Demo Abstract: ARMove: A Smartphone Augmented Reality Exergaming System for Upper and Lower Extremities Stroke Rehabilitation

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ABSTRACT
Effective at-home rehabilitation of both upper and lower extremities is important for regaining proficiency in activities of daily living (ADLs) post-stroke. We introduce ARMove, a smartphone augmented reality (AR) exergaming system for upper and lower extremities stroke rehabilitation. The AR technology facilitates exergaming that utilizes a full range of motion in real-world spatial environments while creating attractive graphics to engage users in gamified environments. ARMove’s novelty comes from its multifaceted rehabilitation of both upper and lower extremities. Furthermore, ARMove provides simultaneous training of fine and gross movements; it also considers bilateral training, preparing users for ADLs such as using computers or playing sports. Additionally, our utilization of smartphone embedded vision sensors and mobile computing give our system scalability, with potential for ubiquitous deployment.

KEYWORDS
Smart Health, Rehabilitation, Stroke, Mobile Computing, Embedded Sensor System, Augmented Reality, Exergame

ACM Reference Format:

1 INTRODUCTION
There are 800,000 Americans per year affected by stroke [2]. Although acute management of stroke is available in clinics, post-stroke individuals can experience a disability that significantly affects the quality of life. For instance, upper extremity impairment affects routine activities, such as meal preparation, bathing, and housework, and lower extremity impairment reduces mobility [7]. Thus, stroke rehabilitation is important to post-stroke recovery to help post-stroke individuals regain lost abilities.

Upper extremities rehabilitation is an area of great research interest [3, 6, 8, 9]. Although at-home physical training utilizing augmented reality (AR) or virtual reality (VR) techniques for stroke rehabilitation is popular, most existing approaches focus on only one aspect of recovery. For example, Hondori et al. designed an AR system training unilateral upper-extremity motions, like pouring water [5]. David et al. used VR and a Leap Motion sensor to train gamified unilateral reaching motions [4]. However, views from clinical medicine suggest that stroke rehabilitation requires the cooperation of all affected brain regions for full benefits since a stroke can kill brain cells in multiple regions [1]. Thus, focusing on one type of rehabilitation (e.g., only upper extremity), which practices only one specific brain region is not fully effective.

In response, we present ARMove, a smartphone AR exergaming system for both upper and lower extremities stroke rehabilitation. We choose AR due to its allowance for practical and applicable movements in a real-world environment while employing elaborate graphics to engage and motivate users in exergames. ARMove is unique in its consideration of both upper and lower extremity stroke rehabilitation. Furthermore, ARMove trains simultaneous gross and fine upper extremity movement, as well as bilateral coordination, which is essential for activities of daily living. Additionally, we use the smartphone’s mobile computing and embedded sensing capabilities to foster a scalable, portable rehabilitation system.
We use AR due to the design principles: 1) functionality and 2) enjoyability. In terms of functionality for rehabilitation purposes, AR allows full freedom of movement in real-world spatial environments; this leads to rehabilitation applicable to ADLs. In terms of enjoyability for users, AR owns the power to create elaborate, detailed, colorful graphics to keep users engaged in exergames.

3 EXERGAMES
Each exergame targets specific skills post-stroke, with gameplay designed to facilitate these rehabilitative objectives. Each game has multiple levels, allowing users to train at an intensity that is appropriate to their current skill, yet challenging. There is also in-game real-time positive feedback, in the form of audible encouragements and visual indicators of success; this motivates and engages users. Post-game, there is a historical progress chart, giving users the opportunity for self-guidance based on past performance; it also helps rehabilitation specialists adjust rehabilitation programs. More details regarding the games are in Table 1.

2 SYSTEM DESIGN
ARMove consists of two parts: embedded sensor hardware and exergame software.

2.1 Sensor Hardware
ARMove utilizes a smartphone as the primary sensor and computing device due to its portability and ease of use. Our system can be run on both Android and iOS, giving scalability to our system, with potential for ubiquitous deployment. The smartphone camera acts as an embedded vision sensor to efficiently track user position in real-time during the exergames, while the mobile computing of modern smartphone CPUs can display AR exergames in real-time.

Our system also makes use of a printable patterned board (Figure 1). This patterned board provides a frame of reference for users, helping users locate themselves in the augmented exergaming environment, which facilitates hand-eye coordination during exergames. Additionally, it helps the augmented reality-based software efficiently calculate the user’s position relative to the augmented exergaming environment.

2.2 Software Design
We use AR due to the design principles: 1) functionality and 2) enjoyability. In terms of functionality for rehabilitation purposes, AR allows full freedom of movement in real-world spatial environments; this leads to rehabilitation applicable to ADLs. In terms of enjoyability for users, AR owns the power to create elaborate, detailed, colorful graphics to keep users engaged in exergames.

Table 1: The exergames in ARMove.

<table>
<thead>
<tr>
<th>Game</th>
<th>Game Goals</th>
<th>Rehab Goals</th>
<th>Relevant ADLs</th>
<th>Images</th>
</tr>
</thead>
<tbody>
<tr>
<td>Kickball</td>
<td>Kick the ball at the net</td>
<td>Lower body coordination, hip flexion, plantar flexion, hamstring movement</td>
<td>Pressing gas ped., walking, soccer</td>
<td><img src="image1.png" alt="Image" /></td>
</tr>
<tr>
<td>Trail Path</td>
<td>Place alternating fingertips to follow footprints</td>
<td>Simultaneous gross and fine motor function in upper extremities, precision, speed</td>
<td>Using a computer, playing musical instruments, dribbling basketball</td>
<td><img src="image2.png" alt="Image" /></td>
</tr>
<tr>
<td>Handprints</td>
<td>Place hands on augmented handprints in alternating order</td>
<td>Bilateral coordination, gross forearm movement, reaction time</td>
<td>Climbing ladder, swimming, playing drums</td>
<td><img src="image3.png" alt="Image" /></td>
</tr>
<tr>
<td>Pizza Cutter</td>
<td>Cut pizza along lines</td>
<td>Arm flexion, arm extension, consistent movement, precision</td>
<td>Food preparation, cleaning</td>
<td><img src="image4.png" alt="Image" /></td>
</tr>
</tbody>
</table>

REFERENCES