Designing Immersive Serious Game Based on Soil Tillage : Polynomial Model for Horizontal Plowing Force Model

by Anang Kukuh

International Journal of Engineering & Technology, 7 (4.28) (2018) 404-410

International Journal of Engineering & Technology

Website: www.sciencepubco.com/index.php/IJET

Research paper

Designing Immersive Serious Game Based on Soil Tillage : Polynomial Model for Horizontal Plowing Force Model

Anang Kukuh Adisusilo [1,*], Mochamad Hariadi [2], Eko Mulyanto [3], Bambang Purwantana [4], Radi [5]

[1,2,3] *Department of Electrical Engineering, Faculty of Electrical Technology, Institut Technology of Sepuluh November Surabaya, Jl. Raya ITS, Keputih, Sukolilo, Suarabaya, East Jawa, 60111, Indonesia.*

[1] *Departement of Informatics Engineering, Faculty of Engineering, University of Wijaya Kusuma Surabaya, Jl. Dukuh Kupang XXV/54, Dukuh Kupang, Dukuh Pakis, Surabaya, East Jawa 60225, Indonesia.*

[2,3] *Department of Computer Engineering, Faculty of Electrical Technology, Institut Technology of Sepuluh November Surabaya, Jl. Raya ITS, Keputih, Sukolilo, Suarabaya, East Jawa, 60111, Indonesia..*

[4,5] *Departement of Agricultural and Biosystems Engineering, Faculty of Agricultural Technology, Gadjah Mada University, Jl. Flora No. 1, Bulaksumur, Yogyakarta, 55281, Indonesia.*

**Corresponding author E-mail: anang@anang65.web.id, anang65@uwks.ac.id*

Abstract

Modeling is successful if it can reflect reality, identify and handle differences between reality and computing. To support the realization experience in the serious game, the results of the experiment are needed. If the results of the computational process have far-reaching differences with the results of the experiment, it can be difficult to achieve the learning function of the serious game and the missing of the immersivity, especially in the player's engagement. Experiment in this study can be generated using soil bin tools to determine the effect of vertical cutting angle, depth of plowing, and speed on horizontal plowing forces. A result of horizontal forces model on tillage using a moldboard plow was created as a basis for immersivity design in the serious game. In the computational process, to produce data close to the results of experiments, polynomial functions are used. In addition, the smallest error results in the 4th order. In short, with computational data based on the model approaching of the experiment, the engagement of players and serious game immersivity will be increased.

Keywords: *Plowing Forces; Polynomial; Serious game; Immersive; Modeling.*

1. Introduction

Towards the engagement player, a part of the immersive in a serious game, and the feeling of players which is immersed in the scenario that provides more experience; the model based on reality is required from experimental. Successful models are able to recognize and identify reality and deal with differences between theory and data [1]. Like components or features contained in objects as part of the model, it can be in the form of interfaces and non-interfaces. In the serious game that has a purpose of a medium of entertainment and learning, in terms of immersiveness, there must be a match between the learning objectives and the side of the game. Serious game, which has the main goal besides entertaining, is a medium that can be used for learning media because it can be used as a means of informing and educating [2]. In addition, according to Aldrich when the players use fun games that aim to entertain, they will be difficult to identify values of education inside [3]. Serious game is also promising for various risk-free active exploration for problems in various fields, either intellectual or social. With the main goal to solve the problem, serious game can simulate events or processes in the real world. Furthermore, serious game can be used both as a suitable tool to achieve many goals and for efficient and attractive transmission [4].

With the aim of computating results on reality and giving deep experience for the players, the basis of developing serious game use data modelling, While, a data-based approach has been tilted towards the introduction of goals, player behavior, and procedural content creation [5]. The most challenge in immersivity design, in serious games, is the extent to which the resulting model which is then processed on a computer. It produces data that are closed to reality and then increase engagement players. Likewise the designs of agricultural equipment driving training, some serious game types for agricultural machinery research's equipment have been lead. The game is design because training traditionally requires high training costs, low efficiency and also a high risk of [6]. In addition, the research of tracks on the ground from the effects of machine farming [7], the shape model's form design of the moldboard plow and the comparison between them aim to optimize the plowing form [8]. In relation to the purpose, a virtual machine farm model's uses 3D interactive technology, dynamic web technology and database [9]. Also, with the polynomial approach, the design of model immersivity serious game for soil porosity is applied [10].

The purpose of this study was to determine models for horizontal forces by the influence of cutting angle, deep and speed of plowing. The researcher used mouldboard plough for the primary subsoil. The data-driven approach used soil data which reflect to the real condition of Indonesia, by taking the sample of land in Yogyakarta. The data were taken from the soil bin experiment on the use of moldboard plow in the laboratory of Agricultural Engineering, University of Gadjah Mada, Yogyakarta, Indonesia. Moreover, the data were analyzed by the polynomial approach using several orders, starting with order 1, 2, 3 and 4. With reference to the smallest error, the calculation of the analysis is from order 1 to order

4. Consequently, these horizontal forces modeling results were used as a base for the immersive serious game design. Furthermore, the game's serious design referred to pedagogy, play and fidelity [11], to make players gain knowledge based on their playing experience, and the freedom of interacting with the game.
For future research, the framework of serious game for plowing with moldboard plows with optimization on data, scenario, and game play; supports the content of plowing which enhances the total immersivity of its game. By developing this serious game, the young generation will be interested in getting to know farming equipment, likewise for training and promotion of farmers. In short, the impact of science can be raised on the idea of how a data-driven approach can be used to improve total immersivity, so as to influence players' behavior in learning.

2. Plowing Forces in Soil Tillage and Serious Game Immersivity

Soil processing is engineered and fertilized soil by using a plow drawn from various sources of energy. Source of power for tillage are such as animal power, human power, and agricultural machinery; are suitable for planting by certain types of plants. Based on the activities and treatment of tillage, soil processing activities are divided into two categories, i.e. the primary and secondary processing. Generally, for depth of soil processing is less than 15 cm, so that the intensive soil erupts on the topsoil. The tillage using plows consists into three parts; the intake process, main flow, and output. The intake process is a process of separating soil layer from the main. Secondly, the main flow process is a process that occurs when the plowing is moved and the output process is a change after the ground slices apart from the tool. Even though the characteristics of the plow are usually limited by the shape of the plow, they have some characteristics. One of them is the horizontal cut point perpendicular to its direction of action.
The share cuts a soil and brings the furrow slice to the moldboard, as the plow moves forward. The moldboard will receive a piece of soil because of its curvature so that the land will be reversed and cracked. Each type of soil in order to obtain a good and fertile soil reversal, use different moldboard curvature [12]. The landslides serve to withstand the side pressure from the ground slit on the moldboard and keep the stability of the plowing. While, the part that most tangents to the soil is the back called the heel. To avoid wear and tear due to friction with the ground, the manufacture of hardened is on the heel. The main parts of a bottom are moldboard, share, and landslide, which are tied to the frog part. This unit is connected to the frame through the beam rod, Figure.1.

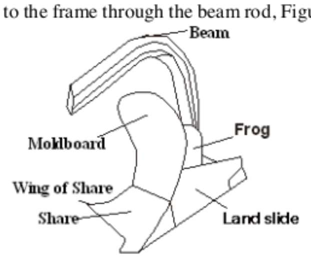

Figure 1: Parts of moldboard plow

There are two types of cutting plows, namely stationary blades and colter cutting blades, which functions to cut soil or crop residues and debris on the ground. Using a knife, the plant residues on the ground can be reversed properly which is part of the share.

2.1. Plowing forces

The gravitational, soil reaction, and reaction between the plow unit and the drive is the generally plowing forces [13]. Illustration of the magnitude of forces occurring in the moldboard plow as in Figure.2.

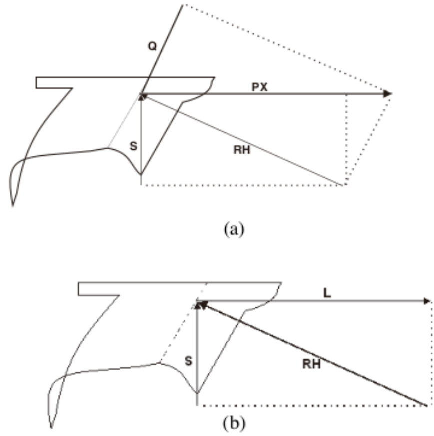

Figure 2: The force and the resultant on the moldboard plow.

In Figure. 2. (a), RH is the ground resistance to the plow and share, the position RH angle varies with the condition and type of soil. The L and S force is substituted by RH. The L and S forces of the substitution of RH, making the plane direction won't be straight, so the need for side resistance to be able to make straight plow direction like Figure.2 (b). This side resistance causes friction as indicated by Q, where Q component is equal to S. The Q with RH is PX greater than L because it has to overcome the side barrier frictional force. If tillage is angled or the direction is not parallel to the side retaining, it will require a large force to overcome the friction of the Q or Q side forces should be larger than the S.

2.2. Serious game.

Serious game aims to provide experience and learning to the players that are obtained while playing [14]. The basic of serious game design is the domain of fidelity that prioritizes simulation design similar to reality, domain play which prioritizes the entertainment and education, and pedagogy, which prioritizes the design for learning purposes [15].
The fidelity concept in the serious game refers to the extent to which it can simulate the real world [16]. Two levels of fidelity are, physically fidelity refers to the extent to which the game environment looks like a real, sounds and feels as real. Therefore, the physical fidelity of the game is determined by the variable physical model of player control by factors including a visual display, and audio [17]. The second is functionally fidelity defined to what extent the gaming environment acts like the real world in terms of response to the player's actions, thus encompassing game narrative elements and interactivity [16]. The base for fidelity in a serious game originates a dual pedagogical goal that are; (a) attractive and immersive players, and (b) perform an effective process of learning to experience. Moreover, being supported by a realistic 3D visual display, a fidelity driven experience learning perspective is certain that the results of it are in line with actual circumstances to evoke the player's experience as in the real world [18].
Player's behavior, which concern on practice that is closed to the reality; is supported by a pattern of repetition that strengthens the stimulus-response and changes in habits and behavior [19], so that it has educational purposes. Playing a serious game is challenging in order to get players to take action to overcome problems in the game. In a serious game design, the purpose is not only to entertain, but also to provide an element of educational information. Many researchers find various ways to make this happen, as stated that the key to the serious effects of games is to balance the side of play and pedagogy [20,21]. The basis of game design is that engagement, motivation, and flow are rapidly emerging in virtualization related to the immersive concept [16,22]. Players often spend hours playing

and repeating the same game so that spend a lot of time (i.e. engagement). They spend a lot of time and energy in mastering the rules of the game and the strategy of the complicated game [23].
Pedagogy in a serious game, as an example of instructional design, should be supported by a clear basic construct and model of how and what learning is [24]. At the base level, it is stated that some games, such as casual games allow players to acquire the knowledge and practice skills of an interesting game environment based on behaviorist principles [25]. From the point of view epistemological, the ability can be measured from the results of learning behavior [26], where knowledge is an abstract concept whose substance is to play and learn from the experience seen as the process of each person when the transfer of information between games and players [15].

2.3. Immersion.

One of the most interesting aspects of games is the immersion that they presented. Much like movie or books, games can draw people into them for extensive periods, occupying the player's full attention in an experience. This is of particular interest from an educational standpoint, to ensure the learners pay close, voluntary, attention to the educational content being delivered. To describe the 'optimal state of immersive experience is called the term "flow" which is described as a state of active, exclusive concentration on a particularly enjoyable activity, which is meaningful to the person undertaking it [27]. When the person kindly ends this flow state, they reflect on their experiences, and how they have been affected by them. The condition happened when the players are completely immersed in the game and forget that it is actually playing [23]. There are three levels that relate to the feelings of players while playing and affect game immersivity [22], namely: (a). Engagement, (b). Engrossment, (c). Total immersion.
First, engagement involves first getting involved in the game, via accessible controls and relevant gameplay. Second, engrossment is the point where the player's emotions become directly affected by the game. Finally, third, total immersion is the feeling of the players being fully engaged in the game, to the exclusion of all else (a phenomenon they call 'presence') – a state very similar to flow. However, they claim total immersion is a brief experience, in contrast to flow, which can last up to the entire length of the activity the people is engaged in [22].
The initial engagement of players with the game is a preference with a preference that can easily remove obstacles that hinder the interest of playing. For example with an easy control even by just dabbling a game button can already run and make players will be proficient. When time involves the game, the game will take a lot of time and energy; so a barrier that keeps players from wasting time playing games needs to be overcome. The player's effort in the game to reach the game's target requires great energy in playing. Therefore, it needs the reward, which is usually in the form of score or bonus game to give satisfaction to the players in play. By breaking through obstacles earlier or by having access to unfavorable preference, the involved players will be interested in the game and want to keep playing.
Engaging in playing is heavily influenced by the design in making games, so players feel drained of energy and power when finished. With an exciting and impressive game, players do not feel drained of energy while playing. Some things that are often used for planning this game are the details of the visual design of the game. In other words, the impression of luxury, task or target in the game are interested based on the scenario of the game story; as well as the plot or game plan of interest in the game environment that makes the players curious to play.
The total immersive games must be able to build the players into the atmosphere of the game, resulting in experience for players in the game. The limitations in total immersive can include empathy and game atmosphere. Empathy players are usually tied to character and the atmosphere or the environment of the game. In addition, the merging of various elements such as graphics, sound, and game play (scenarios and stories) is crucial for the formation of the total immersion. In short, to make a game with the total immersive; the visual, hearing and mental element of the player need to be preferred.

3. Methodology.

The data in this study used soil bin tools based on vertical speed, depth, and cutting angle. The soil used was in the sandy clay texture with the plasticity index value of 7.722%, with the moisture content of 72%. The first steps in the experiment used soil bin which calibrating its equipment so that the data to be generated was valid. The calibration used the linear equation with one variable, in equation (1), for a data taken according to this study was the stress generated from the strain gauge mounted on the moldboard plow beam. The resulting data was the weight value in Kg, then converted in the form of a force where 1 Kg = 9,8066500286389 N. The research flow, as Figure.3.

$$y=ax+b \quad (1)$$

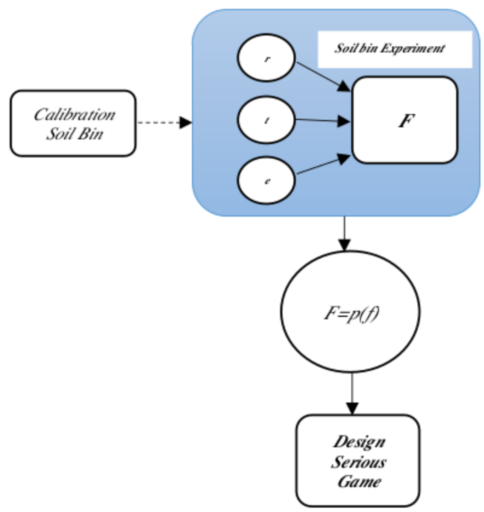

Figure 3: Flow of the research

In the soil bin experiment have a tree variable; denotes r is a speed of plowing, t is vertical cutting angle and e is a depth of plowing. Using the least square approach method to determine the polynomial function $F=p(f)$, F is plowing forces and $p(f)$ is fitting function, a dependent variable F from a set of independent p variable in function $p(f)$ denotes,

$$\{r_1 \ldots r_n, t_1 \ldots t_n, e_1 \ldots e_n\} \quad (2)$$

Forces of plowing equations can be generated by fitting a curve. In the case of a polynomial fit of the order q, these equations take the general form of,

$$\tilde{r}=r+\sum_{i=0}^{n} c_{ri}\, r^{q_i} t^{q''_i} e^{q'''_i},\ \tilde{t}=t+\sum_{i=0}^{n} c_{ti}\, r^{q_i} t^{q''_i} e^{q'''_i},$$
$$\tilde{e}=e+\sum_{i=0}^{n} c_{ei}\, r^{q_i} t^{q''_i} e^{q'''_i} \quad (3)$$

Where c_{ri} ,c_{ti} and c_{ei} are polynomial coefficients, the value n depends on the order k polynomial and equal to the number of permutations, where q'_i, q''_i and q'''_i are the powers of the corresponding terms such that $q'_i, q''_i, q'''_i \in \{0,1,\ldots,q\}, q'_i, q''_i, q'''_i \leq k$ for any $i=0, \ldots, n$ all permutations $\{q', q'', q'''\}$ are unique, $(\widetilde{r}),(\widetilde{t})$ and $(\widetilde{e})$ are a corrected values for the indepedent vareable r,t and e (speed of plowing, cutting angle and depth of plowing). By calculating the coefficients value c_{ri} ,c_{ti} and c_{ei} are used to build

the fitting polynomial for each value of r ,t and e. The equations below are given for r ,t and e have the following structure.
The equations are given for r (speed of plowing) as,

$$\begin{cases} c_{r1} r_1^{q_1'} t_1^{q_1''} e_1^{q_1'''} + \ldots + c_{ri} r_1^{q_i'} t_1^{q_i''} e_1^{q_i'''} + \ldots + c_{rn} r_1^{q_i'} t_1^{q_i''} e_1^{q_i'''} = \bar{r}\text{-}r \\ \ldots \\ c_{r1} r_j^{q_1'} t_j^{q_1''} e_j^{q_1'''} + \ldots + c_{ri} r_j^{q_i'} t_j^{q_i''} e_j^{q_i'''} + \ldots + c_{rn} r_j^{q_n'} t_j^{q_n''} e_j^{q_n'''} = \bar{r}_j\text{-}r_i \\ \ldots \\ c_{r1} r_m^{q_1'} t_m^{q_1''} e_m^{q_1'''} + \ldots + c_{ri} r_m^{q_i'} t_m^{q_i''} e_m^{q_i'''} + \ldots + c_{rn} r_m^{q_n'} t_m^{q_n''} e_m^{q_n'''} = \overline{r_m}\text{-}r_m \end{cases} \quad (4)$$

The equations are given for t (cutting angle) as,

$$\begin{cases} c_{t1} r_1^{q_1'} t_1^{q_1''} e_1^{q_1'''} + \ldots + c_{ti} r_1^{q_i'} t_1^{q_i''} e_1^{q_i'''} + \ldots + c_{tn} r_1^{q_i'} t_1^{q_i''} e_1^{q_i'''} = \bar{t}\text{-}t \\ \ldots \\ c_{t1} r_j^{q_1'} t_j^{q_1''} e_j^{q_1'''} + \ldots + c_{ti} r_j^{q_i'} t_j^{q_i''} e_j^{q_i'''} + \ldots + c_{tn} r_j^{q_n'} t_j^{q_n''} e_j^{q_n'''} = \bar{t}_j\text{-}t_i \\ \ldots \\ c_{t1} r_m^{q_1'} t_m^{q_1''} e_m^{q_1'''} + \ldots + c_{ti} r_m^{q_i'} t_m^{q_i''} e_m^{q_i'''} + \ldots + c_{tn} r_m^{q_n'} t_m^{q_n''} e_m^{q_n'''} = \overline{t_m}\text{-}t_m \end{cases} \quad (5)$$

The equations are given for e (depth of plowing) as,

$$\begin{cases} c_{e1} r_1^{q_1'} t_1^{q_1''} e_1^{q_1'''} + \ldots + c_{ei} r_1^{q_i'} t_1^{q_i''} e_1^{q_i'''} + \ldots + c_{en} r_1^{q_i'} t_1^{q_i''} e_1^{q_i'''} = \bar{e}\text{-}e \\ \ldots \\ c_{e1} r_j^{q_1'} t_j^{q_1''} e_j^{q_1'''} + \ldots + c_{ei} r_j^{q_i'} t_j^{q_i''} e_j^{q_i'''} + \ldots + c_{en} r_j^{q_n'} t_j^{q_n''} e_j^{q_n'''} = \bar{e}_j\text{-}e_i \\ \ldots \\ c_{e1} r_m^{q_1'} t_m^{q_1''} e_m^{q_1'''} + \ldots + c_{ei} r_m^{q_i'} t_m^{q_i''} e_m^{q_i'''} + \ldots + c_{en} r_m^{q_n'} t_m^{q_n''} e_m^{q_n'''} = \overline{e_m}\text{-}e_m \end{cases} \quad (6)$$

that can be written in the matrix form $\boldsymbol{r=Rw}$, $\boldsymbol{t=Tu}$ and $\boldsymbol{e=Ev}$= as,
The matrix from $\boldsymbol{r=Rw}$, as,

$$\mathbf{R}=\begin{bmatrix} r_{1,1} & \cdots & r_{1,i} & \cdots & r_{1,n} \\ \vdots & \ddots & \vdots & \ddots & \vdots \\ r_{j,1} & \cdots & r_{j,i} & \cdots & r_{j,n} \\ \vdots & \cdots & \vdots & \cdots & \vdots \\ r_{m,1} & \cdots & r_{m,i} & \cdots & r_{m,n} \end{bmatrix} \mathbf{w}=\begin{bmatrix} l_1 \\ \ldots \\ l_j \\ \ldots \\ l_n \end{bmatrix} \mathbf{r}=\begin{bmatrix} r_1 \\ \ldots \\ r_j \\ \ldots \\ r_n \end{bmatrix} \quad (7)$$

The matrix from $\boldsymbol{t=Tu}$, as,

$$\mathbf{T}=\begin{bmatrix} t_{1,1} & \cdots & t_{1,i} & \cdots & t_{1,n} \\ \vdots & \ddots & \vdots & \ddots & \vdots \\ t_{j,1} & \cdots & t_{j,i} & \cdots & t_{j,n} \\ \vdots & \cdots & \vdots & \cdots & \vdots \\ t_{m,1} & \cdots & t_{m,i} & \cdots & t_{m,n} \end{bmatrix} \mathbf{u}=\begin{bmatrix} l_1 \\ \ldots \\ l_j \\ \ldots \\ l_n \end{bmatrix} \mathbf{t}=\begin{bmatrix} t_1 \\ \ldots \\ t_j \\ \ldots \\ t_n \end{bmatrix} \quad (8)$$

The matrix from $\boldsymbol{e} = \boldsymbol{Ev}$, as,

$$\mathbf{E}=\begin{bmatrix} e_{1,1} & \cdots & e_{1,i} & \cdots & e_{1,n} \\ \vdots & \ddots & \vdots & \ddots & \vdots \\ e_{j,1} & \cdots & e_{j,i} & \cdots & e_{j,n} \\ \vdots & \cdots & \vdots & \cdots & \vdots \\ e_{m,1} & \cdots & e_{m,i} & \cdots & e_{m,n} \end{bmatrix} \mathbf{v}=\begin{bmatrix} l_1 \\ \ldots \\ l_j \\ \ldots \\ l_n \end{bmatrix} \mathbf{e}=\begin{bmatrix} e_1 \\ \ldots \\ e_j \\ \ldots \\ e_n \end{bmatrix} \quad (9)$$

Where ($r_{j,i}=r_j^{q_i'} t_j^{q_i''} e_j^{q_i'''}$, $t_{j,i}=r_j^{q_i'} t_j^{q_i''} e_j^{q_i'''}$, $e_{j,i}=r_j^{q_i'} t_j^{q_i''} e_j^{q_i'''}$) ($w_i=c_{w,i}, u_i=c_{u,i}, v_i=c_{v,i}$) and($r_j=\bar{r}\text{-}r$, $t_j=\bar{t}\text{-}t$, $e_j=\bar{e}\text{-}de$), the predicted values of the dependent variable $\tilde{r}$, $\tilde{t}$, $\tilde{e}$ are collected in vector denoted $\boldsymbol{r}$,$\boldsymbol{t}$ and $\boldsymbol{e}$ and are obtained is:

$$\boldsymbol{r=Rw} \text{ with } \boldsymbol{w=(R^TR)^{-1}Rr} \quad (10)$$

$$\boldsymbol{t=Tu} \text{ with } \boldsymbol{u=(T^TT)^{-1}Tt} \quad (11)$$

$$\boldsymbol{e=Ev} \text{ with } \boldsymbol{v=(E^TE)^{-1}Ee} \quad (12)$$

The part of the soil bin in Figure .4, consists of: (1). Soil bin tool, (2). Plowshares, (3). Box of soil, (4). Strain gauge on the beam, (5). The Wheatstone bridges, (6). Strain amplifier, (7). Microcontroller, (8). Computers and (9). Motor. The flow starts as the soil inserted into the box. In order to make soil conditions as in the field, it's necessary to have a compaction process by water for about three weeks, Figure.5.(3). By arranging the cutting angle of the moldboard plow, Figure.5.(2), the depth of plowing and the speed of the motor of Figure.5.(9), a process of ground moldboard plow experiments were conducted. After that, the force that arises from the friction plows with the soil will be measured by the strain gauge of Figure.5.(4), which is mounted on the beam. The strain gauge is an electronic component used to measure pressure (deformation or strain). Strain gauge sensors work based on changes in pressure that lead to resistance changes. Moreover, to increase the sensitivity and generate the output voltage by knowing the resistor resistance of the used Wheatstone bridge, Figure.5.(5), the voltage is amplified with the Strain amplifier, Figure.5.(6), and the microcontroller Figure.5.(7). Therefore, the voltage can be directly read by computer.

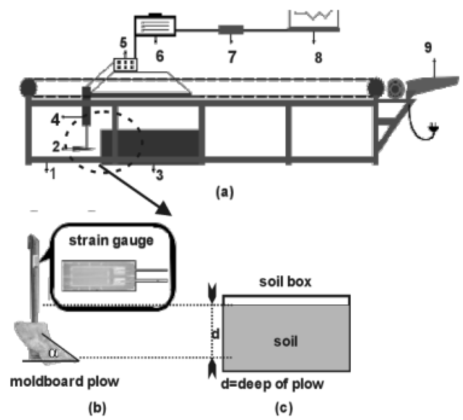

Figure 4: Part of soil bin tools (Adisusilo et al., 2018).

The speed setting with the motor engine, Figure.4.(9), based on the gear is set to 3 parts, is one gear with a speed of 6.808 cm/s, two gears with a speed of 10.169 cm/s and a three gear with a speed of 19.917 cm/s. Meanwhile, the depth of plow are 2, is at 3.5 *cm* and 7 cm. Depth setting based on soil surface on the box against the plow, Figure.4.(c), expressed in a variable. The cutting angle is the angle of plow cut with three types of plows which have different cutting angles, is 70^0, 65^0 and 60^0, as figure.4.(b) expressed in a variable. The result of the strain gauge is the change of the voltage of the electric, so that the calibration of the load is also load which the result is converted into force.

4. Results and Discussion

From the data calibration weight on soil bin obtained equation, as in:

$$y = 117{,}57\, x + 499{,}82 \quad (13)$$

Where x denotes the weight result (kg) and y represents the voltage value (mV). From the graph in figure.5, it is also obtained a high coefficient of determination that is equal to $R^2=0.9853$, which then converted into forces where $1\ Kg = 9{,}807\ N$. In general, the data of the force is a model by assuming that the relationship between data has a linear.

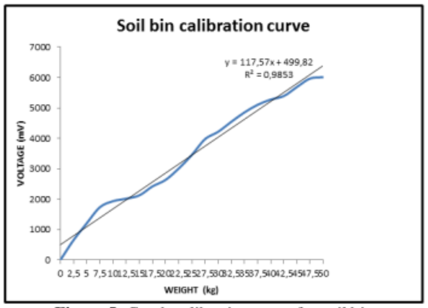

Figure 5: Graph calibration curve for soil bin

Preparation of soil by way of watering is approximately for 3 weeks. With 3 different angles, 2 depths and 3 speeds, it takes 18 soil boxes of soil or 18 times running the plowing process using soil bin. The result of soil bin experiment showing in Table.1.

Table 1: Experiment Result From Soil Bin

No	Speed (cm/s)	Depth (cm)	Cutting angle (^{0})	Force (N)
1	6,808	3,5	60	105,87
2	6,808	3,5	65	68,78
3	6,808	3,5	70	18,04
4	6,808	7	60	221,88
5	6,808	7	65	105,24
6	6,808	7	70	93,08
7	10,169	3,5	60	118,46
8	10,169	3,5	65	70,66
9	10,169	3,5	70	39,01
10	10,169	7	60	314,04
11	10,169	7	65	187,01
12	10,169	7	70	112,74
13	19,917	3,5	60	173,76
14	19,917	3,5	65	101
15	19,917	3,5	70	48,98
16	19,917	7	60	316,64
17	19,917	7	65	306,3
18	19,917	7	70	225,36

From the data in Table.1. using the general equation of polynomial from Equation (3) we can be defined variable $\tilde{r}$ for the speed of plowing as,

$$\tilde{r}=r+(c_{r1}r_1^{q_0'}t_1^{q_0''}e_1^{q_0'''}+...+c_{ri}r_j^{q_i'}t_j^{q_i''}e_j^{q_i'''}+...+c_{rn}r_m^{q_n'}t_m^{q_n''}e_m^{q_n'''}) \quad (13)$$

The equations for two other variables can be built in the same way using $\tilde{t}$ and $\tilde{e}$ following :

$$\tilde{t}=t+(c_{t1}r_1^{q_0'}t_1^{q_0''}e_1^{q_0'''}+...+c_{ti}r_j^{q_i'}t_j^{q_i''}e_j^{q_i'''}+...+c_{tn}r_m^{q_n'}t_m^{q_n''}e_m^{q_n'''}) \quad (14)$$

$$\tilde{e}=e+(c_{e1}r_1^{q_0'}t_1^{q_0''}e_1^{q_0'''}+...+c_{ei}r_j^{q_i'}t_j^{q_i''}e_j^{q_i'''}+...+c_{en}r_m^{q_n'}t_m^{q_n''}e_m^{q_n'''}) \quad (15)$$

The fitting function is searched by comparing the smallest error value of a polynomial function from first order to fourth order, by definition constants which are alternate from the speed of plowing, depth, and cutting angle to create a graph of each analysis. With the speed, a value is constant 6.8085cm/s and comparing the value of the smallest error, from equation (13), is generated in the 3rd order with an error 6,49030161881115e-06, so the value $c_{r,i}$ is constant value , $i=\{0,1,...,n\}$, $n=3$ and $j=\{1,2,...,m\}$, $m=64$, show graphic in Figure.6.

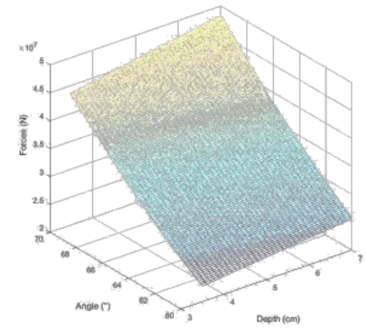

Figure 6. Graphic of relationship for depth and angle to horizontal force with constant plowing speed in 3rd order.

The value of the smallest error from Equation (14) in the polynomial is 8,18472854311223e-06 in the 4th order. With the value of plowing cutting angle is constant 60^0 can be generated graphics in Figure.7. Where $c_{t,i}$ is constant value,

$i=\{0,1,...,n\}$, $n=3$ and $j=\{1,2,...,m\}$, $m=125$.

.

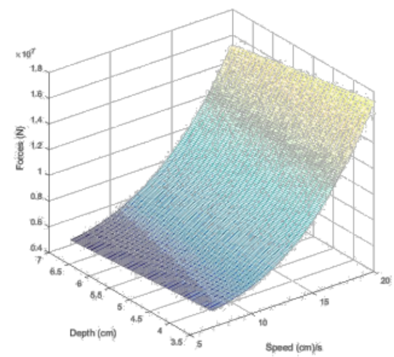

Figure 7: Graphic of relationship depth and speed to horizontal force with a constant cutting angle in 4th order.

Graphics in Figure.8. is produced from Equation (15) in order 4 with a constant depth of 3.5 cm and the result the polynomial error is 4,44135084419391e-05.

Where
$c_{e,i}$ is constant value, $i = \{0,1,\dots,n\}, n = 3$ and $j = \{1,2,\dots,m\}, m = 125$.

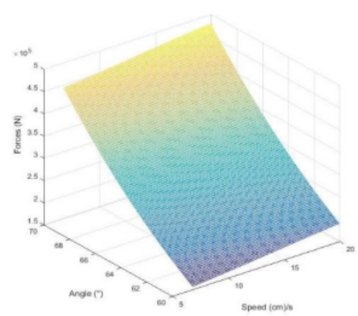

Figure 8: Graphic of relationship for angle and speed to horizontal force with a constant depth in 4th order.

The result comparison of the smallest error from the polynomial function produces the smallest value 4,4413508441939 1e-05 in the 4th order, so that the fittings function used is equation (15). From the graph, this shows that the deeper and faster the force gets bigger, but the bigger the vertically cutting angle the force smaller. The force is the power of pulling the plow or the amount of force required in processing soil tillage with a moldboard plow, called the specific draft of plowing. The specific draft of plowing can be found by dividing the forces of plowing with the wide cross-sectional of the moldboard. In short, the plowing forces model F as follow,

$$F=\{\bar{r},\bar{t},\bar{e}\} \quad (16)$$

The immersive serious game design is based on the model polynomial function using HSM (Hierarchical finite state machines), where the polynomial function $F=p(f)$ becomes a state, in Figure 9.

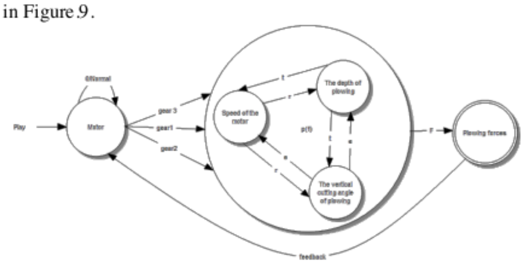

Figure 9: Design immersive serious game using HSM (Hierarchical finite state machines) for soil tillage.

A player starts with turn on the engine motor as an initial state. Where there are three gear choices that affect the speed of the plow, if the transition is 1 then it has a low speed, the value of 2 transitions shows the medium speed and the value of 3 transitions shows the high-speed. The motor starts to move; however, the motor stops if it is 0. Superstate $p(f)$ is a polynomial function influenced by transition s for substate speed of the motor, transition a for substate the vertical cutting angle of the plow, and transitiond for substate the depth of plow. From these parameters, they relate each other and produce the transition value F which is state of the plowing force. Reverse transition or feedback transition from state plowing forces is a form of effort to create a situation where the player feels like the real situation. The Simple calculations are done by assigning values to the depth of plowing , vertical cutting angle and the speed of plowing, (r,t,e). For example, the depth of plowing, vertical cutting angle and the speed of plowing (3.5 70 6.8085), using the polynomial 4th order formula is generated plowing force 18.0576. The value is almost equal to the porosity value in the experiments that have been done, showing in Table. 1. The parameters are the transition of the sub-state speed of the motor $e=6.8085$, the transition of substate the vertical cutting angle $t=3.5$ and the transition substate the depth of plow $r=60$. These parameters are related to each other and produce the transition value $F=18.0576$ which is state of the Plowing force.

5. Conclusion.

By using the polynomial approach and looking for the smallest error is 4,4413508441939 1e-05, produced in the 4th order, we define the mathematical model for the effect of the verticaly angle of the plowing, the depth of plow and the speed of the plow to the horizontal force use equation 13, 14 and 15. From the curve graph, it shows that the deeper and faster the speed of the plow, the bigger horizontal force. On the other hand, the bigger the vertically cutting angle, the smaller horizontal force. In addition, the specific draft of plowing of pulling the plow or the amount of force is required in processing soil tillage with a moldboard plow.
The model can be used as the basis for designing immersive serious game, if the data produced in a serious game closer to the actual data ,with the aim of immersivity. While, serious games have an effect on the engagement of the players with the value of plowing forces that approach the results of the experiment. Moreover, it can make the implication of the player with the return value to the player in the immersive design. In other words, the value is depicted in feedback from state plowing force, where the power of the plow is the driving force of the player. Consequently, the players will feel involved in the field. In short, they will get knowledge in terms of learning; with the return value and determine to the next action as determining the speed, depth, and angle of vertical cutting when plowing. In other words, a form of knowledge based on experience is developed. In the future, we will continue to have research on optimalization of the immersivity level of the serious game.

References

[1] Silvert W. Modelling as discipline. Int J Gen Syst 2001;30:261–82. doi:10.1080/03081070108960709.

[2] Connolly TM, Boyle EA, MacArthur E, Hainey T, Boyle JM. A systematic literature review of empirical evidence on computer games and serious games. Comput Educ 2012;59:661–86. doi:10.1016/J.COMPEDU.2012.03.004.

[3] Aldrich C. Virtual Worlds, Simulations, and Games for Education: A Unifying View. Innov J Online Educ 2009;5.

[4] Noemí P-M, Máximo SH. Educational Games for Learning. Univers J Educ Res 2014;2:230–8. doi:10.13189/ujer.2014.020305.

[5] Hooshyar D, Yousefi M, Wang M, Lim H. A data-driven procedural-content-generation approach for educational games. J Comput Assist Learn 2018. doi:10.1111/jcal.12280.

[6] Ma Q, Yang Z, Chen H, Zhu D, Guo H. A Serious Game for Teaching and Learning Agricultural Machinery Driving. 2012 Int J Inf Artif Intell Soft Comput 2012;12:56–62.

[7] Alexander A, Brunyé T, Sidman J, Weil S a. From gaming to training: A review of studies on fidelity, immersion, presence, and buy-in and their effects on transfer in pc-based simulations and games. DARWARS Train Impact Gr 2005:14. doi:10.1016/j.athoracsur.2004.02.012.

[8] H S Jeshvaghani, S K H Dehkordi MFS. Comparison and Optimization of Graphical Methods of Moldboard Plough Bottom Design Using Computational Simulation. J Am Sci 2013:414–20.

[9] Liu Jianjun. The Study on Agricultural Machinery Design and Modeling Method. Int J Adv Comput Technol 2012;4:678–84. doi:10.4156/ijact.vol4.issue16.2.78.

[10] Adisusilo AK, Hariadi M, Yuniarno EM, Purwantana B, Radi R, Radi R. Soil porosity modelling for immersive serious game based on vertical angle, depth, and speed of tillage. Int J Adv Intell Informatics 2018;4:107. doi:10.26555/ijain.v4i2.215.

[11] Latif E, Lawrence M, Shea A, Walker P. Moisture buffer potential of experimental wall assemblies incorporating formulated hemp-lime. Build Environ 2015;93:199–209. doi:10.1016/j.buildenv.2015.07.011.

[12] Daywin FJ. (Agricultural Cultivation Machines on Dry Land), translate "Mesin-mesin budidaya pertanian di lahan kering" Graha Ilmu 2008.

[13] Smith HP, Wilkes LH. Farm machinery and equipment. McGraw-Hill translate by Tri Purwadi ; editor: GembongTjitro-soepomo, (1990), Yogyakarta : GadjahMada University Press; 1976.

[14] Barbosa AFS, Pereira PNM, Dias JAFF, Silva FGM. A New Methodology of Design and Development of Serious Games. Int J Comput Games Technol 2014;2014:1–8. doi:10.1155/2014/817167.

[15] Ruben BD. Simulations, games, and experience-based learning: The quest for a new paradigm for teaching and learning. Simul Gaming 1999;30:498–505. doi:10.1177/104687819903000409.

[16] McMahon, M. & Ojeda C. A Model of Immersion to Guide the Design of Serious Games. In: Association for the Advancement of Computing in Education (AACE), editor. E-Learn World Conf. E-Learning Corp. Gov. Heal. High. Educ., vol. 2008, Las Vegas, Nevada, USA: Association for the Advancement of Computing in Education; 2008, p. 1833–42.

[17] Dickey MD. Engaging by design: How engagement strategies in popular computer and video games can inform instructional design. Educ Technol Res Dev 2005;53:67–83. doi:10.1007/BF02504866.

[18] Rooney P. A theoretical framework for serious game design: Exploring pedagogy, play and fidelity and their implications for the design process. Int J Game-Based Learn 2012;2:41–60. doi:10.4018/ijgbl.2012100103.

[19] Jeanne Ellis Ormrod. Human Learning. 7th ed. Pearson; 7 edition (February 26, 2015); 2015.

[20] De Freitas S. Learning in Immersive worlds A review of game-based learning Prepared for the JISC e-Learning Programme. JISC ELearning Innov 2006;3.3:73. doi:10.1111/j.1467-8535.2009.01024.x.

[21] Seeney M, Routledge H. Drawing circles in the sand: Integrating content into serious games. Games-Based Learn. Adv. Multi-Sensory Hum. Comput. Interfaces Tech. Eff. Pract., 2009, p. 84–97. doi:10.4018/978-1-60566-360-9.ch006.

[22] Brown E, Cairns P. A grounded investigation of game immersion. Ext. Abstr. 2004 Conf. Hum. factors Comput. Syst. - CHI '04, 2004, p. 1297. doi:10.1145/985921.986048.

[23] Rouse R, Ogden S. Game Design : Theory & Practice. 2005.

[24] Zemliansky P, Wilcox DM. Design and implementation of educational games: theoretical and practical perspectives. Information Science Reference; 2010.

[25] Kebritchi M, Hirumi A. Examining the pedagogical foundations of modern educational computer games. Comput Educ 2008;51:1729–1743. doi:10.1016/j.compedu.2008.05.004.

[26] Jarvis P, Holford J, Griffin C. The theory & practice of learning. Kogan Page; 2003.

[27] Csikszentmihalyi M. Flow: the psychology of optimal experience. 1st ed. New York: Harper & Row; 1990.

Designing Immersive Serious Game Based on Soil Tillage : Polynomial Model for Horizontal Plowing Force Model

ORIGINALITY REPORT

20%	18%	12%	9%
SIMILARITY INDEX	INTERNET SOURCES	PUBLICATIONS	STUDENT PAPERS

PRIMARY SOURCES

1	eprints.soton.ac.uk Internet Source	3%
2	www.mdpi.com Internet Source	2%
3	www.ncbi.nlm.nih.gov Internet Source	1%
4	doaj.org Internet Source	1%
5	sciencepubco.com Internet Source	1%
6	arrow.dit.ie Internet Source	1%
7	V. Kindratenko. "Calibration of electromagnetic tracking devices", Virtual Reality, 1999 Publication	1%
8	www.ijain.org Internet Source	1%

9	prc.springeropen.com Internet Source	1 %
10	pure.rug.nl Internet Source	1 %
11	purehost.bath.ac.uk Internet Source	1 %
12	Submitted to Aspen University Student Paper	<1 %
13	Lucia Vigoroso, Federica Caffaro, Margherita Micheletti Cremasco, Eugenio Cavallo. "Innovating Occupational Safety Training: A Scoping Review on Digital Games and Possible Applications in Agriculture", International Journal of Environmental Research and Public Health, 2021 Publication	<1 %
14	ojs.eselx.ipl.pt Internet Source	<1 %
15	mpaeds.my Internet Source	<1 %
16	ojs.pnb.ac.id Internet Source	<1 %
17	www.liebertpub.com Internet Source	<1 %

18 Sylvia Urban, Robert Brkljača, Russell Cockman, Trevor Rook. "Contextualizing Learning Chemistry in First-Year Undergraduate Programs: Engaging Industry-Based Videos with Real-Time Quizzing", Journal of Chemical Education, 2017 — <1%
Publication

19 D. Hooshyar, M. Yousefi, M. Wang, H. Lim. "A data-driven procedural-content-generation approach for educational games", Journal of Computer Assisted Learning, 2018 — <1%
Publication

20 Meng-Han Tsai, Ming-Chang Wen, Yu-Lien Chang, Shih-Chung Kang. "Game-based education for disaster prevention", AI & SOCIETY, 2014 — <1%
Publication

21 www.tandfonline.com — <1%
Internet Source

22 link.springer.com — <1%
Internet Source

23 mafiadoc.com — <1%
Internet Source

24 Julia Othlinghaus-Wulhorst, H. Ulrich Hoppe. "A Technical and Conceptual Framework for Serious Role-Playing Games in the Area of — <1%

Social Skill Training", Frontiers in Computer Science, 2020
Publication

25	inba.info Internet Source	<1 %
26	nrs.harvard.edu Internet Source	<1 %
27	Hamish Beattie, Daniel Brown, Sara Kindon. "Solidarity through difference: Speculative participatory serious urban gaming (SPS-UG)", International Journal of Architectural Computing, 2020 Publication	<1 %
28	Pauline Rooney. "A Theoretical Framework for Serious Game Design", International Journal of Game-Based Learning, 2012 Publication	<1 %
29	Ruijie Wang, Liming Chen, Ivar Solheim. "A Conceptual System Architecture for Motivation-enhanced Learning for Students with Dyslexia", Proceedings of the 2017 International Conference on E-Education, E-Business and E-Technology - ICEBT 2017, 2017 Publication	<1 %
30	test.editlib.org Internet Source	<1 %

Submitted to Universitas Brawijaya

31	Student Paper	<1%
32	garuda.ristekbrin.go.id Internet Source	<1%
33	Ibrahmi, A., H. Bentaher, M. Hbaieb, A. Maalej, and A.M. Mouazen. "Study the effect of tool geometry and operational conditions on mouldboard plough forces and energy requirement: Part 1. Finite element simulation", Computers and Electronics in Agriculture, 2015. Publication	<1%

Exclude quotes	Off	Exclude matches	Off
Exclude bibliography	Off		