COMPARISON OF GAME DEVELOPMENT FRAMEWORK AND MODEL FOR PARKINSON DISEASE REHABILITATION

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Abstract. Parkinson's disease patients are consulted to frequently exercise and undergo physiotherapy to reduce the progression rate of their disease. However, this can be a problem when the caretakers that bring them to the rehabilitation center are unavailable due to work or other related issues. The cost to go to rehabilitation is also expensive. Therefore, patients tend to exercise at home where there is no one to monitor except for their caretakers. This can lead to problems in evaluating the progress of the patient's rehabilitation. The solution for this issue is to develop a game-based rehabilitation. This paper aims to investigate the element for a game-based Parkinson's disease rehabilitation. Then, the elements are used to develop the preliminary framework which later can be used to develop game-based exercise. A total of eight frameworks and models are studied to identify the core elements. The seven elements which are commonly used are game design, game mechanics, game engine, patient, therapist, results, and database.

Keywords: Game Development Framework, Serious Games, Parkinson

1 INTRODUCTION

Past research has used rehabilitation frameworks to serve the underserved community in Malaysia. There are games to rehabilitate the sharpness of sensory in blind and deaf patients; rehabilitate autism, stroke, and dementia patients; and even rehabilitate Alzheimer's patients (Avola et al., 2018; Ayed et al., 2019; Dewald et al., 2016; Ienca et al., 2017; Yap et al., 2019). Research has also found that underserved community in Malaysia prefer to do activities within the community support group than go to the rehabilitation center. One of the research projects mentions that one-third of its community sample prefers to stay at home and do self-rehabilitation, even though 31% of

those community members end up not doing the correct rehabilitation activity (Latif et al., 2020).

Despite this, underserved community members trust their community support group more in terms of activity that mimics the rehabilitative effects of rehabilitation because the community group provides activities that sustain the rehabilitation environment and help its underserved members to improve motor skills; social and language development; vocational skills; self-management skill; creative skill; music therapy; as well as sports (Elor et al., 2018; Latif et al., 2020). This means that rehabilitation framework research can be done through the participation and sampling of the underserved community members such as PD patients within its community support group.

Based on Malaysia's 2020 report on technological trend and usage, more than 80% of the Malaysian population has experience in using computers, phones, and other devices in their daily lives (Department of Statistics Malaysia, 2020a). This means that the general Malaysian population has basic technological usage and engagement and has a high probability to adapt well to a game-based technology for rehabilitation. This is further supported by many other types of research in the computing, social, and medical field (Fincham, 2013; Latif et al., 2020; Muñoz et al., 2019). Studies related to underserved communities have resulted in both acceptance and rejection of technology due to known and informed consent; data privacy, confidentiality, and sharing conventions; unwanted social implication and attention; and also legal implications (Nebeker et al., 2017). Underserved individuals usually defer to the support and recommendations of their community support group. Hence, developers can review both individual and group Technology Acceptance directly through the community support group. For underserved communities with a high rate of legal problems, developers are advised to prepare a full informed consent document with legal implications covering the issue. However, if the underserved community is willing and encourages its members to participate, the development can be proceeded with and without informed consent documents.

However, the success of the game-based rehabilitation depends on its clear development features (Herrlich et al., 2017). There are currently a scanty number of PD rehabilitation framework with clear game development features in Malaysia. Harzhing's Publish or Perish tools is used to extract papers on game development in Malaysia between the year 2016 to 2020. The keywords used are "Malaysia", "Framework", "Game Design", and "Parkinson's Rehabilitation". A total of 922 papers were extracted and filtered according to research that focuses on the game development framework and its features. The filter resulted in only 183 papers highlighting the game development framework and its features. This means that only 19.85% of the research focus on PD rehabilitation frameworks in Malaysia with game development features between 2016 to 2020. Therefore, there is a gap in understanding the framework elements and mapping its features.

2 EXISTING FRAMEWORK AND MODEL FOR REHABILITATION USING VARIOUS TECHNOLOGIES

2.1 Introduction

A suitable framework is required to assist in designing exergames for PD patients. Currently, there is a limited framework available that focuses on rehabilitation for PD patients. Some samples of past framework are put up as sample of framework discussion. One of the structures which focuses on using Virtual Reality (VR) technology to rehabilitate patients.

2.2 Framework for rehabilitation using Wiimote

The framework in Figure 1 shows the framework for rehabilitation using Wiimote which uses virtual reality as tools that can help to rehabilitate PD patient. Based on Figure 1, it is divided into four processes where the human will be connected to a specific remote, the patient will play the exergames, data will be transmitted to a clinician online, and finally, the clinician can view or keep track of progress from the clinician terminal. Basically, four elements have been identified for the framework which includes patient, game design, database and physiotherapist or clinician. Each of these elements are critical in the development and assessment of the patient.

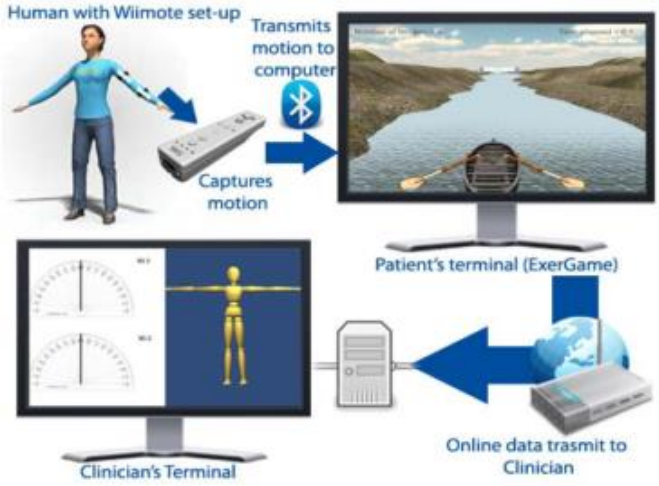

Fig. 1. Framework for rehabilitation using Wiimote (I. Paraskevopoulos & Tsekleves, 2013)

2.3 Framework for gait-based recognition using Kinect

Another framework available for rehabilitating PD patient is shown in Figure 2. Figure 2 shows the framework for gait-based recognition using Kinect. It focuses solely on gait recognition and does not cater to other types of rehabilitation.

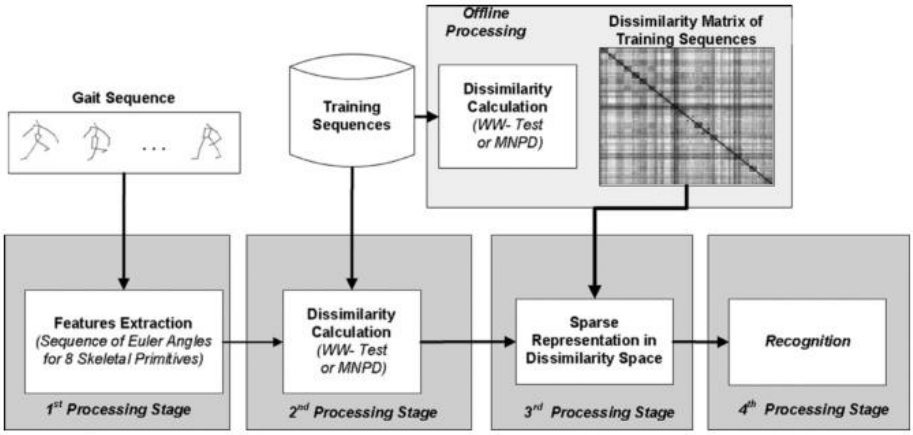

Fig. *2*. Framework for gait-based recognition using Kinect (Kastaniotis et al., 2015)

The framework is divided into four stages which include features extraction, dissimilarity calculation, sparse representation in dissimilarity space and recognition. In the first stage, which features extraction, the gait sequence of the patient is identified, and their walking pattern will be extracted. In the second stage, dissimilarity calculation is conducted to identify differences with a normal walking pattern. In the third stage, a dissimilarity matrix of the training sequence will be generated to fill the gap of the walking pattern of the PD patient. Finally, the last stage, which is the fourth stage, is recognition. Based on framework on figure 2, this framework focuses only on gait for PD patient and its main function is to compare gait – through calculations between a PD patient and a healthy person. Hence, there is limited focus on elements for game development.

2.4 Framework for game-based cognitive rehabilitation

Another framework that focuses on rehabilitation through gaming is shown in Figure 3. It is divided into four components: condition, process, activity, and output. In the first stage, the condition of the patient is being identified. In the next stage, with the help from the therapist, rehabilitation objectives have been set and game characteristics are being adopted to cater to the objectives that are set. The next stage involves the activity of playing the custom games regularly. Three main characteristics

under the game cycle will affect the patient at this stage which are system feedback, user judgement and user behavior.

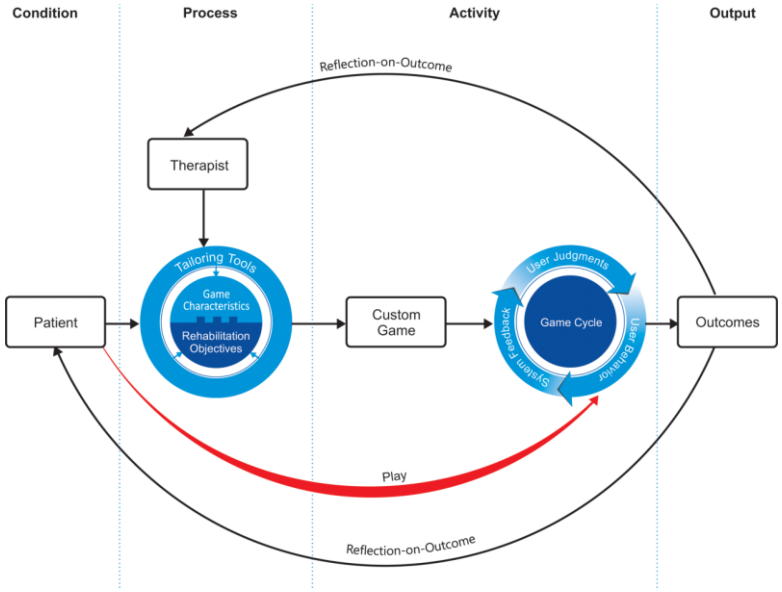

Fig. *3*. Framework for game-based cognitive rehabilitation (Elaklouk, 2014)

Finally, in the outcome stage, the result is generated, and it can be reflected on the patient itself. The framework in figure 3 manages to identify the best elements for game-based rehabilitation. Since it is for cognitive rehabilitation, the focus is on games that involve thinking such as solving puzzles or memorization.

2.5 Framework for game design for PD patient and patient with stroke

Figure 4 provides another framework which can be used for designing games for PD patient as well as patient with stroke. It is divided into four major elements which are experimental accuracy study, games for stroke and PD, evaluation and results and guidelines. For the experimental accuracy study, a comparative study between two systems is conducted which are Wiimote MoCap to Vicon System. The next stage involves games for stroke and PD. Few elements involve at this stage includes 3D asset collection and import to game engine, games design and games engine script. Afterwards, the next stage is the pilot testing which involves pilot testing of games with patients. The final stage is the results and game design guidelines which involves validation of the results.

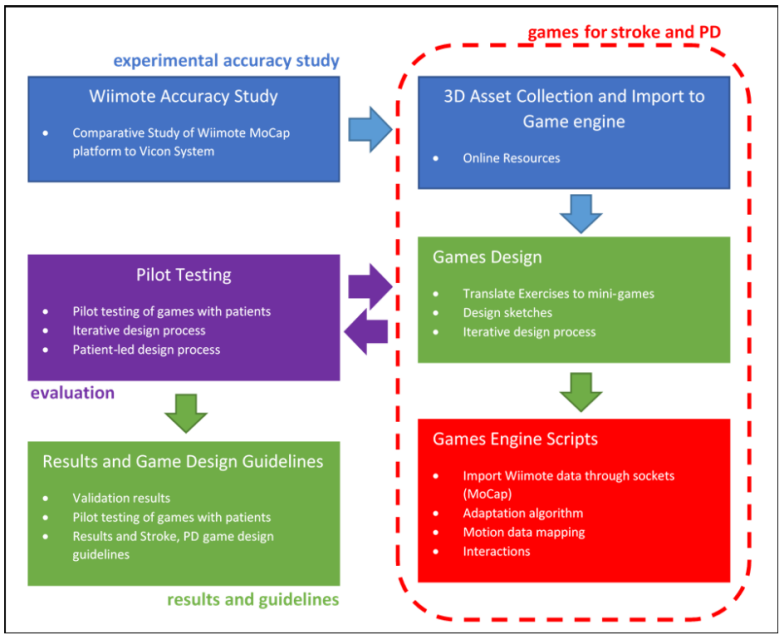

Fig. *4*. Framework for game design for PD patient and patient with stroke (I. T. Paraskevopoulos, 2014)

This framework is one of the best in terms of game design for PD patients and patient with stroke. Elements that should be highlighted are the game engine, game design and game engine scripts. Unfortunately, the framework lacks input from patient at the early stage and experts from healthcare to ensure that the game that have been developed from this framework can be used to gain maximum efficacy.

2.6 Framework for development of serious games for motor skills rehabilitation

Figure 5 provides another framework for the development of serious games for motor skills rehabilitation. It consists of five layers which are user layer, input/output layer, game engine layer, database layer and web application layer. The user layer is composed of the patient and the therapist. The Input/output layer is responsible to interact with the user. The game engine is responsible for the game logic. The database layer is responsible for storing data such as patient's data and the web application layer consumes data stored on the database to provide insights and report patient's progress. This framework manages to accommodate each element for a development of a serious game but not in terms of game design.

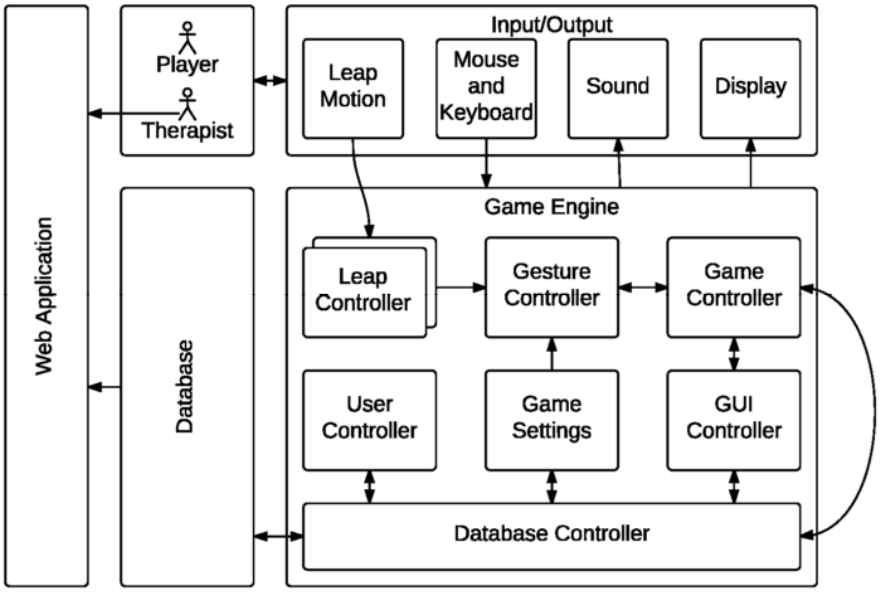

Fig. 5. Framework for development of serious games for motor skills rehabilitation (Foletto et al., 2017)

Basically, the framework focuses on the development process but few elements should be added especially in terms of game design since the objective of the framework is clear – which is to develop serious games (games with specific purpose).

2.7 Architecture and game engine framework for serious games in health rehabilitation

Figure 6 shows the architecture as well as the game engine framework for serious games in health rehabilitation. The main modules of the game engine framework are game engine, game database, social networking, competition, user management and profiling, and logging and monitoring. Game Engine represents the most generic component of the game logic. Game Database is the repository of all the games. Social networking is a mechanism for a patient to group together in a social network. Competition is responsible for creating the interaction mechanism of competition. User management and profiling are managing user profile. Logging and monitoring are the monitor progress of each patient.

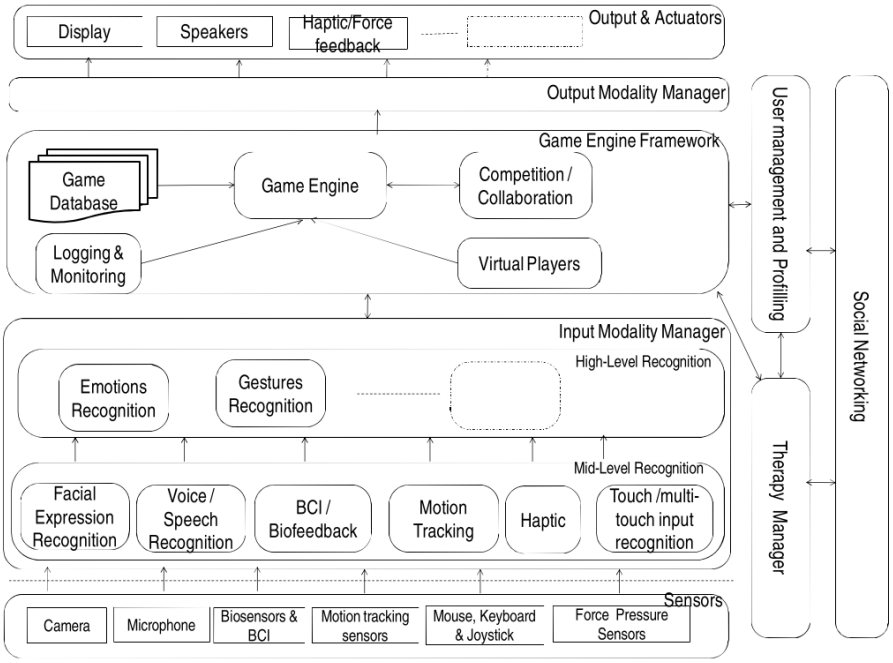

Fig. *6*. Architecture and game engine framework for serious games in health rehabilitation (P. A. Rego, Moreira, & Reis, 2014)

This framework focuses more on the game engine while integrating different types of input or output methods which includes sensors and other devices.

2.8 Framework for serious games as a Structural Class Diagram for learning

Figure 7 shows a conceptual framework for serious games as a Structural Class Diagram for learning. It consists of nine elements which include capability, instructional content, intended learning outcome, game attributes, learning activity, game mechanics, games genre, game achievement and reflection. This framework focuses on the learning outcome. However, for rehabilitation purposes which focuses on teaching patient to carry out simple daily activities, this framework can be applied.

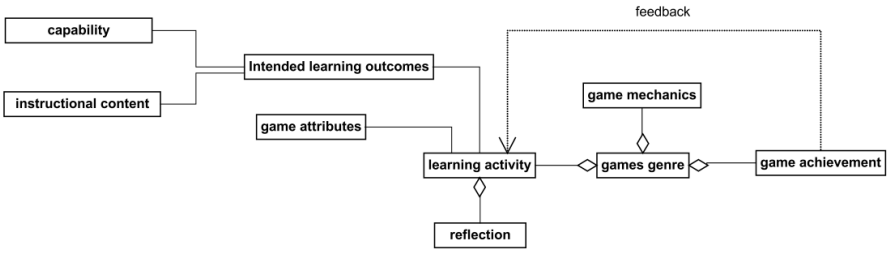

Fig. 7. Framework for serious games as a Structural Class Diagram for learning (Yusoff et al., 2009)

For example, if a pilot spends few hours playing aviation computer games, they can perform better in flights (Yusoff et al., 2009). Although this framework is more towards structural class diagram, it may be considered since some of the elements are important for allowing patient to relearn movement. Some of the important elements that can be considered for future development of framework (later known as MyPard) are game mechanics and game attributes.

2.9 Serious game design assessment framework

Figure 8 shows a serious game design assessment framework. This framework focuses solely on the purpose of the game and its impact. It is important that the game's purpose acts as the driving force for the player to carry out repetitive actions and achieve the objectives of playing the game such as learning, rehabilitation or even reducing weight.

Fig. 8. Serious game design assessment framework (Yusoff et al., 2009)

Serious game design assessment framework consists of six important elements which are fiction or narrative, aesthetic graphics, mechanic, purpose, coherence, framing and content. Description for each component is purpose, content, game mechanics, fiction narrative, aesthetics, graphics, framing, and coherence. Purpose refers to a game's purpose to impact its players. It depends on the objectives of the game. Content refers to information, fact and data offered and used in the game. Game mechanics refer to methods invoked by agents for interacting with the game world. Fiction and narrative refer to creating fictional space and how it relates to the game purpose. Aesthetics and graphics refer to audio-visual language, conceptualized, chosen and developed by the designers for the visualization involved in the game. Framing refers to the playing literacy of the game. Coherence refers to ensuring that all elements are related to each other. For this framework, game mechanics is being given focus since it clearly states that within the game mechanics, learning curve, rules, goals and rewards can encourage player to engage continuously with the game.

2.10 Findings

These are only a sample of past frameworks to understand the visualization of the framework. Preliminary observation shows that 7 elements stand out. Table 1 summarizes each framework that is available in developing and assesses serious games for rehabilitation and learning:

Table 1. Comparison between each framework

No.	Author	Framework Objective	Number of elements	Elements involve
1.	(I. Paraskevopoulos & Tsekleves, 2013)	Schematic diagram of a context using VR	4	Human with Wiimote setup, patients terminal, online data transmit to clinician, clinician terminal
2.	(Kastaniotis et al., 2015)	Gait based recognition using Kinect	4	Features extraction, dissimilarity calculation, sparse representation in dissimilarity space, recognition
3.	(Elaklouk, 2014)	Game-based cognitive rehabilitation	6	Patient, therapist, tailoring tools, custom game, game cycle, outcome
4.	(I. T. Paraskevopoulos, 2014)	Game design for PD patient and patient with stroke	6	Wiimote accuracy study, 3D asset collection and import to game engine, games design, games engine script, pilot testing,

				results and game design guidelines
5.	(Foletto et al., 2017)	Development of serious games for motor skills rehabilitation	5	Web application, player & therapist, input/output, game engine, database
6.	(P. A. Rego et al., 2014)	Serious games in health rehabilitation	8	Sensors, input modality manager, game engine framework, output modality manager, output & actuators, user management and profiling, therapy manager, social networking
7.	(Yusoff et al., 2009)	Serious games as a Structural Class Diagram for learning	9	Capability, instructional content, intended learning outcomes, game attributes, game mechanics, game game achievement, game genre, learning activity, reflection
8.	(Ricciardi et al., 2015)	Serious game design assessment	7	Purpose, content, game mechanics, fiction and narrative, aesthetics and graphics, framing, coherence

Based on the framework obtain and compared in previous table, these elements are crucial for a rehabilitation-based exergames:

Player/Patient: Refers to player or patient who plays the game. The objective of the game is to serve the player or patient.

Therapist/Clinician: Refers to another party who are in charge of monitoring the patient's progress and ensure their safety.

Game mechanic: Construct of rules or method designed for interaction of the game.

Game engine: Game engines are tools available for game designers to code and plan out a game quickly and easily without building one from the ground up. Some of the examples include Unity, HTML5, CRYENGINE and Torque.

Game design: Art of applying design and aesthetics to create a game for entertainment or for educational, exercise, or experimental purposes. Each game design might be different to suit the objectives of the game.

Database: Set of data held in a computer and can be viewed later. It can be viewed, accessed, and updated.

Results: Results is the one that keeps the player motivated to play since it will complement the objective of the game. It can be viewed as progress and can be use as benchmark to track achievement or progress.

3 MATRIX FOR FRAMEWORK

3.1 Comparison

Each framework has its own uniqueness since it caters to different objectives. Table 2 provides mapping for each framework and the elements involved.

Table 2. Matrix for each framework

No.	**Author**	**Framework Elements**							
		Player/Patient	Therapist/Clinician	Game Mechanic	Game Engine	Game Design	Database	Results	Others
1.	(I. Paraskevopoulos & Tsekleves, 2013)	/	/	/				/	/
2.	(Kastaniotis et al., 2015)	/		/			/	/	/
3.	(Elaklouk, 2014)	/	/	/		/		/	/
4.	(I. T. Paraskevopoulos, 2014)	/		/	/	/		/	/
5.	(Foletto et al., 2017)	/	/	/	/		/	/	/
6.	(P. A. Rego et al.,	/	/	/	/		/	/	/

	2014b)								
7.	(Yusoff et al., 2009)	/		/		/		/	/
8.	(Ricciardi et al., 2015)	/	/	/		/		/	/

3.2 Document Analysis

In order to fully map out and compare the most recent frameworks and their elements between the year 2016 to 2020, 183 documents were analyzed to map the game development framework features and elements. Out of all 183, 141 of those papers highlight clearly and specifically the element and its features. 30 documentations were chosen since they focus on game design and human computer interaction. Analysis was conducted using MAXQDA software. Findings are presented in table 3.

Table 3. Document analysis of each element.

No.	*Elements*	*Percentage (%)*
1.	Patient	83.33
2.	Therapist	53.33
3.	Game Engine	33.33
4.	Game Mechanics	70.00
5.	Game Design	73.33
6.	Result	83.33
7.	Database	70.00

4 SUMMARY

Based on the comparison table and document analysis provided in the earlier section of this paper, it is clear that these elements such as patient, therapist, game engine, game mechanics, game design, result and database are crucial. Patients are required because they are the main stakeholders that need rehabilitation. Therapists are the ones that plan types of rehabilitation and its scoring for the patient. Game related elements such as game engine, game mechanics, game design results and database are based on the feedback from therapist. Game designers need to plan and develop accordingly based on the input provided by therapists. Each of these elements must be included in the next stage of the research which is development of the game development framework.

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