Serious Game Mechanism Design for Soil Cultivation using Singkal Plow

Anang Kukuh Adisusilo
Departement of Informatics
Universitas Wijaya Kusuma Surabaya
Surabaya, Indonesia
anang65@uwks.ac.id

Emmy Wahyuningtyas
Departement of Informatics
Universitas Wijaya Kusuma Surabaya
Surabaya, Indonesia
emmy@uwks.ac.id

Nia Saurina
Departement of Informatics
Universitas Wijaya Kusuma Surabaya
Surabaya, Indonesia
niasaurina@uwks.ac.id

Radi
Department of Agricultural and Biosystems Engineering
Universitas Gadjah Mada
Yogyakarta, Indonesia
radi-tep@ugm.ac.id

***Abstract*— Serious games are game systems that do not prioritize the fun side but have a specific purpose, such as learning media. In soil cultivating, to be ready for planting, not everyone knows the right way of processing, so there needs to be a learning process on the soil tillage. One way to cultivate the soil is to use a singkal plow to cut the soil, turn the soil, dispose of the soil and destroy nuisance plants—a research based on the data obtained in the experiment using the soil bin tool. The model uses multilinear regression with the Ordinary Least Squares (OLS) as the basis for designing a serious game mechanism for soil cultivation so that a learning experience emerges for the user. The results show that the model's accuracy that reaches above 80% can be used as the basis for the characteristics of the soil processing learning media.**

Keywords— Serious Game, Soil tillage, Education media, Edu Game

I. INTRODUCTION

Serious games are increasingly used as learning media in various disciplines, including education, health, military, industry, tourism, agriculture, farm, and fishery [1]–[8]. Several research in agriculture has been conducted to improve the performance of agricultural equipment [9]–[11] as a medium for agricultural introduction and training [8], [12]. Several edu-game concepts have been investigated for agricultural land cultivation, such as for farmers in Thailand to enhance soil quality and utilize the appropriate fertilizer [13]and as a game medium for learning agriculture [14].

Tillage improves soil conditions by modifying it to make it more conducive for plant growth. The main purpose of tillage is to prepare an excellent growing place for plant seeds and roots, bury plant debris and eradicate weeds [15]. Tillage using a plow serves to cut the soil, flip the soil, throw the soil and destroy nuisance plants. It was the first tillage with plow equipment such as the disc plow and rotary plow [16].

Serious gaming is a game designed to aid learning and must influence the player on multiple levels. The learning method in this study is to tillage with a singkal plow, and the results are the porosity of the soil and the pulling force of the plow to begin, with the results impacted by the plow blade speed, vertical cutting angle, and plowing depth [17], [18]. Because success in a serious game is tied to a specific score, the level of the serious game mechanism is dynamic. This research focuses on the characteristics of learning media, namely the serious game mechanism, which was created with the primary goal of serving as a teaching tool for land cultivation using a singkal plow.

II. RELATED WORKS

Several past studies on the serious game in agriculture have focused on increasing soil quality, such as in European agriculture, to supply sufficient and high-quality food while being environmentally friendly and examining its long-term impact. The research findings point to an increase in agricultural productivity that is both sustainable and scalable. The next stage of the serious game concept is for players to develop their transition management abilities and gain a systems approach by converting agricultural to organic farming within five years, resulting in the concept of Agroecology [19], [20]

Since 2019, there has been ongoing research on serious games for tillage using the singkal plow, where modeling is used as a foundation for forming Serious Game Immersiveness (ISG). Produces an optimal area for the plow motor speed, the depth of the plow blade, and the angle of the plow blade to the porosity of the soil, as well as the plow pulling force required in the tillage process using the singkal plow [8], [17], [18]. The ideal area is defined as the area that can create the requisite plow pulling force to obtain the required soil porosity for plant growth.

III. DESIGN & METHODOLOGY

A. Experiment and modeling

Experiments were carried out using a Soil Bin device consisting of a driving motor, iron rods/arms, a mini plow, and a box filled with soil, as shown in Fig. 1. The mini plow simulates the process of tilling the soil with a singkal plow in the laboratory.

Fig .1(a), consists of (1) soil bin iron frame, (2) mini plow, (3) box filled with soil, (4) *strain gauge* attached to the iron arm, (5) Wheatstone bridge to measure the value of a resistance caused by the strain of the iron arm, (6) Amplifier resulting from the strain of the iron arm, (7) Microcontroller as an intermediary for computer input, (8) Computer and (9) Electric motor.

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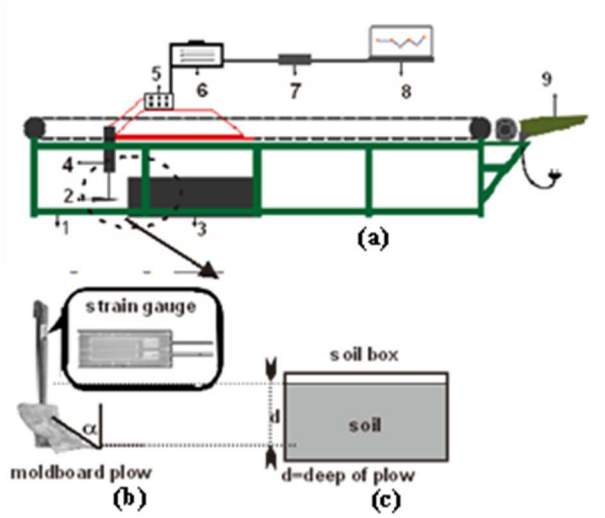

Fig. 1. Part of soil bin tools [18]

After the soil bin is run, it will produce a trajectory of the plow and soil thrown to the left and right of the mini plow. The soil is then taken as a sample and checked for porosity values in the soil laboratory, while the tensile strength of the plow is obtained from the results of computer analysis, shown in Fig. 2.

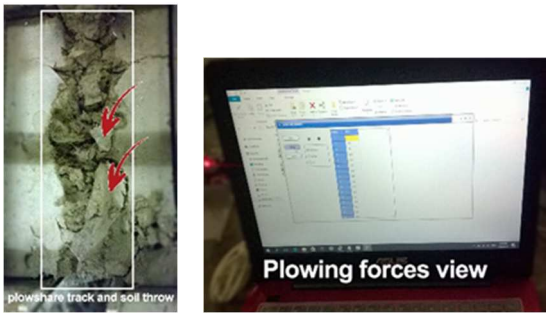

Fig. 2. Plowshare track and view of result plowing forces.

The soil used is included in the texture of sandy clay with a plasticity index value of 7.722% and a water content of 72%. As a parameter of the test data and variations of the mini plow used, three types of plow blades were determined with different vertical cutting angles. Called the variable α and the moldboard width, namely plow A is 65^0 and 7cm, plow B is 70^0 and 7.5cm, and plow C is 60^0 and 9cm. The speed variation used for the driving motor is the variable v through the gears, namely gear 1, gear 2, and gear 3. For the plow blade depth of sinking to the ground, variable d, there are two depth types: 3.5 cm and 7 cm.

The Simple modeling was performed using multilinear regression with the Ordinary Least Squares (OLS) model based on the experimental data. For the influence of the driving motor speed (v), the depth of the plow (d), and the cutting angle of the plow (α) on the pull force of the plow, which is called the *Yg* variable. Which is generated from equation (1), with r2 = 0.895, or the modeling accuracy reaches 89.25%.

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$$Yg = 6.78v + 36.12d - 11.89\alpha + 645.80 \quad (1)$$

As for the effect of the driving motor speed (v), the plow blade depth (d), and the plow blade cutting angle (α) on the porosity of the soil, which is called the *Yp* variable, is obtained from equation (2), with r2 = 0.922 or the modeling accuracy reaches 95.53%.

$$Yp = 0.50v + 0.35d + 0.2589\alpha - 17.99 \quad (2)$$

B. Serious Game mechanism design

By referring to the land cultivation process and the purpose of the serious game as a learning medium, the design of the serious game mechanism takes into account the following points:

- Game system; Game mechanics explain how players interact with in-game structures such as game plots and scenarios. These structures will bring players to the end of a game. The formal structure model is divided into player actions, game methods, and procedures for player actions. In short, the game mechanism is a pattern of rules designed in each part of the system that includes a unique series of interactions during the game, namely the possibility of a feedback mechanism to the player.

- Learning concepts; This refers to changing a player's behavior while playing because players implicitly understand the learning process carried out by playing. As a result of the playing experience, there will be permanent changes in player behavior, referred to as learning success.

The design of serious game mechanics includes a description of what the player can do in the game environment, how to accomplish it, and how it leads to something engaging for a certain purpose. The game mechanism for the role of players modifies the users' experience. They are subsequently led and guided to acquire particular behaviors by limiting the field of viable goals-achievement plans. The game mechanism is depicted in this study using a game flow diagram and a game scenario, a strategy for attaining goals guided within the boundaries of achieving scores based on serious game modeling.

Fig 3. depicts the design of the serious game mechanism for tillage with the singkal plow, with two primary

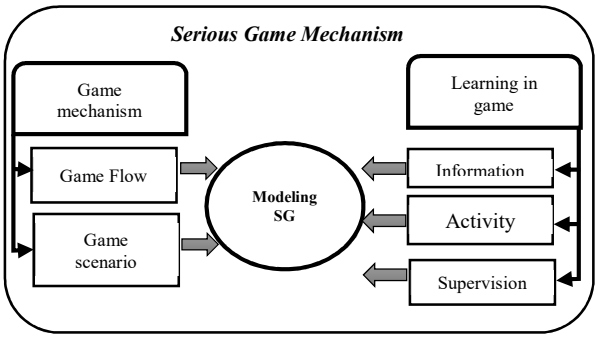

Fig 3. Design of a serious game mechanism for tillage with a plow

components of the game, namely the game mechanism containing the gameplay and game scenarios and the learning component containing clear information, activities, and supervision.

Serious games should have knowledge transfer as a core part of the game mechanics because of the implementation suitability of learning concepts and game mechanics [21]. Increased interactivity motivates students to study, explore, and apply the material offered [22], [23]. However, interactivity alone is insufficient to motivate students [24]. So, if the game can induce more immersive involvement [25] through something fun (game), in this case, a serious game with the primary purpose of learning, the goal will undoubtedly be reached. Therefore, separating the game mechanism from the educational implementation is complicated because this synergy forms an entity that functions to educate and entertain through an exciting experience. The boundaries between entertainment and pedagogy become less apparent when the components of play and learning serve as elements to build an experience. In serious games, tillage using the singkal plow is designed to link game components and learn to become a serious game concept, using modeling as reference data.

IV. Design Characteristics Of Learning Mechanism In Serious Games

The characteristics of the learning mechanism or from the pedagogical side can be explained from the perspective of the game mechanism function that changes the game's dynamics and supports the learning process, as shown in Fig 4.

- Guide
  It is a tool to help players see the structure, links, and direction of learning. The guide starts from the beginning of the serious game for cultivating the land with the singkal plow by guiding how to use the key features (keyboard/joystick/mouse), which are player interaction tools and function guides in the game so that players can understand what to do when playing.
- Instructions
  A facilitator, in this case, is a system of serious games that provides learning support by following the pattern of the game and directing players so that learning objectives can be achieved. Instructions can be done during the cut scene with a quick response. When an error occurs in running the plow, a cut scene is carried out, and then a response is given in the form of instructions, thereby increasing the player's understanding of learning.
- Demonstration
  The learning method is problem-based learning using serious games, providing examples of a series of playing processes, as if players are dealing directly with the teacher. The demonstration is done to maximize players' understanding of learning because they see examples instantly.
- Participation
  The active learning process occurs when directly involved in the game. Players are given the freedom to

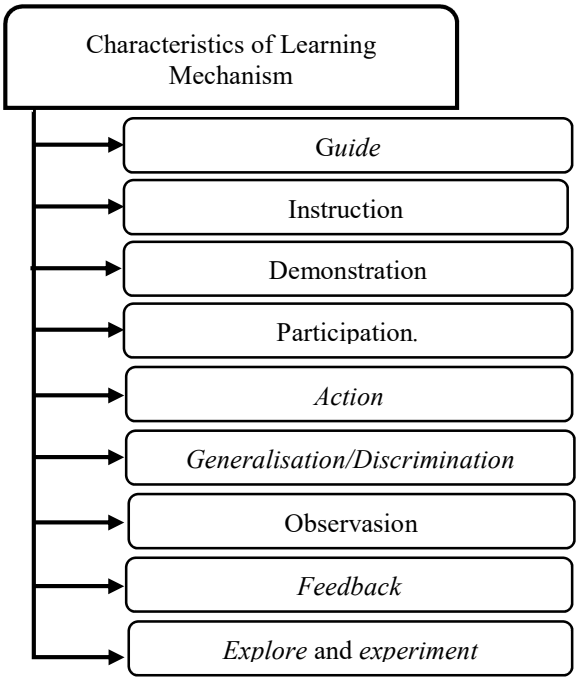

Fig 4. Design characteristic of serious game learning mechanism for tillage with cassava plow.

Determine game strategies such as the plowshare's speed, the vertical cutting angle, and the plow's depth as a form of players' direct participation in the game.

- Action
  It is a method that involves individuals in the actual world to reflect on their experiences and plan their next steps. When role-playing, a surprise factor can be included, such as a stone blocking the plow or uneven ground to be plowed, to allow players to explore their actions in overcoming challenges.
- Generalization/Discrimination
  Generalization or Discrimination is similar to the learning process, in which conditioning is required to produce various reactions to a stimulus. This conditioning is similar to role-playing games, allowing players to identify more effective plowing strategies to solve problems and build quicker problem-solving behavior.
- Observation
  Observational learning (also called representative learning or modeling) is based on the concept that learning occurs as monitoring, maintaining, and replicating actual behavior. In this case, actual behavior is based on experimental results of the soil bin, which has been modeled as a learning reference. The supervisory function is supported by mechanisms of a quick feedback game that will provide a reference so that the plowing results are in a fixed condition in the optimal area of plowing.
- Feedback
  The development is better done in the form of visual or audio related to the results of the plowing strategy. Players have carried that out to understand the ultimate goal of the game better. The feedback can be in an instructional form using the quick feedback mechanism in the game.

- Explore and experiment
  Mechanisms that enable players to investigate and experiment in serious land cultivation games employing a singkal plow and an exploratory learning strategy can aid players' general thinking and problem-solving abilities. Players are given complete flexibility to choose strategies and explore knowledge, allowing them to learn through trial and error.

V. Serious Game Flow and Design

The serious game design refers to the learning and modeling characteristics of the experimental data produced as a success parameter of the soil tillage. Several strategies are presented as options for players, referring to the computational model of equation (1) and equation (2).

- The motor speed inputs are: gear 1 speed between 6.8 cm/s to 10 cm/s, gear 2 speed 1 between 0.17 cm/s to 19 cm/s and gear 3 speed between 19.92 cm/s to 30 cm /s.
- The vertical cutting angle input indicates the type of plow with angles of 60^0, 65^0, and 70^0.
- Plowing depth input is generated by computing randomly with a value between 3.5 cm to 7 cm.

For serious game testing by giving alternate inputs so that from each speed, there are three changes in the selection of the singkal plow. The design of user interfaces for serious game mechanics is shown in Fig 6. On the left is the input consisting of motor speed (gear 1,2,3), type of plow (based on a vertical cutting angle), and plowing depth.

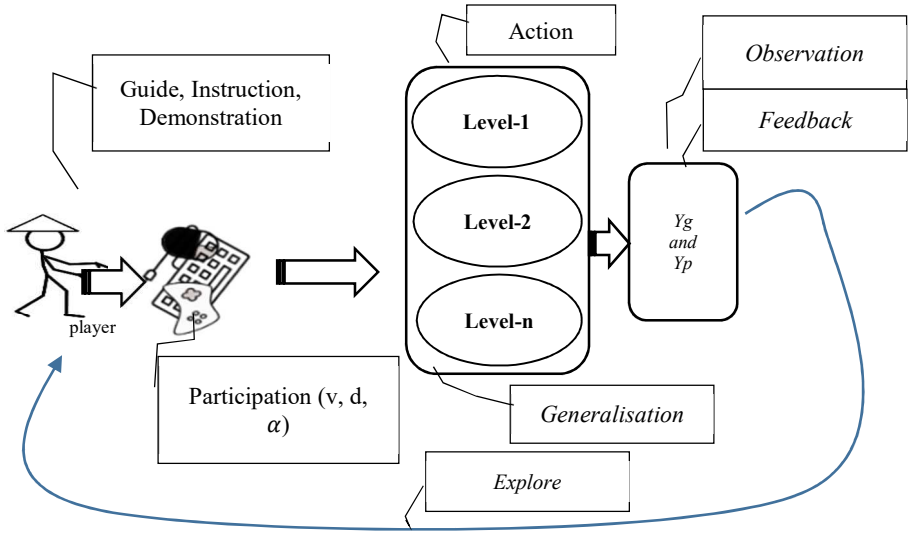

Fig 5. Mechanism of a serious game for tillage with a singkal plow.

The main concept of a serious game is to provide fun and learn soil tillage with the plow. It is neither serious if too much focus is given on learning aside from the game. So serious game a choice of strategies is provided to increase score and become a choice of game scenarios at the game level.

Fig 5. shows that before the player begins the game, there is a guide, instruction, and demonstration to ensure that the player understands what will be done. After that, the participation step needs the player to actively participate by manipulating the values of v, d, and α. Actions that are part of gameplay are adjusted to the game's level. There is role-playing in the game with the generalization, making it more exciting and providing a better user experience. The values of *v*, *d,* and α are calculated based on modeling to produce porosity and tensile strength values (*Yg* and *Yp*); these values are observations from the game's level that is being carried out in the form of porosity and tensile strength of the singkal plow. With the feedback, players are expected to play the game repeatedly so that it is part of exploring and experimenting.

In serious game design, three inputs are used, namely:

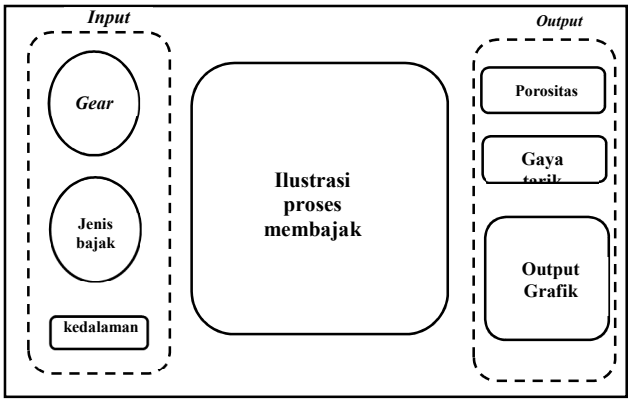

Fig 6. Design of user interfaces for serious game mechanisms for tillage with a singkal plow

The serious game mechanism's system flow design serves as a learning medium for operating the soil tiller, the initial stage of tillage with the singkal plow. Fig 7. depicts the general flow of the system architecture in a serious game.

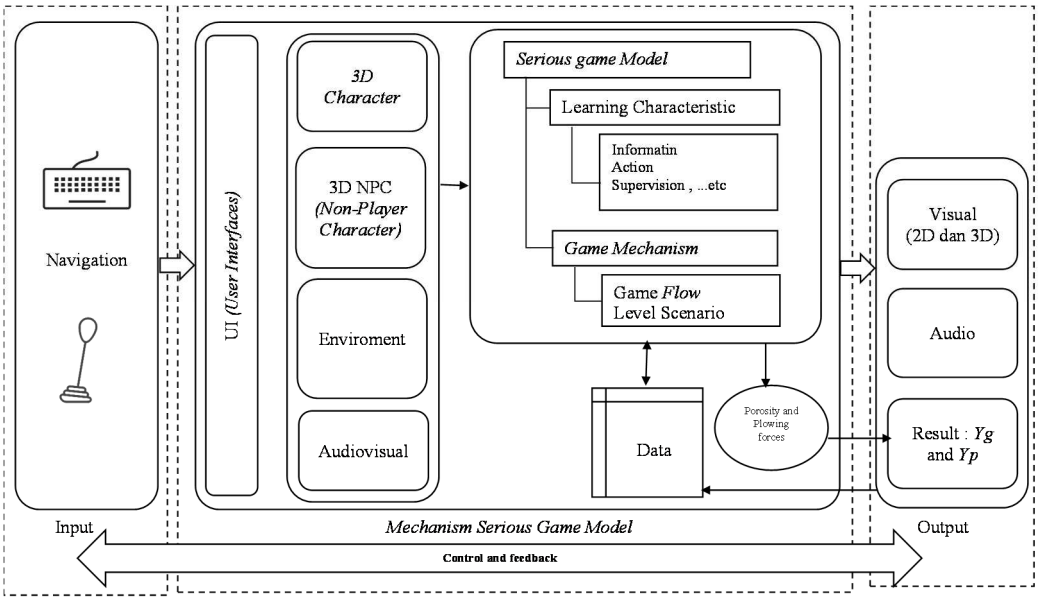

Fig 7. Mechanism architecture of a serious game for tillage with a singkal plow

The keyboard or joystick is used as navigation for players, where there are user interfaces in the form of a monitor screen display with three-dimensional (3D) and two-dimensional (2D) graphics. There are 3D characters, 3D NPCs (Non-Player Characters), environment, and video and audio to support the interface in the graphic display. Then based on the concept of the serious game that has been discussed in the previous subsection and the game mechanism and pedagogy that refers to the optimal dataset, the serious game system is run. The resulting output is in the form of visual, audio, and values resulting from optimization calculations. These values are used as visual feedback and reference values to make the vibration feature in active navigation to feel like they are running a singkal plow.

VI. Conclusion And Future Works

The design of the serious game mechanism for tillage using the singkal plow is based on an experiment using a soil bin tool. Using multilinear regression with the Ordinary Least Squares (OLS) model resulted in a simple model to measure the success of the plow pulling force and soil porosity. The results of the effect between the speed of the driving motor (v), the depth of the plow blade (d), and the cutting angle of the plow blade (α) on the pull force of the plow are r2=0.895 or the modeling accuracy reaches 89.25%. In comparison, the porosity of the soil is r2= 0.922, or modeling accuracy reaches 95.53%. The features of the learning media, including guide, instruction, demonstration, participation, action, generalization, observation, feedback, and exploration experiment, are used to develop the serious gaming mechanism.

In the future study, in addition to the implementation of the mechanism design serious game, Multi-Objective Optimization should be used to optimize the model that has been created

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