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Mechanics of Serious Simulation Game for Karakuri Concept towards Low-Cost Automation

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ABSTRACT

Automation in industrial development is one of the requirements for a manufacturer to increase productivity. This is often accompanied by a big cost with modern machinery. Karakuri is a concept from Japan that utilizes a mechanism by using the laws of simple physics so it doesn't require quite complicated machinery and relatively low cost. This study aims to design a Serious Simulation Game mechanic for learning media in Karakuri concept. Serious Simulation Game is designed to provide real case studies faced by players with unlimited decision-making and provide direct feedback from decisions taken to build mental models of the players. The mechanics used consists of game mechanics and learning mechanics. The results of this study are a basis that can be used for making a complete game to learn Karakuri through simulation to stimulate players to consider using the Karakuri concept for material handling automation solutions.

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1. INTRODUCTION

Automation and robotics, which are recognized as key components of Industry 4.0, are now widely used and connected to digital technology with mostly need a big cost. This research try to explain the alternate automation with similar origins of robotics through the example of premodern Japanese automata, or *karakuri*, with an emphasis on the answers these primitive robots can offer and how humans can benefit from this technology, deliver in the modern setting of Industry 4.0, with the demands of the 21st century in mind.

The majority of human life, which is focused on trade, education, healthcare services, labor, and industry, is influenced by the relationships between people, society, machines, and ever more mesin. As a result, the advancement of technology has increased the demand for all types of energy used to operate machinery, digital devices, and robotics [1]. As can be seen in Figure 1, energy consumption increases significantly with technological advancements discussed here as the number of transistors per microprosessor (the extent of these technological advancements is limited by the assertion that Industry 4.0 solutions are particularly disruptive in today's computerized world) [1].

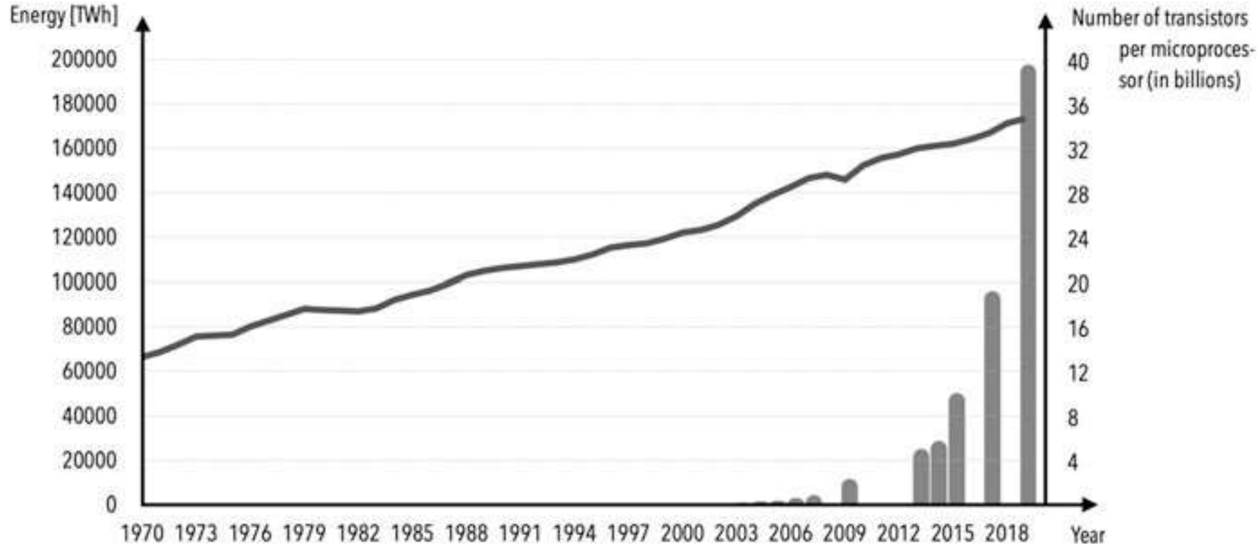

Figure 1. Comparison of number of transistors per microprocessor and global energy consumption (Source : Hussain et al., 2022)

The phrase "karakuri kaizen," which refers to continuous improvement through the use of updated karakuri applications, is associated with the current application of karakuri. As can be seen from Fig. 2, this modern application has piqued academics' curiosity, however somewhat. In contrast to Industry 4.0, which is digitalized, karakuri kaizen is analog automation. However, unlike Industry 4.0, it is not connected to every variety of recently developed technologies, such as Narrow Band Internet of Things (NB-IoT), Global Positioning System (GPS), Wireless Sensor Network (WSN), Near-Field Communication (NFC), Global Positioning System (RFID), Wireless Fidelity (Wi-Fi), Fifth- Generation mobile networks (5G), Global Positioning System (GPS), and robotics [2].

It is susceptible to the straightforward physical phenomena and workings of the times before electricity was invented; it is both simple to create and sustain. In many manufacturing subsectors, karakuri kaizen is implemented through the utilization of very complicated mechanical systems that make use of simple phenomena. Gravity, magnetic, friction, force, lever, weight-shift, gears, spring, pulley, roller, water jets, seesaws, counterweights, dampers for energy dissipation, light reflection and refraction, gas or liquid flow, etc. are a few examples of mechanisms used in karakuri implementation [3]. These mechanisms are all applied to transform the initial input into a different kind of movement. (Besiroglu 2017 recalled them all to the following forces' terms: force of gravity, clamping force, radial force, tensile force, spring force, hydropower)

2. RESEARCH METHODOLOGY

Research from [4] develop a framework to design a Serious simulation game in 7 steps. Of the several methods most widely used in developing a serious simulation game, this research uses two methods, namely the Triadic Game Design game design philosophy [5]and the game design framework [4]. First, analyzing the elements of the real system. Second, defining the overall aim of the game. Third deciding which elements of reality underpin the real-world problem as well as the objective of the game. Forth defining how these elements should be represented within the game. Fifth defining how the player can use and act upon these elements within the game. Sixth testing and redefining the game design. Seventh, designing a game session from debriefing and additional research tools to provide feedback both to the players as well as the researchers. Triadic Game Design (TGD), is a philosophy of three elements that must be present in a game with serious goals, namely reality, meaning and the nature of play. These three elements are inherently connected and interdependent on each other. There is a balance between these three elements and must be balanced in designing the game. If the elements in it are not balanced, then the game's objectives will not be achieved.

Serious simulation games are a learning tool that is free from doubts about failure and can change thinking models [6]. This can be seen in Figure 2 which shows that the simulation provides feedback from the real world model so that it can build a mental model which will ultimately influence the decision making system.

At the philosophical level of game science, serious simulation games can be used as research tools, to support the analysis and design of complex systems. Serious simulation games are useful in representing dynamic systems and situations, including social or human factors and represent a tool for studying and discussing system complexity and behavior.

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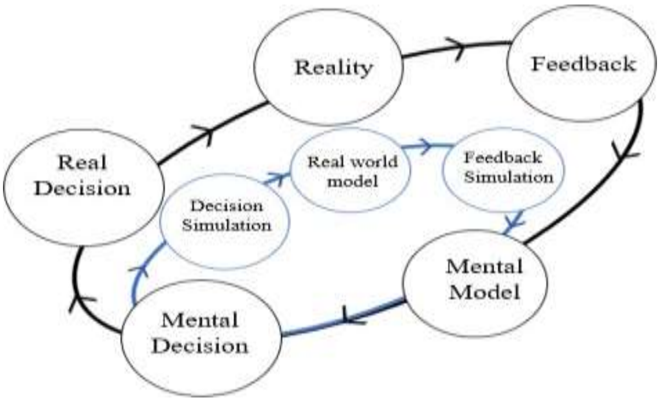

Figure 2. The role of simulation in the learning cycle (Source : Hidayatno et al., 2018)

3. RESULT AND DISCUSSION

The designed game expects players to reach the creating point which is the fifth level of the Revised Bloom Taxonomy [7] as shown in Figure 3.

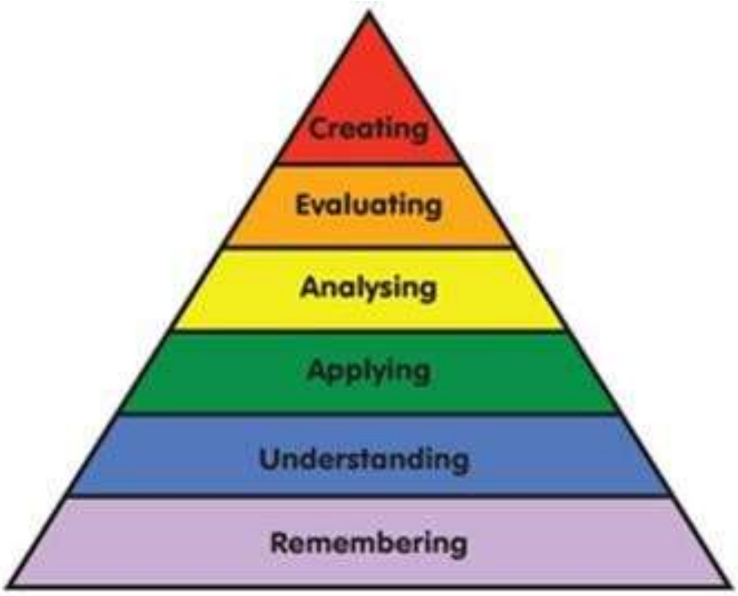

Figure 3. Revised Bloom Taxonomy (Source : Anderson & Krathwol, 2001)

This activity starts with how players can understand the condition of abilities during the game and then applying strategies that are thought to improve the situation. After carrying out the strategy the player receives feedback from the strategy and can analyze the difference between the expectations to be achieved and the events that occur. Then, players can evaluate the flow of strategy and feedback so they can predict events and make decisions. Finally, the player can create a new design for further development.

3.1 Learning - Game Mechanics from the Game

To translate learning outputs into the form of required learning mechanisms, the framework. In simple terms, the LM-GM model has two axes [8]. The middle column shows the abilities at the level of thinking according to the revised Bloom taxonomy [7] while on the right side are the learning points at that level of thinking. Meanwhile, on the left side is game mechanics, namely how to translate these learning points in the game.

Table 1. Learning and Game Mechanics Framework

Game Mechanics		Thinking Skills	Learning Mechanics	
Design/Editing Infinte Game play Ownership Protégé Effect	Status Strategy/Planning Tiles/Grids	Creating	Accountability Ownership Planning Responsibility	
Action Points Assessment Collaboration Communal Discovery Resource Management	Game Turns Pareto optimal Rewards/Penalties Urgent Optimism	Evaluating	Assessment Collaboration Hypothesis Incentive	Motivation Reflect/Discuss
Feedback Meta-game Realism		Analysing	Analyse Identify Experimentation Observations Feedback Shadowing	
Capture/Elimination Competition Cooperation Movement	Progession Selecting/Collecting Simulate/Response Time Pressure	Applying	Action/Task Competition Cooperation Demonstrationg	Imitation Simulation
Appointment Cascading Information Questions and Answes	Role-play Tutorial	Understanding	Objectify Tutorial Participation Questions & Answers	
Cut scenes/Story Tokens Virality	Behavioural Momentum Pavlovian Interactions Goods/Informations	Retention	Discover Guidance Explore Instruction	Generalisation Repetition

(Source: Anderson & Krathwol, 2001)

3.2 Karakuri for Kaizen

In many manufacturing subsectors, kaizen is applied to complex mechanical systems that still make use of everyday events. A few examples of the mechanisms used in karakuri implementation are gravity force, magnetic force, friction force, lever mechanisms, weight- shift mechanisms, gears, spring mechanisms, pulley mechanisms, roller mechanisms, water jets, seesaws, counterweights, dampers for energy dissipation, light reflection and refraction, gas or liquid flow, etc [3]. All of these force types are applied to change the initial input into a different kind of movement. [9] reminded them all of the terms for the following forces: force of gravity, clamping force, radial force, tensile force, spring force, hydropower. It is not totally accurate to characterize karakuri as energy-free motion as [10] did. Karakuri technology, as noted by [11] and [12], uses elemental physical contrivances in conjunction with natural energy.

3.3 Basic of Karakuri Mechanism

There are some basic mechanisms of Karakuri [13] that can be used to apply the Karakuri concept. The way it works is based on physical movement with the basis of applying force at one point which can provide a chain reaction to surrounding objects. Hal tersebut antara lain:

3.3.1 Lever

One of the first devices that people have created is the lever. A lever is a basic mechanism that has the ability to multiply, divide, and alter the direction of mechanical force. Because practically every tool and machine has a mechanism, levers are often overlooked.

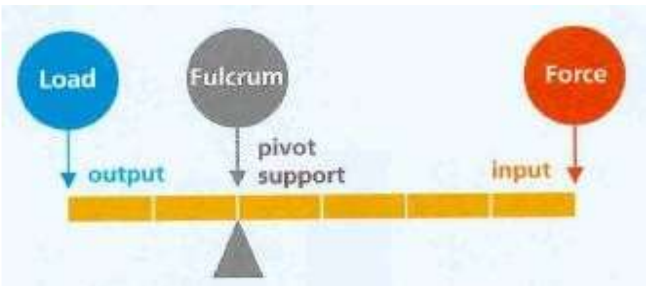

Figure 4. Example of Lever (Source : Keisuke, 2010)

3.3.2 Cam

A cam is a device that moves or rotates disks of different shapes to alter the rhythm or direction in which pieces move along its contour. It is utilized in various machines to create complex movements with fewer parts by simply altering the disk's form.

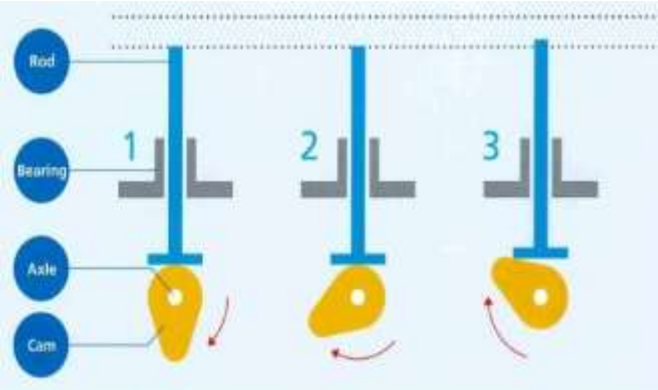

Figure 5. Example of Cam (Source : Keisuke, 2010)

3.3.3 Crank

A crank is a device that enables the conversion of a rotation into a linear motion or vice versa using an axle with a hook form. A crank and linkage can be used to create an extremely complex motion.

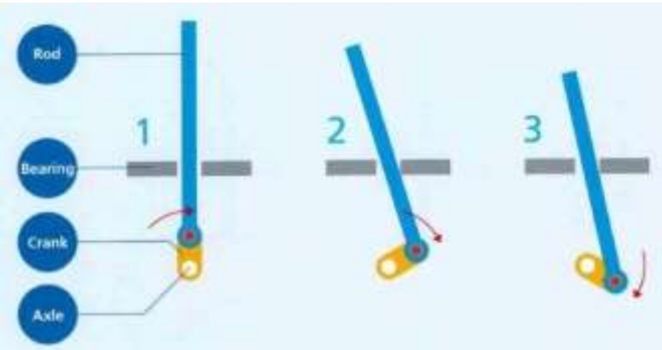

Figure 5. Example of Crank (Source : Keisuke, 2010)

3.3.4 Gear

A gear is a mechanism found in items like bicycles and watches. It has the ability to alter force, speed, and rotational direction. In order to apply force across a distance, gears might mesh with chains or belts in addition to other gears.

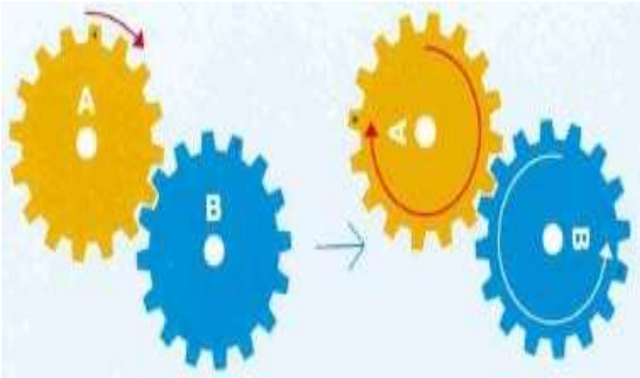

Figure 5. Example of Gear (Source : Keisuke, 2010)

The four basic movements above can be developed or combined to create movements according to your needs. Basically this can be achieved just by using shaped paper for a small experiment. However, it does not rule out the possibility of being made using stronger materials in accordance with industrial needs.

4. Game Mechanic Determination

In determining Game Mechanics (GM), it is necessary to first determine the learning mechanics (LM) of the game. Because players in this game are expected to not only increase their knowledge but are expected to be able to create automation with Kararuki, the expected Taxonomy Bloom level is at level 6, namely creating. So from determining this level, learning targets can be created and game mechanics determined as follows:

Table 2. LM-GM of the Game

Actor	Rule and responsibility	Specification	Output	Game Mechanics	Learning Mechanics
Kaizen Team	Production flow	Material Handling	On time goods	Design/ Editing Infinte Game play, Status Strategy/Planning, Ownership	Accountability Ownership, Planning, Responsibility

The actors in this game are the Kaizen Team whose task is to expedite the movement of goods in the production process with the target of arriving the product on time. The game mechanics provided are that players are expected to be able to design the construction of the karakuri system to ensure a smooth process so that they can also learn a sense of responsibility for the results of the designs that have been made.

Next, a translation of LN-GM to Game was made. In accordance with the solution offered to Karakuri, it is low cost and does not require energy from fuel, this is the actor's output target. Of course, the target is that the goods sent will arrive on time to the next production station. Determination of elements is carried out in accordance with learning needs, namely the presence of a production flow board to make it easier for actors to understand the flow and also the basic components of the karakuri that has been made so that they can immediately run the simulation and get feedback from the construction changes made.

Table 3. Translation of LM-GM to The Game

Actor	Decision Variables	The interests/outputs of each actor	Thinking Ability	Game Mechanics	Learning Mechanics	Input in game elements	Translation of game elements	Game mechanic translation
Kaizen Team	Moving goods without a fuel engine	Material handling without fuel	Creating	Design/Editing Infinte Game play, Status Strategy/Planning, Ownership	Accountability Ownership, Planning, Responsibility	Current construction of goods movement	Production flow board and four karakuri components	Simulate the application of karakuri with the available scenarios
	Transport time does not increase	Material handling went smoothly				Items to be moved	Material components	

The planned production flow is displayed in the form of a board which is divided into several levels of difficulty and scenario cards. The base level has cases that can be fixed with a Lever mechanism. Then it will become increasingly difficult until you need to combine the use of the Karakuri Mechanism. The implementation of Karakuri is planned by building Karakuri components so that improvements to the desired Karakuri mechanism can be felt. Of course, in the game there will be an element of money that represents Karakuri's investment. The player's role is planned to achieve production targets on time and wisely invest in improvements using the Karakuri mechanism.

5. CONCLUSION

Basically, this research tries to adapt the Karakuri simulation to the context of material movement based on basic Karakuri standards. The learning target of the designed game is at level 6 of Bloom's taxonomy with the context of serious simulation games which are divided into learning mechanics and game mechanics. The players in this game are a kaizen team whose target is to improve material handling by considering Karakuri. This is based on a decision-making variable that avoids the use of fuel but produces material movement times that are no slower than before.

6. FUTURE RESEARCH

Research needs to be carried out to determine additional elements and scenarios from the industrial sector to determine the game flow in accordance with the SSG creation framework so that further game experiment iterations can be carried out.

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