A Computerized Numerical Control Machine Assembly Virtual Laboratory on Virtual Reality Technology

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Abstract. Along with the development of industry 4.0 and the ongoing pandemic conditions, an interactive media is needed for learning that adapts to the times. Based on these problems, it is necessary to make an informative and attractive learning media. By using virtual reality technology that utilizes a 360-degree camera, visualization in the Computerized Numerical Control (CNC) machine assembly laboratory can be presented. So that the display of the laboratory atmosphere can be accessed on computer and mobile devices such as tablets, smartphones, and laptops. Virtual reality-based learning media itself is made to develop online courses that are not yet available on the internet, especially for vocational colleges whose orientation is practice-based. The virtual reality creation takes place in the CNC assembly lab, Manufacturing Engineering Workshop. In the process, a GoPro Max camera was used to take it, with footage in the form of a 360-degree panorama photo. Then the editing process using 3D Vista application software. The results of making virtual reality can be accessed using VR headsets such as Oculus Quest 2, smartphones, and laptops / PCs. The proposed method is validated by audience experiment by smartphones and VR goggles. Finally, the audience fill in the questionnaires which consist of 9 quality aspects. The audience experience has 98% agree and quite agree that the virtual laboratory has 9 quality aspects and it can be used for assembly learning process.

Keywords: Virtual Laboratory; Machine Assembly; Virtual Reality.

1. Introduction

The COVID-19 pandemic that has occurred in the world since the beginning of 2020 has had a wide impact both socially and economically [1]. Indonesia is no exception; this also has an impact on the education sector. To stop the spread of COVID-19, the government through the Minister of Education and Culture and the Minister of Research and Technology decided to organize online educational activities. This decision was welcomed by various Indonesian people, both from among teachers, student parents, and students or university students themselves. Quoting from the CNN Indonesia article "Director General of Higher Education of the Ministry of Education and Culture, Nizam said 98 percent of universities throughout Indonesia have conducted online

learning" [2].

However, in practice, online learning has an obstacle, namely that there is no online course based on competency skills yet. For example, at the Bandung Polytechnic for Manufacturing, which has more practical hours than theoretical hours, there is currently no solution for supporting facilities for practicing competency skills when online educational activities take place [3]-[6].

For this reason, it is necessary to increase learning media so that student competency skills can increase even though it is hindered by space and time. By using 360-degree camera technology, a virtual reality of a place can be created. For example, a practical laboratory can be displayed with a broad perspective, this allows students to feel a more real practice atmosphere, from this virtual reality the concept of a mini practice tool can be made that can be used for online skill competency certification [7]-[11].

The choice of the CNC assembly lab as the object of this final project research, because Bandung Polytechnic for Manufacturing itself has a vision to be able to create a production line for small CNC machines, for that the making of learning media by the author is expected to help students gain an understanding of CNC machine assembly even though in limitations caused by the pandemic. The virtual reality that the author wants to create is like figure 1.
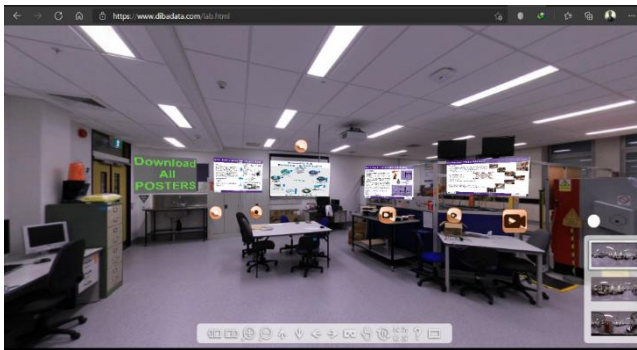
**Fig. 1.** Benchmark virtual laboratory

2.   Research Methodology

A CNC machine assembly laboratory has a purpose to assemble a partial CNC component into a full CNC machine product as shown in Fig. 2. The student learns how to assemble a CNC machine by machine construction course for 40 course-hours [13].
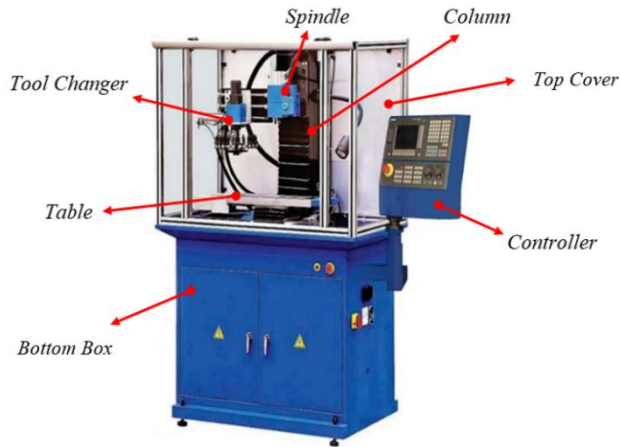
Fig.2. A CNC Machine Product.

A CNC machine consists of 4 sub-components, there are Table, Column, Spindle, and tool changer as illustrated Fig. 3. A total machine component is 236 components which consists of 53-part Table, 48-part column, 48-part spindle, and 87-part tool changer. The concept of a CNC machine virtual laboratory is 360-degree virtual tour, pop-up information, comprehensive visual information, assemble guide caption, real assemble video tutorial, multi-mode (Virtual Reality mode and normal mode), gyroscope sensor movement. A virtual laboratory is developed by following research methodology. The proposed laboratory is designed to support a CNC machine assembling practical course. The quality of assembly process causes a quality machine directly. Each machine axis must have quality guarantee by properly assembling process [14]. [15].
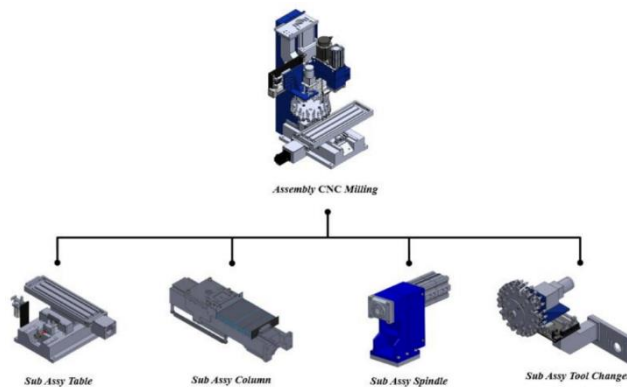
Fig.3. A CNC Machine Structure assy.

2.1.   Assembly Video Creation

A full machine assembly video is recorded by high quality video. It is divided into 4 group assembly videos according to 4 group machine components. The feature of video consists of real life assemble tutorial, assemble guide caption, a component name information, and full assemble step. The assembly video is recorded by using Davinci Resolve software, with the video format that will be rendered is an mp4 video with full HD 1080p 30 fps resolution which is equipped with subtitles. Assembly video footage taken using a GoPro Hero 7 camera as shown in Fig.4
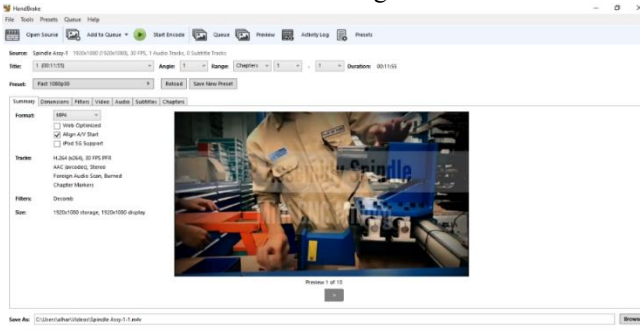

Fig.4. Assembling video tutorial.

2.2.   Simulation Creation

The machine assembling process is animated by simulation software. It is possible to view the assembly process from many sides. Making simulations using Solidworks software, then editing with Davinci Resolve software.

2.3.   Module Creation

The machine assembling module course is an assembly material which is learned by students. The module has all machines and assemble information, practical course step. The module consists of machine structure, ID component, name component, assembling diagram, operation plan component, assembling operation plan, assembling tool list, and student assignments. The assembling module is created by using PowerPoint Presentation software and then converted to an accessible file by iSpring software. The material submitted comes from existing practice modules. Converting to iSpring itself aims to make the file more attractive with several available features, and the output can be uploaded to Bandung Polytechnic for Manufacturing web hosting, so that it can be accessed more easily.

2.4.   Compression Video

The videos that have been made are usually quite large, therefore it is necessary to compress the file size to make it easier to upload and save storage on a laptop / pc. The video

compression process is done with the handbrake application software. This handbrake application allows compression of files in batch or simultaneously.
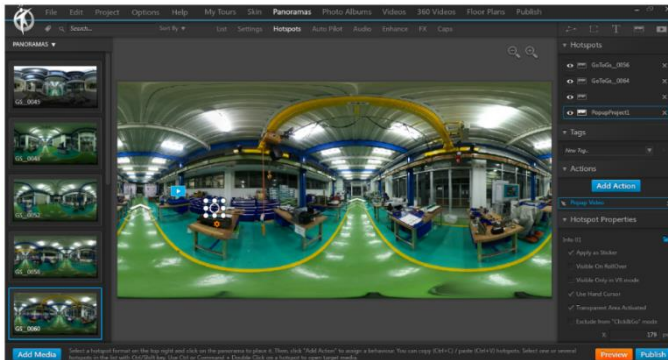

Fig.5. A virtual lab footage.

2.5. Footage Virtual Reality Capture

The footage for virtual reality was taken by using a 360-degree camera, the GoPro Max. During the recording process, the GoPro Max is connected to a smartphone using the GoPro Quik application. This is so that the retrieval process can be easier and the results of taking either photos or videos can be viewed on the smartphone screen. The place where the footage was taken is the CNC assembly lab at the Manufacturing Engineering Workshop. During the process of taking footage, the assembly lab was empty without anyone.

2.6. Virtual Reality Creation

After the footage has been taken, the next step is to create virtual reality using 3D Vista application software. The concept created is a virtual reality tour. So that users can feel the sensation of being in that place and exploring the CNC machining lab room. In this process, footage is inputted and connected to the hotspot feature so that it can move from one panorama photo to another. In addition, the hotspot features included are pop up videos, pop up photos, and embedded videos from URL links. A virtual laboratory is uploaded and can be accessed in https://virtuallab.polman-bandung.ac.id/ as shown in following figure.

Fig.6. A CNC machine virtual laboratory website.

Fig.7. Virtual laboratory testing by smartphone.

2.7.   Test Planning

The learning media that has been made will be tested. The purpose of this trial is to find data that will be used as a benchmark for the value of effectiveness. The data collection of this teaching media trial was carried out using the questionnaire method. Questionnaire is a data collection tool with indirect communication, namely through writing. A questionnaire is a type of instrument that contains questions or written statements to obtain information related to the development of this learning media [16], [17].

After the data from the required test results have been collected, the next step is to analyze the data using percentage descriptive data analysis techniques. This percentage descriptive analysis technique is a data analysis technique used to analyze the trial. The percentage descriptive analysis technique is data in the form of numbers (quantitative data) converted into percentages and then described in descriptive qualitative sentences. Data processing was analyzed using the following formula:

$$P = (X/Xi)*100\% \tag{1}$$

Where P, X, and Xi are result percentage, respondent answer, and ideal value. for the interval of the effectiveness of the developed media is presented in the following table.

TABLE I.   LIKERT SCALE ASSESSMENT OF THE EFFECTIVENESS OF TEACHING MEDIA

No	Interval	Category
1	76% - 100%	Very effective
2	56% - 75%	Effective
3	40% - 55%	Less Effective
4	< 40%	In Effective

3.   Result And Analysis

In order to validate the effectiveness of virtual laboratories, 23 respondents are chosen for experiment activity. The virtual reality experiment consists of 3 steps, first, testing by smartphone, Second, testing by Oculus Quest 2, and questionnaire step.

3.1.   Virtual Reality Testing Using Smartphone

At this testing stage, respondents are asked to access the following link in https://virtuallab.polman-bandung.ac.id/ to view the virtual reality display that has been created as shown in figure 7. After the link can be opened, respondents are asked to use the available VR modes. When using VR mode, respondents must first install the Google VR service. The Google VR service functions so that the browser on an Android smartphone can display virtual reality like the VR headsets on the market. Those VR headsets are Oculus, Samsung VR, HTC VIVE etc.

3.2.   Virtual Reality Testing by Using Oculus Quest 2

In this test, respondents used a VR headset, Oculus Quest 2 to see the virtual reality display as shown in figure 8. Oculus Quest 2 was connected to the laptop first and shown to screen.

Fig.8. Virtual laboratory testing by oculus quest 2.

3.3.   Questionnnarie Result

After the tests were carried out, respondents were asked to fill out a questionnaire that was provided via a link access using Google Form. The questionnaire given contains questions about respondents' opinions regarding virtual reality that has been tried.

Respondents filled out this questionnaire after doing the test, with the following instructions, in each question, choose one answer according to the reality received. Below table are category value and question data.

TABLE II.   LIKERT SCALE QUESTIONNAIRE ASSESSMENT.

No	Value	Category
1	(1)	Strongly disagree
2	(2)	Do not agree
3	(3)	Quite agree
4	(4)	Agree
5	(5)	Strongly agree

TABLE III.   QUESTIONNAIRE QUESTION DATA.

Code	Questions	1	2	3	4	5
P1	Virtual reality can be accessed using various devices (laptop/pc, smartphone, tablet)	0	0	0	0	0
P2	The virtual reality display is easy to learn and use	0	0	0	0	0
P3	Information about components is easy to accept and understand	0	0	0	0	0
P4	Virtual reality is interesting and fun	0	0	0	0	0
P5	The display of objects in virtual reality is good	0	0	0	0	0
P6	Online learning is more interesting by using virtual reality	0	0	0	0	0
P7	This virtual reality provides additional information regarding practical activities	0	0	0	0	0
P8	This virtual reality is a renewal of the online learning system at Bandung Polytechnic for Manufacturing	0	0	0	0	0

Code	Questions	1	2	3	4	5
P9	The creation of virtual reality is one of Bandung Polytechnic for Manufacturing first steps towards industry 4.0	0	0	0	0	0

The experimental results of a virtual laboratory based on virtual reality technology in a CNC machine assembly laboratory are shown in the table below.

TABLE IV.   LIKERT SCALE QUESTIONNAIRE ASSESSMENT.

Code	Quite Agree	Agree	Strongly Agree
1	0 %	30.4 %	69.6 %
2	0 %	34.8 %	65.2 %
3	13 %	30.5 %	56.5 %
4	4.3 %	8.7 %	87 %
5	4.3 %	56.5 %	39.1 %
6	0 %	17.4 %	82.6 %
7	0 %	30.4 %	69.6 %
8	0 %	30.4 %	69.6 %
9	0 %	4.3 %	95.7 %
Average	2 %	27 %	71 %

3.4.   Discussion

Accessible is important to make sure, the proposed virtual laboratory has many accesses alternative. The student can use any devices according to availability. 69.6 % of the audience strongly agree and 30.4 % agree that virtual laboratory can be accessed using various devices such as computer, laptop, smartphone, tablet, and VR goggle. The purpose of virtual laboratory is facilitating the student to learn easily. 65.2 % of the audience strongly agree that a virtual laboratory display is easy to learn and use. A virtual laboratory consists of any information to support the learning process. It needs to be acceptable and understandable. The audience strongly agree and agree previous statements 56.5 % and 30.5 %, respectively.

Another aspect is the virtual reality should be interesting and fun. It achieves 87 % of audience strongly agree. In terms of display quality, 95.7 % of the audience agree and strongly agree that the display of objects in virtual reality is good. A virtual laboratory

is accessed as online learning. By virtual reality, it is more interesting. It is said by the audience 82.6 % strongly agree. The proposed virtual laboratory is designed to support CNC machine assembling practical courses. 69.6 % and 30.4 % of the audience strongly agree and agree that virtual reality provides additional information regarding practical activities, respectively. Last discussion, 69.6 % and 95.7 % of the audience strongly agree that this virtual reality is a renewal of the online learning system at Bandung Polytechnic for Manufacturing and the creation of virtual reality is one of Bandung Polytechnic for Manufacturing first steps towards industry 4.0, respectively. In general, the audience agree that the virtual laboratory can be used to support a CNC machine practical course accessible, easy to learn, easy to use, acceptable, understandable, interesting, fun, good display quality, online access, useful information, renewable technology method, and industry 4.0 trending.

Fig.9. A CNC machine assembly virtual laboratory display.

4.   Conclusion

Virtual reality is a renewal of the online learning system as well as being one of the first steps for Bandung Polytechnic for Manufacturing towards an IOT-based industry 4.0. The virtual reality display that has been made is easy to learn and use. Virtual reality can be an insight into the practicum activities that will be carried out. The use of virtual reality in online learning is fun and interesting. Respondents can access virtual reality by using various devices such as laptops/pc, smartphones, tablets, and VR headsets. Virtual reality-based learning media is expected to be a solution in delivering learning material in a more fresh and attractive way. The author realizes that the results of making virtual reality are still far from perfect. However, the development of the created project can continue to be refined so that it can produce even better output.

The author hopes that in the future the development of virtual reality that has been made can be integrated with augmented reality. So, users will experience a better interaction. In addition, it can also be combined with 3D animation applications or cross-platform game engine applications such as Unity. Then for labs where virtual reality has been made, it can increase not only labs in the Manufacturing Engineering Workshop, but also all places in Bandung Polytechnic for Manufacturing. For this reason, it is necessary to prepare and plan more maturely so that the expectations conveyed by the author can be realized

Acknowledgement

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