 | 1 | 1 | 1 |
| 10 | 1651859 | 0 | 0 | 0 | 0 |
| 11 | 1609213 | 0 | 0 | 0 | 0 |
| 12 | 1529157 | 0 | 0 | 0 | 0 |
| 13 | 1637340 | 0 | 0 | 0 | 0 |
| 14 | 1480556 | 0 | 0 | 0 | 0 |
| 15 | 1593560 | 1 | 1 | 1 | 1 |
| 16 | 1657004 | 1 | 1 | 1 | 0 |
| 17 | 1619342 | 0 | 0 | 0 | 0 |
| Amount | | 6 | 6 | 6 | 5 |
| Average | | 5,75 | | | |

Table 5. RFID Sensitivity test distance 5 cm.

| No | Tag ID | T17 | T18 | T19 | T20 |
|----------------|---------|----------|----------|----------|----------|
| 1 | 5743650 | 1 | 1 | 1 | 1 |
| 2 | 6213489 | 0 | 0 | 0 | 0 |
| 3 | 1598415 | 1 | 1 | 1 | 1 |
| 4 | 1493257 | 0 | 0 | 0 | 0 |
| 5 | 1588784 | 0 | 0 | 0 | 0 |
| 6 | 1512454 | 0 | 0 | 0 | 0 |
| 7 | 1555829 | 0 | 0 | 0 | 0 |
| 8 | 1446774 | 0 | 0 | 0 | 0 |
| 9 | 6180978 | 1 | 1 | 1 | 1 |
| 10 | 1651859 | 0 | 0 | 0 | 0 |
| 11 | 1609213 | 0 | 0 | 0 | 0 |
| 12 | 1529157 | 0 | 0 | 0 | 0 |
| 13 | 1637340 | 0 | 0 | 0 | 0 |
| 14 | 1480556 | 0 | 0 | 0 | 0 |
| 15 | 1593560 | 1 | 1 | 1 | 1 |
| 16 | 1657004 | 0 | 0 | 0 | 0 |
| 17 | 1619342 | 0 | 0 | 0 | 0 |
| Amount | | 4 | 4 | 4 | 4 |
| Average | | 4 | | | |

In the table above, the test from 1-5cm is rarely tested where a total of 20 tests are tested to determine the sensitivity level of the device on a 3D map, the sensitivity level calculation uses the Guttman scale where to determine the percentage level of sensitivity in each test with the following information:

Guttman scale percentage calculation:

Information on table:

T = is the test number symbolizer T1 until T20**Number of ID Tags =17**

Detected is symbolized by number = 1.

Not detected is symbolized by the number = 0.

If converted into percentage then:

Detected answers = $1 \times 100 = 100\%$.

The answer is not detected = $0 \times 100 = 0\%$ (so it doesn't need to be calculated).

Then what is calculated is the number that is detected only with the formula:

average / Number of ID $\times 100\%$

1cm = $17/17 \times 100\% = 100\%$

2cm = $17/17 \times 100\% = 100\%$

3cm = $16,5/17 \times 100\% = 97,05\%$

4cm = $5,75/17 \times 100\% = 32,35\%$

5cm = $4/17 \times 100\% = 23,52\%$

From the sensitivity test results using the Guttman scale, the RFID sensitivity level at a distance of 1 to 5cm is presented in the table. 6, Figure8.

Table.6: Test results 1-5 cm on the Guttman skala scale

| 1cm | 2cm | 3cm | 4cm | 5cm |
|-------|-------|--------|--------|--------|
| 100 % | 100 % | 97,05% | 32,35% | 23,52% |

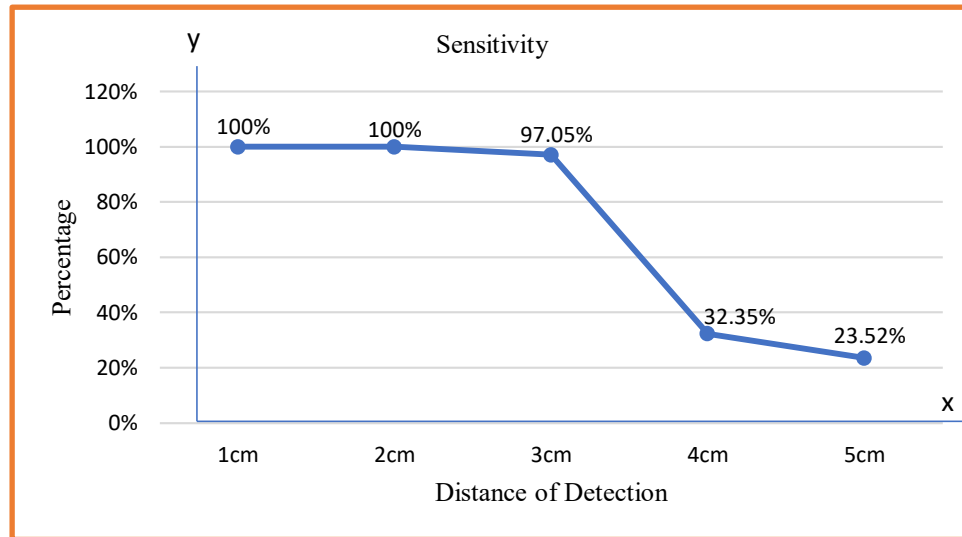


Figure 8: Graph result of sensitivity test of 3D Map

From the results of sensitivity testing, it is concluded that the closer the detection signal is, the stronger it is at a distance of 1-2cm, then it decreases at a distance of 3-5cm. this is more suitable for blind users because it is closer to the user's touch area.

However, this study has a weakness because the hardware used depends on the device used and the specifications of the chip tag used, namely that it does not support

UHF (ultra-high frequency) ID tags. Based on this research question focuses on designing a 3D map for the visually impaired, the results of this study are expected to be able to answer the problems in this study and can be useful and developed for further research.

From the results of our research, the process of obtaining interactive 3D map results for the visually impaired is making 3D designs obtained from air surveys using drones that are converted into DSM data, the process of reconstructing shapes so that they can be printed on a 3D printer, prepares the hardware needs for RFID Reader and Tag. as well as supporting software for calling and identifying data from RFID and voice output. The significance test of the tool ensures that the tool can last a long time of use.

The design of 3D maps in this study begins with the problem that maps are currently not available for the blind, the introduction of tactile maps where the information presented has minimal supporting features, RFID was chosen because it has high sensitivity, the results of sensitivity testing are 20 times on a 3D map, namely between 1 - 5 centimeters. This innovation is active when it is close to touch areas such as buildings, locations, and information on maps. To answer this problem, the researcher proposes a full-featured interactive 3D map design. Then implemented to design and develop on a 3D map.

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