Intelligent Environments 2020
C.A. Iglesias et al. (Eds.)

doi:10.3233/AISE200020

Automatic Generation of Customised Exergames for Home Rehabilitation Based on Physical Mobility Constraints and Key Performance Indicators

Cristian GÓMEZ-PORTES [a], David VALLEJO [a] [1], Ana I. MOLINA [a], Carmen LACAVE [a]

[a] *Faculty of Computer Science (University of Castilla-La Mancha), Paseo de la Universidad 4, 13071 Ciudad Real, Spain*

Abstract. Remote rehabilitation systems allow the supervision and monitoring of physical exercises by therapists without the need to move, temporally and spatially, the patients who perform them. The main advantage of this approach is the patient's increased autonomy and flexibility to carry out rehabilitation from home, especially in situations of lock-down and movement restrictions. In order to make the execution of repetitive exercises more dynamic and to motivate patients to perform them from home, in recent years gamification techniques, exergames, and serious games have been extensively used. In this context, and to increase the remote monitoring capabilities of therapists, this paper proposes the use of a language for the specification of exergames oriented to the definition, by therapists, of key performance indicators and mobility constraints adapted to the rehabilitation process of each patient. The sentences of this language can be processed by software, allowing the automatic generation of personalised games for rehabilitation. A case study describing an exergame for the upper limb rehabilitation of stroke patients is also presented.

Keywords. home rehabilitation, customised exergames, automatic code generation, key performance indicators

1. Introduction

The technological tools that support rehabilitation at home aims at increasing the autonomy of patients when performing physical rehabilitation exercises [19]. This increase in autonomy is a direct consequence of the elimination of temporal and spatial barriers, traditionally linked to the face-to-face and synchronous supervision of a therapist with respect to his/her patients [16]. This advantage is more than evident in situations such as that which, unfortunately, occurs in the current sanitary context, where there is physical confinement in a large part of the world. Even in countries with low-and middle-income [24], where access to clinicians capable of guiding the rehabilitation process is, more often than not, non-existent.

Home rehabilitation tools face the dual challenge of motivating patients to perform inherently repetitive exercises and to ensure an adequate synchronous remote supervision by therapists. [3].

The first challenge is not an easy one, since without the right motivation, a patient who does not feel obliged to have a therapist by his/her side could abandon the exercise routines if the artificial system is not capable of providing an adequate, real-time *feedback*. In this sense, in recent years a whole range of gamification techniques and serious games have been used, mainly aimed at turning an extremely repetitive task, such as physical rehabilitation, into a playful activity [15]. In essence, the patient is being rehabilitated while playing or feeling immersed in a virtual world in which he or she recreates real-world activities [11].

The second challenge brings up the need for home rehabilitation to be done in a safe environment and, at the same time, to ensure that the patient is properly monitored by the therapist. This supervision does not have to be synchronous. In fact, it is usually of an asynchronous nature which maintains a one-to-many relationship between therapist and patients. In this context, the use of metrics and indicators that the therapist can access at all times to know the level of progression of their patients and adapt the therapy to their dynamic and changing situation is especially relevant.

Ideally, the design and development of rehabilitation support tools should be carried out through a co-creative approach between clinicians, patients, and developers. In this way, in addition to involving all the agents in the rehabilitation process from its genesis, the chances of success of the use of technology in the medical field increase considerably. One of the dimensions to consider in this approach is the potential capacity of the therapists themselves to become content generators. This capacity refers to the use of technological tools by therapists, which are intuitive and easy to use. Also, it allows them to design their own rehabilitation exercises in a playful context and with the possibility of defining the metrics they will use to monitor their patients.

In this particular context, the present work proposes the use of a system capable of automatically generating personalised therapeutic exergames for home rehabilitation based on the design specified by the therapists themselves. A therapeutic exergame can be understood as a game that tries to recreate, through a virtual or augmented world, a physical exercise linked to a therapeutic treatment. Typically, some kind of device will be needed to recognise the patient's movements or to track his/her body parts. In our work, we make use of Azure Kinect DK[2].

The design of exergames by therapists, currently represented in a formal way by a language devised by the authors, makes possible both the inclusion of game mechanics, which the therapist can associate with physical rehabilitation exercises, and the definition of performance indicators, aimed at measuring the progress of each patient. The sentences of this language are interpreted by a processing module capable of generating exergames or therapeutic games. This proposal is framed within the concept of personalised rehabilitation, that is, it adopts a philosophy in which the therapist is provided with technological tools to treat each patient individually.

The rest of the work is structured as follows. Section 2 provides a description of related work within the scope of the proposal. Then, section 3 outlines the main sentences of the language that can be used to define exergames, discussing the most relevant char-

[2]https://azure.microsoft.com/en-us/services/kinect-dk/

acteristics of the language and with a special emphasis on the specification of mobility constraints and the use of performance indicators. Section 4 introduces a case study in which an exergame has been generated for home rehabilitation of stroke patients. Finally, section 5 presents the conclusions obtained and outlines a series of future lines of research.

2. Related work

In the last decade, technological advances have been incorporated into physical rehabilitation treatments with the aim of improving the quality of life of patients [19]. Among the most outstanding are solutions based on motion capture devices, such as Microsoft Kinect, whose use has led to a large number of systems employed as a complementary tool in rehabilitation therapies [28]. In fact, their effectiveness has been clearly demonstrated [17,6], which has meant the development of systems that provide rehabilitation from home [26,27,9].

However, the fact that technology enables remote rehabilitation does not mean that it is entirely effective. Taking this into account, there are several works in the literature that choose to apply gamification techniques and serious games to the rehabilitation process [22]. Indeed, this approach has been successfully studied in young people, adults, and elderly, providing clear evidence of its effectiveness [2,13,10,14].

Nevertheless, in the vast majority of cases, these games are usually aimed at patients with a specific pathology [1,4]. Consequently, their application in other contexts is limited, given that they have not been created considering patients with multiple limitations [18]. In addition, misuse or poor design of these games can aggravate existing patient injuries or even cause new ones [25]. In view of this situation, there are several proposals that try to solve this issue from two main points: the efficient and effective design of exergames, and the customisation and automatic generation of them.

The design of games for people with needs requires the consideration of obstacles or barriers that prevent their development effectively, safely, and adequately. For example, [15] proposes to design games considering the user's profile, as well as taking care of the quality of the game or its experience.

Similarly, [29] provides recommendations for an optimal exergame design, including user-centred design. On the other hand, [21] presents a methodology based on four phases focused on the creation of effective and safe exergames. Along these lines, [20] presents a set of guidelines and best practices for the design of exergames, among which highlight the use of daily activities such as rehabilitation exercises, games that provide fun experiences, or even those that promote competitiveness.

On the other hand, the second research line consists in providing tools to clinicians so that they can configure game parameters and thus reducing the cost and time involved in their production. Taking this into account, the literature covers general purpose solutions to facilitate the automatic generation of custom exergames. For example, [8] presents a system that integrates the concept of narrative story, where experts, without knowledge in information and communication technologies, adapt and customise training games for elderly and disabled people. In this line, [7] establishes a platform that offers a graphic tool for professionals to create games adapted to the needs of patients.

Finally, in [12], the authors describe a cooperative environment, in which clinical professionals record postures that are later reproduced by a 3D avatar to facilitate the patient the execution of rehabilitation exercises. Similarly, [5] presents an system which analyses a video of a rehabilitation exercise, generating a grammar used to produce animations applied to a 3D avatar for guiding patients to perform rehabilitation.

2.1. Our proposal

The study of previous works has served as a basis for defining the requirements of a home-based rehabilitation system based on exergames.

At the hardware support level, the use of a more up-to-date compact and low-cost device is proposed (Azure Kinect DK), which facilitates the installation of the system at home. This device allows to capture accurately patient movements, as well as saving the information generated during a therapy thanks to a cloud storage support.

Regarding the feedback received by the patient, it is considered appropriate that this can be immediate, by the application itself, or deferred, by the therapist. In addition to the indicators used by most systems of this type (based on the game score or the evaluation of the specialist), it is considered useful to include a more complete set of indicators, based on the time of completion of the exercise, as well as on the precision and range of movements performed.

A noteworthy and differentiating aspect of the proposal is the support to the specification and personalisation of the exercise routines, as well as the automatic generation of the exergames, which allows the system to adapt them considering the patient needs. This design and generation process can be carried out in the context of a co-creative methodological proposal between the different stakeholders involved in rehabilitation therapy.

3. Definition of personalised mobility constraints and key performance indicators

The created language for defining exergames is supported by the GL Transmission Format (glTF) specification [23], which represents an open standard devised for the efficient transmission and loading of 3D models and scenes into applications. glTF was the adopted standard because it involves an extensible format regarding the management and integration of 3D contents. With glTF, it is possible to describe scenes by means of JSON files, which can be extended as needed. Particularly, glTF extensions provide properties, semantics and formats to be included.

From a high-level point of view, exergames defined with this language are composed of 3 major components: *scene*, *actors*, and *gameplay*.

- *Scene*. This component represents the different exergame views, which can be understood as the different parts of a video game. 3 basic views are proposed for every exergame: i) *tutorial view*, which aims at playing an animation of the virtual avatar that shows how the exergame must be executed by the patient, ii) *participation view*, related to the situation where the patient actually plays and needs to reach a specific goal, and iii) *results view*, which provides real-time, visual feedback to the patient.
- *Actors*. This element is composed of exergame items that recreate some type of behaviour, such as those associated to 3D animations or transforms in the 3D space to translate/rotate objects. Every exergame contains, at least, one actor: the virtual avatar that replicates the patient's movements.

- *Gameplay*. This component refers to the actions that the patient must do to make a repetition of the exergame. The correct execution of the game dynamics will trigger, consequently, a sequence of actions, such as increasing the number of performed repetitions.

In this general context, this work focuses on the definition of mobility constraints by the therapist when performing exergames. It is quite common that, when a patient performs rehabilitation exercises, he/she tries to compensate the lack of mobility (or strength) in a joint with the use of other parts of his/her body. A specific example might be using the hip to compensate for the lack of mobility when performing a shoulder mobility exercise.

In this sense, listing 1 shows an example that contains three constraints associated with an exergame. Thus, the component *constraints* is a list of elements (actually dictionaries) that comprises the individual definition of each constraint. This definition is simple, since it is only necessary to specify the joint that the patient should not move when performing the exergame that is being defined (the component *joint*), along with the level of flexibility of compliance with the constraint (the component *flexibility*). The latter component contemplates the use of fuzzy logic to easily represent text labels associated with various degrees of constraint compliance: *low*, *medium*, and *high*, depending on the level of flexibility that the therapist desires to associate to each patient.

Listing 1: Example of definition that involves 3 constraints (component *constraints*) related to an exergame that recreates the movement *shoulder abduction*.

```
"constraints": [
    {
        "joint_name":  "hip-centre",
        "flexibility": "middle"
    },
    {
        "joint_name":  "spine",
        "flexibility": "low"
    },
    {
        "joint_name":  "shoulder-centre",
        "flexibility": "low"
    }
]
```

On the other hand, another of the aspects that we mainly deal with in this article is the definition of metrics or performance indicators, associated with the monitoring of patients and their level of improvement as rehabilitation progresses. Listing 2 shows the different types of indicators contemplated in the current definition of the language.

The first of these is called *performance*, and aims to measure how well the patient has performed the exergame. To do this, a *fuzzyfication* of the discrete score obtained by the patient is used. For example, if the obtained score is *low*, then the feedback visually given to the patient in the exergame will be that of the label *not bad*.

The second indicator, *rehabilitation_time*, serves to explicitly activate the measurement of the time the patient has needed to perform the exergame. Typically, the execution of an exergame will involve a certain number of repetitions associated with the exercise being modelled. In addition, this indicator allows the therapist to activate another internal metric associated with the time spent between consecutive repetitions (element *time_between_repetitions*). When the exergame code is automatically generated, it will be able to perform this measurement.

Listing 2: Example of definition that involves key performance indicators.

```
"metrics" : [
    {
        "kpi"    : "performance",
        "score"  : ["low", "average", "high"],
        "labels" : ["not bad", "good", "perfect"]

    },
    {
        "kpi" : "rehabilitation_time",
        "time_between_repetitions": true
    },
    {
        "kpi"    : "mobility",
        "joints" : ["shoulder-right"]
    }
 ]
```

Finally, the indicator *mobility* is designed so that the software that runs the exergame is able to monitor the level of mobility of a given set of joints. This set is specified by the component *joints*. From an internal point of view, the maximum level of amplitude recorded when performing an exergame (in degrees), considering one or several joints, will be stored.

4. Case study: exergame for the upper limb rehabilitation of stroke patients

This section offers a description of an exergame generated for the physical rehabilitation, from home, of patients affected by stroke.

4.1. Overview of the exergame definition language

The current version of the exergame definition language, previously introduced, allows the automatic generation of the game mechanics and the associated metrics, as an example, with respect to the exergame shown in Figure 1. This exercise is done in a virtual gym, with the aim of making the patient feel immersed in a sporty scenario and thus allowing him/her to abstract from the fact that he/she is actually doing the exercise in his/her own living room. The physical exercise itself consists of the execution of a lateral movement with the right arm, which is part of those routines aimed at improving the quality of life of patients affected by hemiparesis (loss of strength and dexterity) or hemiplegia (paralysis).

Before going deeper into the definition of mobility constraints and performance indicators, the main visual characteristics of the exergame are summarised next:

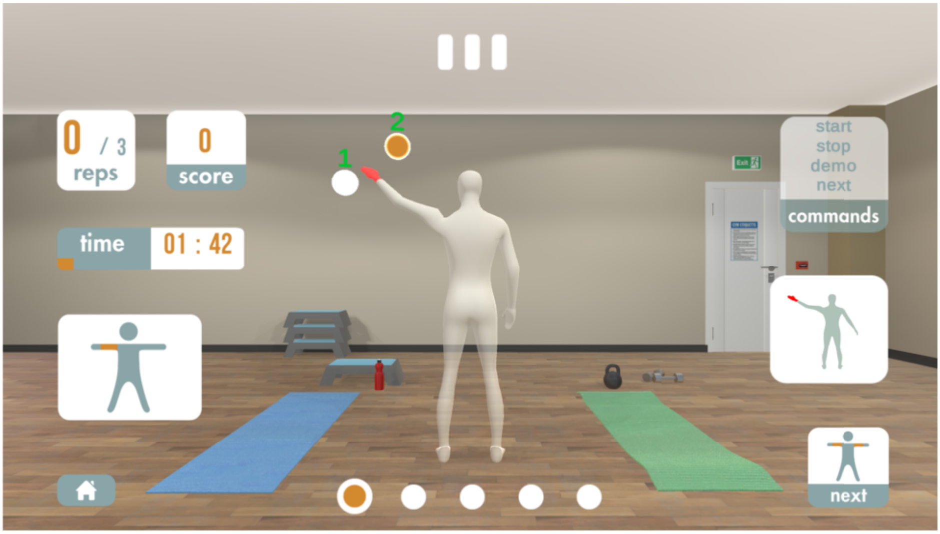

Figure 1. Visual aspect of the generated exergame. The visual feedback provided to the patient offers information about the current exercise, i.e., how it must be performed, the number of remaining repetitions, or the obtained scored. The interaction is carried out through voice commands.

1. The dominant interaction mechanism is voice-based in order for the patient to issue voice commands. This applies in the context of the entire system, including, for example, the exergame selection menu. At the top of the interface, a *boometer* is displayed, which serves to provide visual feedback to the patient when he/she speaks. Occasionally, stroke patients cannot use traditional interaction mechanisms, such as mouse and keyboard.
2. The components on the left contain information about the execution of the exergame, including the score as a basic gamification technique.
3. On the right side, a context component is shown that contains a textual description of the voice commands the patient can issue. One of them is the command *demo*. This command is used to play a visual animation for demonstrating the movement a patient must perform.
4. In the central part, the virtual avatar appears, which will recreate the patient's movements. Currently, the Azure Kinect DK device is used to obtain the tracking information of the patient's joints, which includes the rotations and positions in 3D space of those directly involved in the execution of the exergame.

With respect to the constraints defined for this exergame, those specified in listing 1, previously discussed in section 3, in relation to the exercise of *shoulder abduction*, apply. Thus, it is intended that the patient exercises the recovery of mobility in the right lateral part of his/her upper trunk, but avoiding compensation with the hip or upper trunk. Similarly, the performance indicators defined in listing 2 are activated for the exergame that makes up this case study.

4.2. Preliminary clinical evaluation

This exergame was presented to a group of 12 therapists of the General University Hospital of Ciudad Real (Spain), with the aim of knowing its applicability in a home rehabilitation context. The presentation consisted of a detailed description of the system, along with the exergame demonstration. The experts could also ask some doubt they had. The meeting lasted about 45 minutes. One week later, all therapists were invited to fill out a survey, 4 of whom responded offering very valuable information in order to continue with the project development regarding mobility constraints and performance indicators. The content of the questionnaire can be accessed online[3].

Among the results obtained from the experts' answers we highlight the most outstanding ones. Three of the four therapists agreed that the system would be very useful for i) adults affected by stroke, ii) adults who require another physical rehabilitation process, and iii) adolescents (Question 3). Interestingly, all therapists also pointed to children as potential users, due to the playful immersion offered by the gamification elements (Question 4). Furthermore, they indicated that the system may encourage patient autonomy and treatment adherence (Question 4).

All therapists agreed on obtaining i) the frequency with which patients perform exercises, ii) a video of the patient performing the exergame, and iii) the data generated during the rehabilitation process (Question 6). 3 out of 4 therapists were interested in monitoring the precision with which the exergames are performed (Question 6). The predominant response about the frequency for obtaining the patient information was *weekly*, which was answered by three of the four therapists (Question 7). Generally, specialists rated each item very positively, providing values 4 and 5 (Question 8). It is noteworthy that three of the four therapists would use the system and recommend it to other colleagues (Question 8). Regarding the representation of the scene, they also valued it positively, highlighting the decorative elements (Question 9). The therapists noted that the system i) is easy to use and understand; ii) it is designed like a video game; iii) it provides reinforcement and motivation; and iv) the motion capture device is small (Question 10). The weaknesses identified include those related to the appearance of the avatar and the cost of the device (Question 11). All four specialists have indicated that they wish to be informed of future enhancements of the system (Question 13).

Overall, the system was highly appreciated by the therapists and they showed interest in its use.

5. Conclusions and future work

The work presented in this article is framed within the context of physical rehabilitation at home, supported by a system capable of running exergames that are automatically generated from a set of sentences specified in an exergame definition language. This language, built on the glTF standard and supported by JSON, allows therapists (currently with the help of developers) to define the essential aspects of a therapeutic exergame, from the game mechanics, such as the interaction of the virtual avatar in the 3D world, to basic aspects of gamification, such as the score or the use of virtual messages that motivate the patient.

In this context, the particular contribution discussed in this article is the possibility of defining mobility constraints and performance indicators, both associated with the execution of an exergame by a patient. On the one hand, constraints make it possible to

[3]https://www.esi.uclm.es/www/dvallejo/WISHWell2020/Questionnaire.pdf

explicitly establish which parts of the body a patient should not move when carrying out rehabilitation. On the other hand, the performance indicators are aimed at monitoring the patient's skill in an exergame and his/her level of improvement as the rehabilitation process progresses. The integrated language statements to model these aspects with glTF enable automatic code generation and integration into the final executable file.

The carried out experiments are related to a case study of exergame for the rehabilitation of patients affected by stroke. The associated software prototype makes use of the Azure Kinect DK device to track the patient's skeleton, so it is not necessary to use wearable devices. This decision was made to promote rehabilitation at home and to increase flexibility when a patient performs exergames. This software prototype was presented to a group of 12 therapists from the General University Hospital of Ciudad Real (Spain), 4 of whom responded to an online survey about the proposed system. This preliminary evaluation by clinical professionals allows us to reach positive conclusions in terms of met clinical needs and functional capacity offered by the proposed system.

Although the results are satisfactory and promising, their validity is limited by two factors: the very small number of specialists who have participated in the evaluation, and the lack of participation of real patients. This is why we are in touch with the Association of Cerebral Palsy patients of Ciudad Real (Spain), in order to perform a more complete evaluation of the system in the near future.

Other future work is oriented towards the automatic generation of exergames that are more related to real-world actions, particularly in people affected by a stroke, such as the simple act of putting a cup in the mouth and leaving it on the table, placing virtual utensils in a virtual kitchen, or simulating food shopping in a supermarket.

References

[1] Bonnechère, B., Jansen, B., Haack, I., Omelina, L., Feipel, V., Jan, S. V. S., & Pandolfo, M. (2018), "Automated functional upper limb evaluation of patients with Friedreich ataxia using serious games rehabilitation exercises", Journal of neuroengineering and rehabilitation, 15(1), 87.

[2] Corona, F., Chiuri, R. M., Filocamo, G., Foa, M., Lanzi, P. L., Lopopolo, A., & Petaccia, A. (2018), "Serious games for wrist rehabilitation in juvenile idiopathic arthritis", In 2018 IEEE Games, Entertainment, Media Conference (GEM) (pp. 35-42), IEEE.

[3] Chua, K.S.G., Kuah, C., and Wee K. (2017), "Innovating With Rehabilitation Technology in the Real World: Promises, Potentials, and Perspectives", American journal of physical medicine & rehabilitation, 96(10):150-156.

[4] Eichinger, F. L. F., Soares, A. V., Noveletto, F., Sagawa Júnior, Y., Bertemes Filho, P., & Domenech, S. C. (2020), "Serious game for locomotor rehabilitation of hemiparetic stroke patients", Fisioterapia em Movimento, 33.

[5] Fernandez-Cervantes, V., Neubauer, N., Hunter, B., Stroulia, E., & Liu, L. (2018), "VirtualGym: A kinect-based system for seniors exercising at home", Entertainment Computing, 27, 60-72.

[6] Da Gama, A., Fallavollita, P., Teichrieb, V., & Navab, N. (2015), "Motor rehabilitation using Kinect: a systematic review", Games for health journal, 4(2), 123-135.

[7] González, C. S., Toledo, P., Padrón, M., Santos, E., & Cairos, M. (2013), "TANGO: H: creating active educational games for hospitalized children", In Management Intelligent Systems (pp. 135-142), Springer, Heidelberg.

[8] Hardy, S., Dutz, T., Wiemeyer, J., Göbel, S., & Steinmetz, R. (2015), "Framework for personalized and adaptive game-based training programs in health sport", Multimedia Tools and Applications, 74(14), 5289-5311.

[9] Haas, D., Phommahavong, S., Yu, J., Krüger-Ziolek, S., Möller, K., & Kretschmer, J. (2015) "Kinect based physiotherapy system for home use", Current Directions in Biomedical Engineering, 1(1), 180-183.

[10] Katajapuu, N., Luimula, M., Theng, Y. L., Pham, T. P., Li, J., Pyae, A., & Sato, K. (2017), “Benefits of exergame exercise on physical functioning of elderly people”, In 2017 8th IEEE International Conference on Cognitive Infocommunications (CogInfoCom) (pp. 000085-000090), IEEE.
[11] Lee, S., Kim, W., Park, T., and Peng, W. (2017), “The psychological effects of playing exergames: A systematic review”, Cyberpsychology, Behavior, and Social Networking, 20(9):513-532.
[12] Li, B., Maxwell, M., Leightley, D., Lindsay, A., Johnson, W., & Ruck, A. (2014), “Development of exergame-based virtual trainer for physical therapy using kinect”, In Games for Health 2014 (pp. 79-88), Springer Vieweg, Wiesbaden.
[13] Madeira, R. N., Antunes, A., Postolache, O., & Correia, N. (2017), “Serious… ly! Just Kidding in Personalised Therapy Through Natural Interactions with Games”, In International Conference on Advances in Computer Entertainment (pp. 726-745), Springer, Cham.
[14] Matallaoui, A., Koivisto, J., Hamari, J., & Zarnekow, R. (2017), “How effective is “exergamification”? A systematic review on the effectiveness of gamification features in exergames”, In Proceedings of the 50th Hawaii International Conference on System Sciences (pp. 3316-3325).
[15] S. McCallum (2012), “Gamification and serious games for personalized health”, Stud Health Technol Inform, 177(2012):85-96.
[16] Morales-Vidal, S. and Ruland. S. (2013), “Telemedicine in stroke care and rehabilitation,” Topics in stroke rehabilitation, 20(2):101-107.
[17] Mousavi Hondori, H., & Khademi, M. (2014), “A review on technical and clinical impact of microsoft kinect on physical therapy and rehabilitation”, Journal of medical engineering (pp. 1-16).
[18] Omelina, L., Jansen, B., Bonnechère, B., Van Sint Jan, S., & Cornelis, J. (2012), “Serious games for physical rehabilitation: designing highly configurable and adaptable games”, In Proceedings of the 9th International Conference on Disability, Virtual Reality & Associated Technologies (pp. 195-201).
[19] O’Sullivan, S.B., Schmitz, T.J., and Fulk, G. (2019), “Physical rehabilitation”, *F.A. Davis Company*.
[20] Paraskevopoulos, I. T., Tsekleves, E., Craig, C., Whyatt, C., & Cosmas, J. (2014), “Design guidelines for developing customised serious games for Parkinson’s Disease rehabilitation using bespoke game sensors”, Entertainment Computing, 5(4), 413-424.
[21] Pirovano, M., Surer, E., Mainetti, R., Lanzi, P. L., & Borghese, N. A. (2016), “Exergaming and rehabilitation: A methodology for the design of effective and safe therapeutic exergames”, Entertainment Computing, 14, 55-65.
[22] Proença, J. P., Quaresma, C., & Vieira, P. (2018), “Serious games for upper limb rehabilitation: a systematic review”, Disability and Rehabilitation: Assistive Technology, 13(1), 95-100.
[23] Robinet, F., Arnaud, R., Parisi, T., and Cozzi, P. (2014), “gltf: Designing an open-standard runtime asset format”, GPU Pro, vol. 5, pp. 375-392.
[24] Semrau, M., Evans-Lacko, S., Alem, A., et al. (2015), “Strengthening mental health systems in low-and middle-income countries: the Emerald programme”, BMC Medicine, 13(1):79-85.
[25] Sparks, D. A., Coughlin, L. M., & Chase, D. M. (2011), “Did too much Wii cause your patient’s injury? Motion-controlled game consoles like Wii may be used to play virtual sports, but the injuries associated with them are real. Here’s what to watch for–and a handy table linking specific games to particular injuries”, Journal of family practice, 60(7), 404-410.
[26] Su, C. J., Chiang, C. Y., & Huang, J. Y. (2014), “Kinect-enabled home-based rehabilitation system using Dynamic Time Warping and fuzzy logic”, Applied Soft Computing, 22, 652-666.
[27] Venugopalan, J., Cheng, C., Stokes, T. H., & Wang, M. D. (2013), “Kinect-based rehabilitation system for patients with traumatic brain injury”, In 2013 35th annual international conference of the ieee engineering in medicine and biology society (embc) (pp. 4625-4628), IEEE.
[28] Webster, D., & Celik, O. (2014), “Systematic review of Kinect applications in elderly care and stroke rehabilitation”, Journal of neuroengineering and rehabilitation, 11(1), 108.
[29] Wiemeyer, J., Deutsch, J., Malone, L. A., Rowland, J. L., Swartz, M. C., Xiong, J., & Zhang, F. F. (2015), “Recommendations for the optimal design of exergame interventions for persons with disabilities: Challenges, best practices, and future research”, Games for health journal, 4(1), 58-62.
[30] Zadeh, L.A. (1999), “Fuzzy logic= computing with words”, Computing with Words in Information/Intelligent Systems 1, pp. 3-23.