

RehaSpeeder: A Gesture-Based Rehabilitation System That Supports the Free Definition of Movement Inputs for Enhanced Personalization and Motivation in Hand Therapy

René Baranyi
TU Wien, INSO
Vienna, Austria

rene.baranyi@inso-world.com

Luke Nemeskeri
TU Wien, INSO
Vienna, Austria

e11925203@student.tuwien.ac.at

Selina Breuer
TU Wien, INSO
Vienna, Austria

selina.breuer@inso-world.com

Christoph Aigner
TU Wien, INSO
Vienna, Austria

christoph.aigner@inso-world.com

Werner Hoerner
Human&Digital (H&D)
Vienna, Austria

werner.hoerner@humanomed.at

Thomas Grechenig
INSO
Vienna, Austria
thomas.grechenig@inso-world.com

Abstract—Full recovery from hand injuries is often a tedious and lengthy process involving recurring therapy sessions and mostly boring and repetitive exercises. This work presents RehaSpeeder, an adaptive rehabilitation system designed to support personalized hand therapy through the use of freely configurable gestures captured by the Leap Motion Controller 2. Unlike many existing solutions that rely on fixed exercises, RehaSpeeder allows patients and therapists to define custom hand poses, enabling greater flexibility and alignment with individual therapeutic goals. The system was developed in close collaboration with experts in physiotherapy and occupational therapy, and the core requirements were derived from structured interviews. In total, 20 distinct functional and design requirements were identified across five categories: usability, configurability, functional features, feedback, and in-game objectives. The resulting prototype combines gamified elements with intuitive, contactless control to enhance patient motivation and engagement. Although limited by the technical constraints of the sensor—such as the inability to track dynamic motion sequences—RehaSpeeder demonstrates the potential of personalized gesture-based interaction in rehabilitation settings. Future work will focus on integrating real-time movement analysis, adaptive difficulty, and enhanced feedback systems to further improve therapeutic outcomes and extend applicability beyond hand rehabilitation.

The concept demonstrates the potential of adaptive, gesture-based serious games and highlights how wearable interaction technologies can support personalized therapy.

I. INTRODUCTION

Hand injuries and diseases that impair the motor skills of the hand are among the most common medical challenges in rehabilitation. The resulting limitations in the motor skills of the hand have a significant impact on the quality of life of the affected patients, as the hands are essential for everyday activities [1]. In 2019, the most common anatomical sites for fractures included the patella, tibia or fibula, and ankle, followed by the femur (excluding the femoral neck) and the

hand, wrist, or other distal parts of the upper extremity, as reported by Wu et al. [2]. In Austria alone, approximately 366,000 individuals sustained bone fractures that year, with around 10% affecting the wrist area, according to the Global Burden of Disease Collaborative Network [3]. Activities such as mountain biking and various contact sports, which have grown in popularity in recent years, are particularly associated with a heightened risk of long-term wrist injuries due to falls [4]. Despite an overall global trend of declining hand and wrist injury rates since 1990, as shown in the comparative study by Crowe et al. [5], significant regional disparities persist. For instance, Central Europe reports an incidence of 7.6 per 100,000 inhabitants, while in South Asia, the rate rises markedly to 25.9 per 100,000. Notably, regions with a low socio-demographic index tend to deviate from the global decline, exhibiting a sustained or even increasing incidence of such injuries.

Targeted rehabilitation is therefore crucial to restoring hand mobility, strength and coordination. However, traditional therapies often consist of monotonous, repetitive exercises, and therefore resulting in poor motivation and adherence to therapy [6]. This is where serious games offer a promising opportunity in optimisation: they combine therapeutic exercises with playful elements in order to support patients not only effectively but also in an entertaining way [7]. Serious games are utilized across a diverse array of domains, including education, training and simulation, performance enhancement, strategic communication, and healthcare [8].

However, many existing serious games for hand rehabilitation rely on predefined hand movements or gestures, which can limit their applicability across diverse therapeutic contexts [9]. For example, patients recovering from tendon injuries, carpal tunnel syndrome, or fractures may require vastly different mo-

tion ranges, movement types, and levels of resistance during therapy [10]. As a result, fixed gesture-based systems may not offer the flexibility needed to accommodate such varying rehabilitation needs [9].

This paper introduces the development of a serious game specifically designed for hand rehabilitation, with a focus on adaptability and user-centered customization. Unlike many existing rehabilitation applications that rely on predefined exercises or rigid motion patterns, this approach enables patients and therapists to individually select the hand poses used for interaction. This functionality allows training sessions to be tailored to personal needs and therapeutic goals, supporting a more flexible and effective rehabilitation process.

The system utilizes the Leap Motion Controller 2 [11], a contactless device capable of accurately tracking hand and finger movements in real time. This input is integrated into an interactive maze game developed using the Unity engine, which provides a flexible and user-friendly environment for implementing playful therapeutic experiences.

The motivation for this project lies in the growing recognition of serious games as promising tools for enhancing the rehabilitation process. In particular, the field of hand rehabilitation may benefit significantly from innovative and engaging interaction concepts. By combining gesture-based input with customizable game mechanics, the presented system aims to increase patient motivation and promote long-term participation in therapy.

II. RELATED WORK

Various serious games have been developed to support hand rehabilitation, often leveraging motion tracking technologies such as the Leap Motion Controller to enable intuitive gesture-based control. Previous work by Elnagger et al. [12] introduced games like a space shooter and an Angry Birds-style game, using predefined gestures detected by the Leap Motion sensor.

Virtual reality (VR) is often used for this types of games. The use of VR helps players identify better with the game and make the gaming experience feel more realistic for them. Postolache et al. [13] integrated VR technology in combination with the Leap Motion Controller in their serious game called "Collect Color Cube". The researchers investigated the difference between performing a real task and the same task in that virtual environment. Nevertheless, no clear conclusion could be drawn as to whether the real exercise or the game is more suitable for hand rehabilitation.

Hidalgo et al. [14] proposed the serious game "Place the Figure" that also uses the Leap Motion Controller to record hand movements and transfer them directly into the game. This makes it possible to place various objects in boxes in the game.

Similarly, Baranyi et al. [15] developed "RehaFox", a serious game for patients that suffered from stroke that utilizes gesture-based interaction for upper limb rehabilitation. While demonstrating the potential of gamified hand motion training, the system also focuses on predefined movements and tasks,

which may limit adaptability across different types of injuries or therapy stages.

Recent research emphasizes the importance of personalization in rehabilitation systems. For example, González-González et al. [9] present a recommender-based serious game that tailors gestural exercises to individual needs, highlighting the benefit of adaptive approaches for long-time therapy engagement.

Guo et al. [16] introduced a deep learning-based hand gesture recognition system using surface electromyography (sEMG) signals, aiming to offer more robust control mechanism for rehabilitation. Although their approach does not rely on visual tracking, it supports the broader argument that systems must account for patient-specific motor capabilities and limitations.

ReHabgame, introduced by Esfahlani et al. [17], is a Kinect and Myo-based rehabilitation game that adapts its difficulty to each user by analyzing their movement abilities through Monte Carlo tree search. The game dynamically selects appropriate tasks based on the patient's performance, which therefore supports personalized and progressive motor rehabilitation.

As seen in these examples, several serious games already employ a variety of sensors and movement-based interactions to support therapeutic interventions—ranging from motion-tracking cameras to pressure-sensitive input devices. Some systems also utilize the Leap Motion sensor to capture detailed hand and finger movements in real time. However, the concept of enabling users to freely define and record custom hand gestures using Leap Motion for direct control within a serious game represents a novel approach. This study contributes to closing that gap by demonstrating the feasibility and therapeutic relevance of such an adaptive control mechanism.

III. METHODOLOGY

To develop a meaningful and usable rehabilitation game, this work followed a user-centered design process, combining qualitative research with iterative prototyping. The methodological approach consisted of two main phases: expert interviews and a requirements analysis.

In the context of this study, expert interviews were conducted to gather professional insights for the development of a serious game aimed at hand rehabilitation. To ensure a structured and consistent interview process, a detailed interview guideline was developed. Prior to each interview, the four participating experts (see Tab. I) received an informed consent form, which clarified the voluntary nature of their participation, their right to withdraw at any point, and the assurance of full anonymity regarding their responses.

The interviews commenced with a brief introduction to the research topic and the collection of general demographic and professional information. The initial part of the discussion addressed core medical aspects related to hand injuries, including common causes and effective therapeutic practices. Subsequently, the focus shifted to the use of serious games in rehabilitation, with experts being asked to share their expectations, opinions on relevant features, and potential applications

in clinical contexts. In several cases, experts also demonstrated typical hand and finger exercises to support the conceptual development of gesture-based controls.

TABLE I. OVERVIEW OF INTERVIEWED EXPERTS

ID	Age	Gender	Profession	Experience
P01	30 years	M	Physiotherapist	7 years
P02	27 years	F	Occupational Therapist	5 years
P03	25 years	F	Occupational Therapist	3 years
P04	31 years	M	Physiotherapist	8 years

Following the initial round of interviews (with participants P01-P03), the gathered information was analyzed, and key requirements were systematically categorized and prioritized. These findings formed the basis for a preliminary requirements analysis. An early prototype of the serious game was then developed and presented to both the initial and additional experts for feedback. This iterative process was repeated with an advanced version of the game to refine its design and functionality in alignment with practical therapeutic needs. As part of the iterative development process, two follow-up interviews were conducted to gather feedback and evaluate the prototype. This feedback also included an addition therapist (P04) Based on this input, minor improvements were made—such as allowing players to review their stored poses during a pause and highlighting completed levels and full token collection. After these changes, the experts expressed high satisfaction with the final version of the game.

IV. RESULTS

The following chapter presents the results of the conducted study and the subsequent development process of the serious game RehaSpeeder. Based on expert interviews and a detailed literature review, key requirements for the design of an effective and user-centered rehabilitation system were identified and systematically categorized. These requirements form the foundation upon which the technical architecture and the game concept were developed.

In the first section of this chapter, the identified requirements are presented in detail. These were derived from qualitative expert interviews with therapists and categorized into five main thematic groups. The structured collection and prioritization of these needs represent a central outcome of the empirical phase and offer valuable insights for the design of rehabilitation technologies tailored to real-world clinical practice.

Following the requirements analysis, the second section describes the system architecture of RehaSpeeder. Here, the technical components and their interaction are explained, with a focus on the use of the Leap Motion Controller 2 as the central input device. Moreover, considerations regarding usability, robustness, and integration into clinical workflows are addressed.

Subsequently, the third section introduces the game concept of RehaSpeeder. The game was developed with the dual goal of maintaining high patient motivation while simultaneously fulfilling therapeutic functions.

Finally, the fourth section addresses a core innovation of this project: the adaptive control mechanism through customizable pose recording. In contrast to many existing rehabilitation systems, RehaSpeeder enables therapists and patients to freely define hand poses that serve as game controls. This novel approach not only allows for a high degree of personalization but also facilitates alignment with specific therapeutic goals and movement restrictions. The implementation of this mechanism is examined in detail, including the process of pose recording, assignment to in-game actions, and the underlying logic for gesture recognition. The potential of this feature to enhance therapeutic relevance and patient engagement is discussed in the context of the broader trend toward individualized digital healthcare.

Through this multi-stage presentation, the results chapter provides a comprehensive view of how user needs, technological capabilities, and game design considerations converge in the creation of RehaSpeeder. It highlights the interplay between clinical insights and technical innovation and lays the groundwork for further refinement and evaluation of adaptive serious games in rehabilitation.

A. Requirements

Based on the conducted expert interviews with physiotherapists and occupational therapists, requirements were identified, which can be found in Tab. II. The structured requirements analysis identified 20 requirements, grouped into five categories: usability, configurability, functional requirements, feedback, and in-game objectives. These categories reflect different aspects of user experience and therapeutic relevance, and served as the foundation for the game's design. Following the initial wave of expert interviews, key statements relevant to the serious game were extracted, synthesized, and assigned to these categories. Each requirement was given a unique identifier (e.g., A1: Easy game operation). Additionally, it is indicated which therapists mentioned each requirement, highlighting its perceived relevance. The following section provides a detailed explanation of each requirement to illustrate the underlying reasoning and implications derived from the expert input.

In the area of usability, several core requirements were consistently highlighted. Foremost among these was the need for an intuitive and straightforward interaction model (A1), ensuring that patients of all ages and ability levels could navigate and play the game without prior gaming experience. This requirement was implemented through a minimalistic interface and a control scheme based on simple hand poses, captured via the Leap Motion Controller. In addition, motivational aspects were emphasized (A2), with experts noting that maintaining engagement over time is crucial for therapeutic success. To address this, RehaSpeeder integrates motivational elements such as time-based challenges and token collection to create a sense of achievement. Furthermore, it was considered essential that the game provide clear and immediate feedback on the correctness of performed movements (A3), to support learning and motor control. This was achieved by linking character

TABLE II. OVERVIEW OF REQUIREMENTS BY CATEGORY AND CITED EXPERTS

ID	Requirement	Experts
<i>Usability</i>		
A1	Easy game operation	1, 2, 3
A2	Game should motivate players	1, 2, 3
A3	Clear feedback when movements are correct	1, 3
A4	Clear in-game instructions	2, 3
<i>Configurability</i>		
B1	Adjustable game difficulty	1, 2, 3
B2	Customizable for individual players	1, 2, 3
B3	Option for timed/untimed modes	1, 3
B4	Integration of repetitive movements	1, 2
<i>Functional Requirements</i>		
C1	Game should be pausable	1, 2, 3
C2	Several short game modules	2, 3
C3	Game duration max. 15 minutes	2, 3
C4	Ability to save complete motion sequences	1, 2
<i>Feedback</i>		
D1	Indication if performance improves	1, 2, 3
D2	Indication if movement worsens	1, 3
D3	Visual feedback on progress between games	1
D4	Feedback on movement speed (too fast/slow)	3
<i>In-Game Goals</i>		
E1	Ability to track achievements	1, 2, 3
E2	Leaderboard	2, 3
E3	Points/reward system	1

movement in the game only to correctly executed poses. Lastly, comprehensible in-game instructions (A4) were seen as indispensable for usability. A brief onboarding sequence explains the purpose and function of each hand pose, helping users quickly understand the mechanics.

The category of configurability deals with the flexibility and adaptability of the system to individual therapeutic contexts. All interviewed experts emphasized the importance of adjustable difficulty levels (B1), so that both beginners and more advanced patients could benefit from the game. RehaSpeeder addresses this through progressively structured levels that gradually increase in complexity and duration. Closely related to this is the requirement for general personalization (B2), which was realized by allowing users to define their own gestures. This ensures that the input method can be aligned with each patient's motor abilities and therapy goals. Experts also suggested offering the option to play with or without time pressure (B3). While the final version does not allow users to disable the timer explicitly, it is displayed passively—allowing players to ignore it if desired. The incorporation of repetitive motion sequences (B4) was implemented by requiring users to execute multiple correct poses per level, thus reflecting the repetitive nature of traditional rehabilitation exercises.

In terms of functional requirements, the game was expected to offer basic comfort features that support integration into therapy routines. The option to pause the game at any time (C1) was implemented without restriction, enabling users to take breaks without losing progress. Experts also recommended offering multiple shorter gameplay segments (C2, C3), as these are especially suitable for elderly patients or those with limited stamina. Accordingly, RehaSpeeder consists of numerous compact levels, each of which can be completed in a few minutes. However, the ability to store entire motion

sequences (C4) could not be realized due to current technical limitations. The Leap Motion sensor used in the system supports static pose recognition, but not the capture of continuous, dynamic movement patterns. This remains an open challenge for future development.

The feedback category revealed some of the most ambitious but technically challenging suggestions. Therapists expressed a desire for features that provide patients with nuanced information on their performance progress. For example, indicators of whether movements are performed more accurately or smoothly over time (D1), or warnings when motion quality decreases (D2), were considered helpful for both therapists and patients. Visual progress summaries between sessions (D3), and alerts on movement speed—either too fast or too slow (D4)—were also proposed. However, due to the limitations of the Leap Motion Controller in detecting motion dynamics, these features could not be fully implemented in the current version of the game. They remain relevant targets for future iterations, especially if more advanced motion capture systems are integrated.

Finally, the category of in-game goals focused on motivational structures and progress tracking within the game environment. The ability to monitor patient progress (E1) was implemented through color-coded level completion, which gives immediate visual feedback on achieved milestones. The inclusion of a leaderboard (E2) adds a social comparison element, which can further increase engagement, especially among younger users. Additionally, a point or reward system (E3) was introduced in the form of collectible tokens. While these do not unlock new features, they serve as a motivational indicator and support repetitive play, which is beneficial from a therapeutic perspective.

In summary, the requirements gathered from expert interviews provided a robust foundation for the development of RehaSpeeder. The systematic implementation of these features—despite certain technical constraints—demonstrates how user-centered design principles can be effectively applied to serious games in rehabilitation contexts. While not all requirements could be fully realized in the current prototype, the modular and extensible architecture of the game lays the groundwork for future enhancements that may incorporate more sophisticated sensors, adaptive feedback, and dynamic motion tracking.

B. Architecture

An important component of the serious game RehaSpeeder is the Leap Motion Controller 2 [11]. The high tracking accuracy combined with the easy detection of finger movements makes the Leap Motion Controller 2 particularly suitable for applications that enable intuitive and natural interaction. The controller can be used in a tabletop version (lying on a table) or a head-mounted version (e.g., mounted on a VR headset). Since VR headsets are not used in this work, a suitable mount with a 30° negative tilt was created using a 3D printer. The Leap Motion Controller 2 can be easily inserted into the wearable component and secured with a locking plate. The

mount has an opening in the top center for connecting the controller to the computer using a suitable USB-C cable. The entire device can then be worn and used like a head-mounted flashlight using the two straps attached to the back, which is shown in Fig. 1.



Fig. 1. Head-mounted Leap Motion Controller 2

C. Game Concept

RehaSpeeder is an adaptation of the popular smartphone game "Tomb of the Mask" [18]. The player character moves through a vertical labyrinth, collecting points and coins, and avoiding traps and enemies. This game was chosen as a model due to its minimalist and simple controls and the opportunity to develop a relatively simple, level-based game that still offers fun and challenge. RehaSpeeder features three different difficulty levels, each with a specific number of levels. The difficulty levels "Easy" and "Medium" each contain six different levels, which differ in terms of length, number of moves, and number of tokens. Only three moves are required to complete the first level in "Easy" mode, while between 12 and 18 moves are required for the final level, depending on the number of points collected. In "Medium" mode, the number of required moves varies from 9 to 19 in the first level to 50 or more in the fifth level. The third mode, "Hard," is divided into three levels and is aimed at players who want to complete the game completely or test their skills. Level 1 of this mode can be seen in Figure 2. In this mode, the range of moves ranges from 25 to over 100, which presents a significant challenge. Collecting all the tokens requires finding the correct paths, which requires a certain amount of effort.

The serious game is controlled using gesture recognition. The four poses recorded and selected in advance by the player each represent a direction in which the character can move (up, down, left, or right). If one of the four poses is recognized by the Leap Motion Controller, the corresponding functions are called up, and the character moves accordingly in the recognized direction until they encounter a wall. Thus, a single "step" is never performed; instead, the character moves relatively quickly to the next obstacle. Once there, the next pose can be recognized and the subsequent movement can be performed until the goal is finally reached.



Fig. 2. RehaSpeeder: Modus "Hard", Level 1

Numerous tokens are distributed throughout each level, recognizable by the yellow discs located along the paths. These are automatically collected as soon as the character moves over them. The achieved token score is displayed after each level and in the main menu. In addition, the time required to reach the goal is measured in each level. Players can view their best time for each level on the scoreboard. This primarily serves to increase motivation to complete the levels with increasing speed and precision, while ensuring that the correct execution of the poses is not neglected.

D. Adaptive Game Controls

RehaSpeeder is controlled via personalized hand gestures, which are detected using the Leap Motion Controller. To support a wide range of patient abilities and therapy goals, the system includes an adaptive control architecture with freely configurable hand gestures, as shown in Figure 3. This interface allows users to define their own hand poses by holding a specific gesture during a short countdown period. Once recorded, the system provides visual feedback and verifies whether the pose has been successfully recognized. These custom gestures can then be linked to specific in-game actions as movement (up, down, left, right) commands. So for example, a peace gesture (index and middle finger extended) can be used to trigger upward movement, a hang loose gesture (thumb and little finger extended) to move down, a pinch gesture (thumb and index finger touching) to go left, and a thumbs-up to move right. These freely assigned poses are then recognized by the Leap Motion Controller during gameplay and translated into directional commands for the in-game character.

The flexibility to select gestures based on comfort, therapeutic relevance, or even user preference introduces a new level of adaptability in rehabilitation gaming. It ensures that exercises remain accessible for users with different levels of motor ability, and that gameplay can evolve alongside patient progress. The implementation of this feature—including the

technical logic for gesture capture, calibration, and reliable recognition—is detailed in the corresponding section. Overall, this mechanism offers a significant step toward personalized rehabilitation experiences that adapt to the user rather than the other way around.

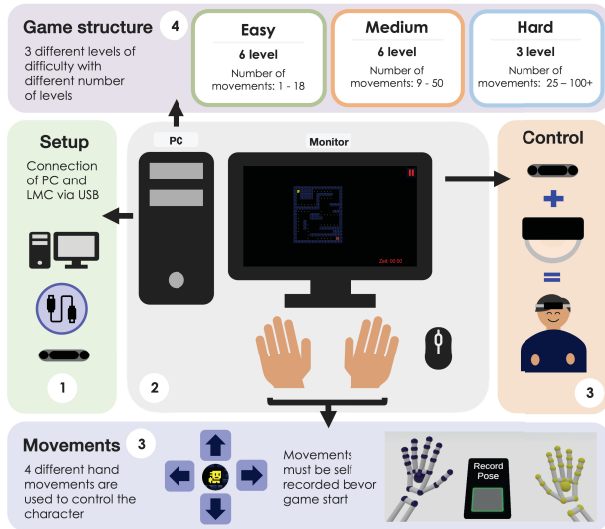


Fig. 3. System overview and control flow.

In order to ensure consistency across different game sessions and levels, a persistent system for managing user-defined poses was implemented. Hand poses are stored in a structured format that allows for saving, loading, and reusing them at any point in the game. This avoids the need to redefine gestures multiple times and makes the system more practical for repeated therapeutic use.

An additional menu interface enables users to either record new poses or select from a list of previously saved ones. This feature enhances the system's adaptability, allowing therapists to create and switch between different exercise configurations depending on the patient's progress or rehabilitation focus. Since hand therapy often involves a variety of targeted movements tailored to individual needs, the ability to define and reuse a larger number of custom poses supports a more flexible and engaging therapeutic experience.

V. CONCLUSION

This work presented RehaSpeeder, a novel serious game designed for adaptive hand rehabilitation using the Leap Motion Controller 2. A key innovation of the system is its ability to record and integrate freely defined hand gestures into gameplay, allowing for a high degree of personalization and therapeutic relevance. Based on qualitative interviews with physiotherapists and occupational therapists, a total of 20 core requirements were identified and implemented—ranging from usability and configurability to feedback mechanisms and motivational game elements. The development process followed an iterative, user-centered design approach, incorporating expert feedback at multiple stages. The final prototype demonstrated that gesture-based, personalized rehabilitation

systems are not only technically feasible but also well-received by professionals in the field. The use of contactless, intuitive controls was found to reduce barriers for patients, while the ability to adapt the game to individual needs significantly enhanced its therapeutic potential. Overall, RehaSpeeder contributes to the growing body of research in digital rehabilitation by introducing a flexible and engaging system that can complement traditional therapy in both clinical and home-based contexts.

VI. DISCUSSION

This study highlights the promising role of serious games by technologies like the Leap Motion Controller 2—in delivering personalized and engaging hand rehabilitation. By allowing users to define their own hand gestures, the developed game introduces a high degree of adaptability to individual patient needs, setting it apart from conventional, static therapy tools. The use of intuitive, contactless hand-tracking not only enhances usability but also reduces barriers to participation, encouraging long-term motivation and adherence to therapy. The combination of gamified elements and personalized interactions under professional supervision proved to be both effective and enjoyable for patients. This underscores the relevance of technology-supported and user-centered approaches in modern rehabilitation and paves the way for broader applications beyond motor recovery, such as general fitness or cognitive-motor training.

Looking ahead, future development should focus on integrating dynamic movement tracking, enabling real-time analysis of fluid motions like grasping or rotating. Enhanced feedback mechanisms could inform patients about movement quality (e.g., speed, precision, and consistency), helping to visualize progress and highlight areas for improvement. In addition future work should also cover reducing completely individual movements to better fit the possibilities of the sensor (e.g. not every movement is possible to be integrated into a game and might not be detected very well). These advancements could also benefit related domains such as stroke or sports rehabilitation, supporting broader accessibility and therapeutic success.

REFERENCES

- [1] C. A. Jaworski, M. Krause, and J. Brown, "Rehabilitation of the wrist and hand following sports injury," *Clinics in sports medicine*, vol. 29, no. 1, pp. 61–80, 2010.
- [2] A.-M. Wu, C. Bisignano, S. L. James, G. G. Abady, A. Abedi, E. Abu-Gharbieh, R. K. Alhassan, V. Alipour, J. Arabloo, and M. Asaad, "Global, regional, and national burden of bone fractures in 204 countries and territories, 1990–2019: a systematic analysis from the global burden of disease study 2019," *The Lancet Healthy Longevity*, vol. 2, no. 9, pp. e580–e592, 2021, publisher: Elsevier.
- [3] Global Burden of Disease Collaborative Network, "Global burden of disease study 2019 (GBD 2019) disease and injury burden 1990–2019," *The Lancet*, 2020, type: dataset.
- [4] I. Mehling and M. Sauerbier, "Knöcherne Verletzungen der Handwurzel," *Trauma und Berufskrankheit*, vol. 17, no. Suppl 2, pp. 338–344, 2015.
- [5] C. S. Crowe, B. B. Massenburg, S. D. Morrison, J. Chang, J. B. Friedrich, G. G. Abady, F. Alahdab, V. Alipour, J. Arabloo, M. Asaad et al., "Global trends of hand and wrist trauma: a systematic analysis of fracture and digit amputation using the global burden of disease 2017 study," *Injury prevention*, vol. 26, no. Suppl 2, pp. i115–i124, 2020.

- [6] M. Gonzalez-Franco, S. Gilroy, and J. O. Moore, "Empowering patients to perform physical therapy at home," in *2014 36th Annual International Conference of the IEEE Engineering in Medicine and Biology Society*. IEEE, pp. 6308–6311.
- [7] M. Szaniawski, S. Boess, G. Kraan, and R. Goossens, "Enhancing engagement with motor rehabilitation therapy through gamified rehabilitation interactions," 07 2015.
- [8] M. Zyda, "From visual simulation to virtual reality to games," *Computer*, vol. 38, no. 9, pp. 25–32, 2005.
- [9] C. S. González-González, P. A. Toledo-Delgado, V. Muñoz-Cruz, and P. V. Torres-Carrión, "Serious games for rehabilitation: Gestural interaction in personalized gamified exercises through a recommender system," *Journal of Biomedical Informatics*, vol. 97, p. 103266, September 2019, epub 2019 Aug 10.
- [10] S. C. Takata, E. T. Wade, and S. C. Roll, "Hand therapy interventions, outcomes, and diagnoses evaluated over the last 10 years: A mapping review linking research to practice," *Journal of Hand Therapy*, vol. 32, no. 1, pp. 1–9, Jan–Mar 2019, epub 2017 Jun 21.
- [11] Ultraleap, "Leap motion controller 2," 2023, accessed: 2025-04-13. [Online]. Available: <https://leap2.ultraleap.com/products/leap-motion-controller-2/>
- [12] A. Elnaggar and D. M. Reichardt, "Digitizing the hand rehabilitation using serious games methodology with user-centered design approach," *2016 International Conference on Computational Science and Computational Intelligence (CSCI)*, pp. 13–22, 2016. [Online]. Available: <https://api.semanticscholar.org/CorpusID:10935599>
- [13] G. Postolache, O. Postolache, G. Lupu, D. Sera, and M. Ivanovici, "Serious game for rehabilitation based on virtual reality and leap motion controller," in *2017 9th International Conference on Electronics, Computers and Artificial Intelligence (ECAI)*, 2017, pp. 1–4.
- [14] J. Hidalgo, "Interactive hand rehabilitation game using leap motion," 2016, referenced in Bachelor's thesis; original source not available online.
- [15] R. Baranyi, Y. Körber, P. Galimov, Z. Parandeh, and T. Grechenig, "Rehafox – a therapeutical approach developing a serious game to support rehabilitation of stroke patients using a leap motion controller," *Clinical eHealth*, vol. 6, pp. 85–95, 2023. [Online]. Available: <https://www.sciencedirect.com/science/article/pii/S2588914123000199>
- [16] Y. Guo, K. Wang, D. Luo, J. Luo, X. Ma, W. Du, C. Guo, and Y. Gu, "Hand gesture recognition based on semg and deep forest for hand rehabilitation," *Frontiers in Neurorobotics*, vol. 17, p. 1171582, 2023.
- [17] S. S. Esfahlani and G. Wilson, "Development of rehabilitation system (rehabgame) through monte-carlo tree search algorithm using kinect and myo sensor interface," in *2017 Computing Conference*. IEEE, Jul. 2017, p. 1021–1028. [Online]. Available: <http://dx.doi.org/10.1109/SAI.2017.8252217>
- [18] Playgendary Limited, "Tomb of the mask," <https://tombofthe-mask.com/>, 2016, zugriff am 13. April 2025. [Online]. Available: <https://tombofthe-mask.com/>