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Research paper

Development of Virtual Manufacturing Architecture Using Wearable Sensor, Image Processing and 3D CAD System

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Abstract

This research aims to develop an architecture that can read the movement and contraction of human arm muscles to allow human interact with virtual objects in a novel way. Experiments were conducted to allow users to have both kinesthetic and visual interaction with virtual objects by combining biofeedback from electromyogram (EMG), kinesthetic and visual information from hand image processing. From the results of the research, this model architecture allows virtual objects to be grasped, moved and dropped through muscle exertion classification based on physical world masses.

Keywords: *Computer-Aided Design, Image Processing, Muscle Contraction, Virtual Manufacturing, Wearable Sensor.*

1. Introduction

Under the manufacturing fourth wave, non - touch technology such as augmented reality and virtual reality, is significantly advanced in providing semi-real manufacturing experiences to users. However, while vision and sound can be replicated using gadgets such as virtual reality headset, the sense of touch is progressively seen as a way to perceive science fiction. This research is expected to find out what is felt by the sense of touch and human muscle to become an important part of existing virtual technology. In designing and developing products at this time it is usually done in virtual laboratories or utilizing digital fabrication models. Then the product itself is formed after the digital design and virtual engineering process has been successfully carried out. The advanced machine network raises industrial societies that are very aware of technology that can respond quickly, flexibly, not only respond to direct human commands but also have the ability to make perceptions of the machine itself. [1]. While virtual manufacturing technology is often updated, the immersive experience of virtual reality systems is still being an important part of strengthening the presence of users. To achieve more advanced machine-user interaction, a study by Slater et al. found that the movement of the whole body was needed [2, 4, 5]. Barfield and Hendrix reported that the better the system in immersive capabilities will lead to better sense of user presence in the virtual environment when interacting as in the physical world [3, 5].
The concept of virtual reality has grown over the past two decades. Virtual reality technology combines several human environments with computers to provide multi-sensory immersion that plays an important role in simulating interactions between humans and computers in 3D by making it appear as if the user is entering the virtual world displayed on a computer screen [6]. The use of computers in making manufacturing plans often helps in solving engineering problems. Engineers use CAD in 2D or 3D displays to observe objects and analyze simulations before they are made into physical forms. Using virtual reality technology, simulations can be carried out and different manufacturing sequences can be analyzed using existing CAD data. Virtual interactions, such as taking objects, are determined by the level of muscle activity needed to manipulate the appropriate physical object. This study combine hand muscle contraction from wearable sensor and motion detection techniques to interact with 3D models in software for virtual manufacturing through classification of muscle contractions based on the mass of the physical world.

2. Virtual Manufacturing

Planning the manufacturing process is an important step in the development of products which includes details of manufacturing operations that describes the most quickly, accurately and efficiently steps. A good manufacturing plan by combining consideration for minimum manufacturing time, low cost, ergonomics and operator safety. The design of the manufacturing process that will either be able to improve the quality, efficiency, reduce costs or shorten product time to market [6]. In this complex and evolutive environment, industrialists must know about their processes before trying them in order to get it right the first time. To achieve this goal, the use of a virtual manufacturing environment will provide a computer-based environment to simulate individual manufacturing processes and the total manufacturing enterprise.
Virtual manufacturing is nothing but manufacturing in the computer. This short definition comprises two important notions: the process (manufacturing) and the environment (computer). Virtual manufacturing in this paper is defined as the ability to manufacture a real representation of the physical model, the 3D models in CAD through a realistic simulation of the environment as the natural movement of the human hand in the manufacturing process. Three paradigms are proposed in [7]:
Design-centred Virtual Manufacturing: provides manufacturing information to the designer during the design phase. In this case virtual manufacturing helps designers to evaluate many production

scenarios and the level of information and production decisions using simulation.

Production-centred Virtual Manufacturing: use the ability to model manufacturing processes with the aim of cheap and fast evaluations of various processing alternatives. From this point of view, virtual manufacturing optimizes existing manufacturing processes and adds production simulation analysis to other integration technologies to enable high confidence validation of new processes and results.

Control-centred Virtual Manufacturing: is the addition of simulations to control the actual model and process, to optimize simulation smoothly during the actual production cycle.

3. Development of Virtual Manufacturing Architecture Using Wearable Sensor

Users can interact with virtual objects by viewing, listening, or moving them from one place to another. However, the user has not been able to feel the mass of object as in the physical world. It means that the user still cannot feel the mass of objects while interacting with them in the virtual environment. Therefore, this research is focused on creating a model of virtual manufacturing architecture that can meet the needs of users to interact and also sense the mass of virtual objects same as the physical world conditions while doing virtual manufacturing operations.

Virtual interactions, such as picking, dragging or moving up objects are defined by the level of muscle activity required to manipulate corresponding physical objects. Our approach uses surface EMG to record the muscle activity of biceps brachii muscle. Although no forces are exerted by the hands and body appendages, muscle activity in the user's forearm muscle activity immerses the action against physical objects. [5].

This study combines wearable sensor and approaches for detecting the movement is by using system machine vision and image processing techniques as a reading methods for contraction of the hand muscles when lifting or moving the object. Therefore, the output data in this stage still in raw signal form and filtering would be needed, so that the output signal displayed is accurate and stable. Furthermore the output data in calibration refers to the mass of objects in the real world. This experiment was conducted by taking samples of diverse individuals in order to get a better calibration result.

The electrical data of muscle contraction that has passed through the calibration into force unit then becomes the input on 3D CAD System which is developed as a media of user to do interaction later. The movement of data read by muscle sensor is done wirelessly using nRF24l01 transceiver to make the model of architecture easier for user movement while interacting with virtual object.

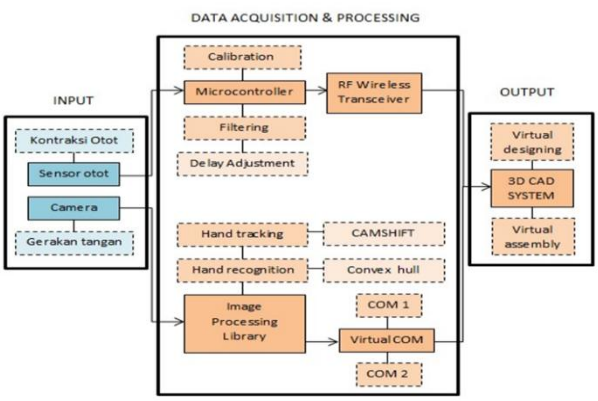


Fig. 1: Virtual Manufacturing Architecture

In 3D CAD System there is a second input that is the result of hand image processing so that the users can interact visually, by utilizing the hand image, captured by camera then hand detected and read as a command by the system to perform a working hand that is represented through the hand model that does the work in the virtual environment. While interacting with a virtual object, muscle contraction will be the same like moving a physical object.

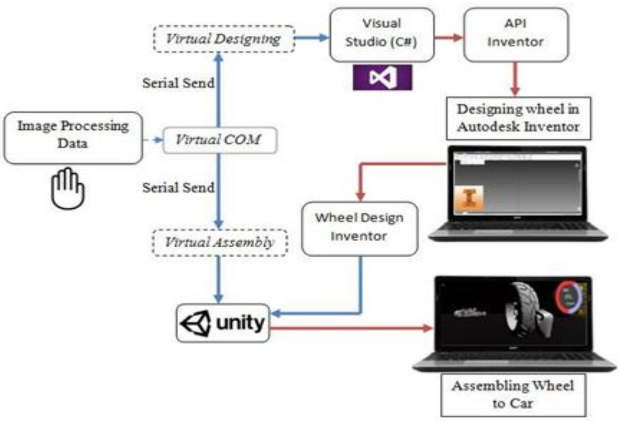


Fig. 2: Virtual Manufacturing Modelling in 3D CAD

Virtual manufacturing software development utilizes the results of human hand-image processing research to get a hand as a virtual movement input. Hand movement data is used as input which is then sent through virtual COM1 and virtual COM2 as communication path between software. Virtual manufacturing model system in this research is divided into two function, virtual prototyping and virtual assembly. In virtual prototyping the result of hand movement is utilized to make object design by using Autodesk Inventor API. This API is utilized with the integration of Visual Studio software to access libraries that can invoke special functions on Autodesk Inventor. The wheels that have been designed then will be served as objects in virtual assembly by utilizing Unity software. Hand movements are used to move the hand virtual model and the object to be assembled on the framework that has been provided.

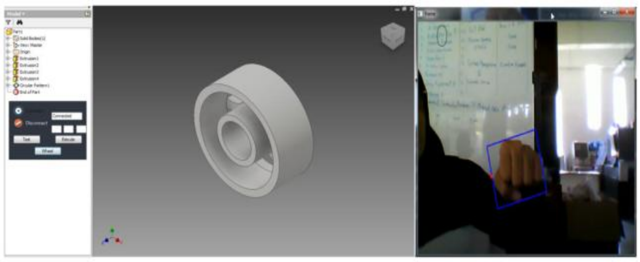
4. Results

Simulation results show that the system works successfully, in this case the system is able to utilize hand gestures or read the number of fingers detected during image processing and contraction of muscle.

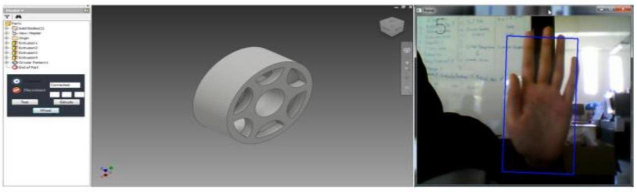
Table 1: Hand Gesture and API feature

Hand Gesture	API Feature
Gesture-0	Circle Feature
Gesture-1	Delete All Feature
Gesture-2	Extrude
Gesture-3	Extrude
Gesture-4	Zoom
Gesture-5	Rotate

Referring to Table 1, the hand image has been able to perform work orders as expected. In this study the hand image is utilized as a work order for the implementation of virtual prototyping in the Autodesk Inventor application as shown in Figure 3.



(a)



(b)

Fig. 3: Virtual Prototyping Simulation in Autodesk Inventor (a) create a circular object (b) rotate object

In addition, the hand image has also been used as a work command in a virtual assembly implementation using Unity as shown in Figure 4.

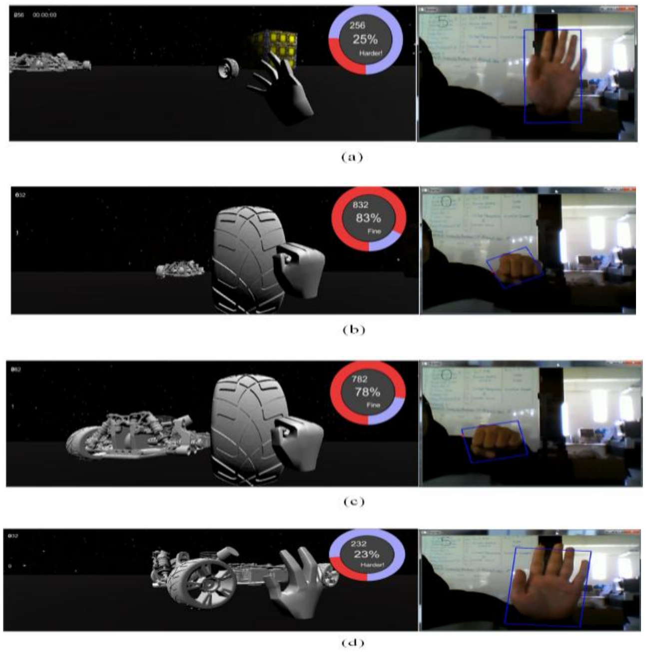


Fig. 4: Virtual Assembly Simulation in Unity (a) move closer to object, (b) retrieve object, (c) deliver object, (d) release object

Referring to Figure 4, (a) the movement of the hand towards the object can be done by utilizing the x-axis and y-axis data on image processing to move forward and move the virtual hand model. Then in part (b) the object picking can be done by looking at the number of fingers which amounted to 0 or the hands in a clenched state and given the condition when the hand model close to the target object then the object will be gripped, so that it can move along with the hand model. In part (c), the grasped object moved along with the virtual hand model to the car framework that already provided. In part (d), the object is released, so that assembling the object of the wheel by car can be completed.

In this simulation, the virtual object mass has been set. Based on the mass calibration that has been done from previous muscle sensor data, the mass is then used as parameter to move the virtual object. In this test, the object mass is set to 5kg and based on a 5kg mass calibration equivalent to a muscle contraction of 300mV. By this condition, if the hand muscle performs a contraction not reaching 300mV, the object cannot be grabbed or moved and the 'harder' command appears as a sign that increased contraction should be required because it is not meet the standard of hand contraction to lift the weight of 5kg as shown in Figure 4 (a) and (b). Meanwhile, when conditions have been reached then the object can be grasped and moved to the desired location. In this case the command that is done is grasping, move the object and assembly it to the framework that has been provided. Based on the simulation results, the developed model has been able to implement virtual assembly as shown in Figure 4 (c) and (d). The existence of minimum contraction standard that established from the previous mass calibration process is used as parameter to move the virtual object, this condition makes the user not only able to interact visually with virtual objects, but also can sense the mass of objects that interact with them. This is certainly a positive achievement as the trend toward touch less technology, with the fulfillment of such a kind of feedback, i.e. sensory feedback enhance the user's illusion of presence and control.

5. Conclusion

Model of virtual manufacturing architecture capable of implementing virtual prototyping and virtual assembly in 3D CAD System by using wearable sensor input and hand image processing. Electromyogram (EMG) able to identify muscle contraction characteristics and the force. 3D CAD system can perform movement commands on components: translation, rotation, zoom, create, and delete using hand image data processing. This allows virtual objects to be grasped, moved and dropped through muscle exertion classification based on physical world masses. Model successfully worked well, in which force and muscle contraction can be read and have both kinaesthetic and visual interaction with virtual objects.

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References

[1] Bernard Marr, 2016, What everyone must know about industry 4.0, https://www.forbes.com/sites/bernardmarr/2016/06/20/what-everyone-must-know-about-industry-4-0/#e0866ae795f7. Retrieved 19-6-2018 11.48 WIB.

[2] Bragt, J. 2nd Twente Student Conference on IT, The Netherlands, volume 24. Citeseer. 2005. Do exertion interfaces provide better exercise environments.

[3] Barfield W, Hendrix C. The effect of update rate on the sense of presence within virtual environments. Virtual Reality. 1995; 1:3–15.

[4] Slater M, Steed A, McCarthy J, Maringelli F. The influence of body movement on subjective presence in virtual environments. Human Factors: The Journal of the Human Factors and Ergonomics Society. 1998; 40(3):469–477.

[5] Kevin Ponto, Ryan Kimmel, Joe Kohlmann, Aaron Bartholomew, Robert G. Radwin. Virtual Exertions: a user interface combining visual information, kinesthetics and biofeedback for virtual object manipulation Proc IEEE Symp 3D User Interfaces. 2012; 2012:85–88. doi:10.1109/3DUI.2012.6184189.

[6] Arif Krisbudiman, Gandjar Kiswanto., Development Prototype Design of Virtual Assembly Application-Based Leap Motion. International Journal of Advanced Engineering, Management and Science, Vol-3, Issue-5, 2017, ISSN: 2454-1311

[7] P. Depinc ´ e, D. Chablat., E. Noe., P.O. Woelk., 2004, The Virtual Manufacturing Concept: Scope, Socio-Economic Aspects And Future Trends.