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# A New AR-Based Framework For Wrist Assessment And Rehabilitation

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## Abstract

The existing rehabilitation systems based on augmented reality (AR) are lacking of the targeted training of joint and requiring a large number of auxiliary equipment. This paper proposes a novel framework for wrist-rehabilitation assessment and training that integrates AR technology with kinesiotherapy and occupational therapy in rehabilitation medicine, which focuses on coaching patients to wrist radial and ulnar deviation rehabilitation at any time and any place. Particularly, an AR-based water-droplet training game, suggested by clinical doctors in hospital, is developed to improve the flexibility of the wrist movement. The effect of rehabilitation can be achieved by measuring the range of motion (ROM) of the wrist. Finally, the evaluation scheme of this framework is designed in detail.

## 1 Introduction

Wrist is the pathway that flexor or extensor tendons of forearm blood vessels and nerves arrive to the hand[1]. However, because of bearing a larger load in the support, thrust and other movements, so the wrist is easily damaged. Fortunately, research studies have confirmed that early rehabilitation training is extremely important to wrist function recovery[2]. At present, the "one-to-one" rehabilitation model of traditional rehabilitation can not meet the needs of society; Rehabilitation training system based on Virtual Reality (VR) technology such as BioMaster [3] and Upper Limb Rehabilitation Intelligent Robot[4], the patients tend to feel boredom when facing the virtual world which is completely different from the real world. Augmented Reality technology (AR) is introduced into rehabilitation medicine. It can add virtual object which is generated by computer into accurate place in the real scene and present a new sense of the real effect of the new environment[5]. The system, which combines AR technology with the functional training of the wrist, can construct a virtual-reality fusion training environment to make patients keep in touch with the real world. Obviously, it is helpful to improve the rehabilitation better.

This paper presents a novel framework that provides an entertaining and natural environment for wrist-rehabilitation assessment and training. The rest of the paper is organized as follows: in session 2 related works are highlighted while session 3 presents the overall architecture of the system and general process of wrist assessment and rehabilitation in details. Conclusions and future work is provided in section 4.

## 2 Related Work

At present, foreign researches are started earlier and developed rapidly while domestic researches are still in the early stage of laboratory research at present. The following Table 1 enumerates some of present AR-based rehabilitation systems[6,7,8,9,10,11,12], which can be carried out wrist training, with a comparative analysis of these systems' three aspects that include the components, training process, evaluation methods and features of system.

These systems can provide a favorable training environment for patients with high interest and deep immersion. But as shown in Table 1, there also are the following disadvantages: 1. these systems constitute cumbersome, resulting in the patient's comfort is not high; 2. Most of the systems are lacking of professional rehabilitation, which is according to the mechanism of sports mechanics and recovery mechanism of the wrist .What's more, all the current AR developments are concentrated only on game design principles, user convenient and just to train for upper limb movements but do not consider for any biofeedback[13]; 3. Most of the rehabilitation evaluation methods are based on the score of games to judge the rehabilitation condition, lacking of specific quantitative indicators and medical evaluation basis.

Different from the existing systems, this paper proposes a new architecture of wrist rehabilitation system that combines AR with kinesiotherapy and occupational therapy in rehabilitation medicine.

| Project | Components | Training process | Evaluation methods | System Features |
|---|---|---|---|---|
| A multi-sensor multi-rate algorithm for motor rehabilitation with Augmented Reality devices（2016） | HMD, Web-Camera, MPU6050 (IMU) | Through the head mounted display (HMD), in the right way to open a real plastic bottle with the guidance of virtual 3D hands. | Hand-track error and virtual object alignment error in nominal condition and critical condition | Multi-sensor and multi-rate algorithm can make a reliable alignment between real and virtual objects in real-time |
| Development of a haptic interface for motor rehabilitation therapy using augmented reality （2015） | PC, HMD, Camera, Markers , Haptic device | The patient wears a HMD to see the rendering of the virtual ball and completes the training by touching the haptic device to hit the virtual ball. | The number of repetitions performed, the total runtime and the norm of tracking error | Allows different types of visually and tactilely stimulating exercises |
| Perception of Health Professional about Clinical Utility of an Augmented Reality Musical System to Motor and Cognitive Rehabilitation（2014） | PC, Camera, Markers, Audio | Training through the rotation and translation note markers with hand, the system gives the sound feedback. | The time required to complete specific tasks | The combination of visual and hearing, so it can use the markers to bring auditory feedback |
| AR Based Upper Limb Rehabilitation System （2012） | PC, Camera, Color Markers, Electromyogram (EMG) | Training through the balloon collection, feeding animals and other 4 games rehabilitation.For example, the balloon collection game: collect the balloon which randomly generated from top of the display screen and place into the collection box. | Real time feedback of EMG signals | A subtle blend of biofeedback system with AR and it can detect the level of muscle activation of trainees |
| Out of reach?a novel ar inerface approach for motor rehabilitation （2011） | PC, Wide-Angle Webcam, Modified Fiber-Board Boxes | The patient put their hands in the fiber-board boxes and then move the virtual tiles which is displayed by screen to complete the training. | IBM's usability satisfaction questionnaire and 7-point Likert-scales to assess the usability | The use of mirror-box therapy can eliminate the tension and can completely immerse in the training environment |
| Hand rehabilitation training system based on Augmented Reality （2015） | PC, Camera, Markers | The system includes three kinds of training: trajectory training, cup training and table tennis training. For example,trajectory training: the user makes the virtual ball along the virtual trajectory with holding a small box attached to the marker. | Comparison the time to fulfill tasks and the score obtained within the fixed time | AR system renders the real scene better and the game task is more abundant |
| Upper limb rehabilitation system using augmented reality technology （2013） | PC, Camera, Markers | According to the system prompts , the patient move the upper limbs to complete the task which is same with gophers game. | Comparison the score obtained within the same degree | Two types of interaction: UI interaction and gesture interaction |

Table 1 The comparisons of the existing AR-based wrist rehabilitation systems.

## 3 Framework Design

### 3.1 Rationale and Principle

In rehabilitation training, kinesiotherapy is the most commonly used method, which using equipment or the patients' own strength, through some movement, to make the patient obtain systemic or local motor function and sensory function recovery; Occupational therapy refers to the process of evaluating, treating, and training patients who have a physical disability or developmental dysfunction and lose the ability to work independently in some degrees, with a purposeful, selected activity [14].

The combination of kinesiotherapy and occupational therapy combined with AR technology can provide a highly professional and comfortable wrist rehabilitation program for patients: (1) In the early stage of rehabilitation, through the kinesiotherapy, it can be a good way to avoid the secondary injury by wrist radial and ulnar deviation rehabilitation in small angle; (2) in the late stage ,through the occupational therapy, it can enhance the flexibility of the wrist joint and improve the coordination between the bones by completing the receiving water droplets game; (3) AR technology can interact the real world with the virtual world in real time by rendering the virtual scene on the real training joint and provide a strong interest, high immersion training environment for many repetitive training. Obviously, it is more effective than the traditional kinesiotherapy and occupational therapy, which is the way by using wrist function trainer and thumbing screws, etc.

### 3.2 System Architecture

AR-based wrist rehabilitation system can realize the sensor data input, multi -screen (PC, TV, Projector, Android machine) display output function. The conceptual architecture overview is shown in Figure 1.

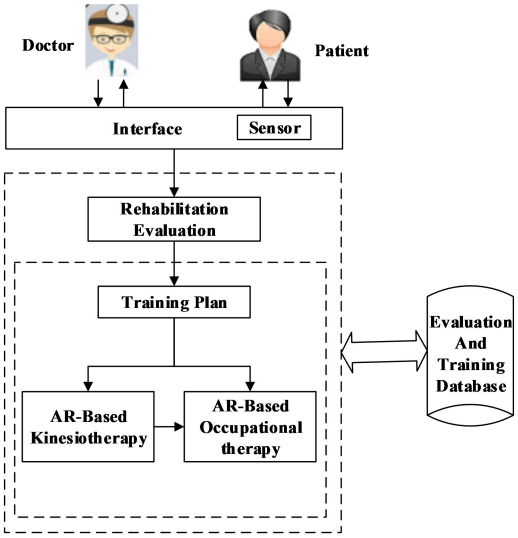


Figure 1: The conceptual architecture overview of AR-based wrist rehabilitation

As shown in Figure 1, the system mainly includes: doctor and patient interface module, rehabilitation evaluation module, rehabilitation training module and data storage module. Among them, rehabilitation training module, which mainly includes two small modules: AR-based kinesiotherapy rehabilitation and AR-based occupational therapy rehabilitation, is the core module of the whole system. The data storage module mainly stores the patient's periodic evaluation records and real-time training records in the evaluation and training database.

### 3.3 Evaluation and Training Process

Before rehabilitation, the patient must undergo a rehabilitation assessment. According to the patient's assessment record, the doctor make the corresponding training plan, including the target angle of kinesiotherapy rehabilitation, the water drop game level of occupational therapy rehabilitation, training time and so on. In the process of rehabilitation, firstly, the patient should log on to their account and see the doctor's training plan. Secondly, wear and proofread the sensor, then select AR-based kinesiotherapy rehabilitation and AR-based occupational therapy rehabilitation for training. Timely training feedback can provide a good incentive to the patient's active training, so after the training, the system will show the patient's comprehensive situation of the training.

#### 3.3.1 The Work Flow of AR-Based Kinesiotherapy Rehabilitation

AR-based kinesiotherapy rehabilitation mainly through the virtual 3D wrist rendered by the systems to guide and regulate patients' training actions of wrist radial and ulnar deviation. The specific working process is shown in Figure 2.

Figure 2 The swimlane flowchart of AR-based kinesiotherapy rehabilitation

The patient' real wrist interacts in real time with the system's rendered virtual 3D wrist as depicted in Fig. 2. The system adjusts 3D coordinate information of virtual wrist and redraws other virtual scene information according to the location of the real wrist .So that the real wrist and virtual wrist are always in the same plane anytime. Therefore, patient training is more digestible because of the clearer goal.

#### 3.3.2 The Work Flow of AR-Based Occupational Therapy Rehabilitation

AR-based occupational therapy Rehabilitation is mainly the design of water droplets game. The game flow is shown in Figure 3.

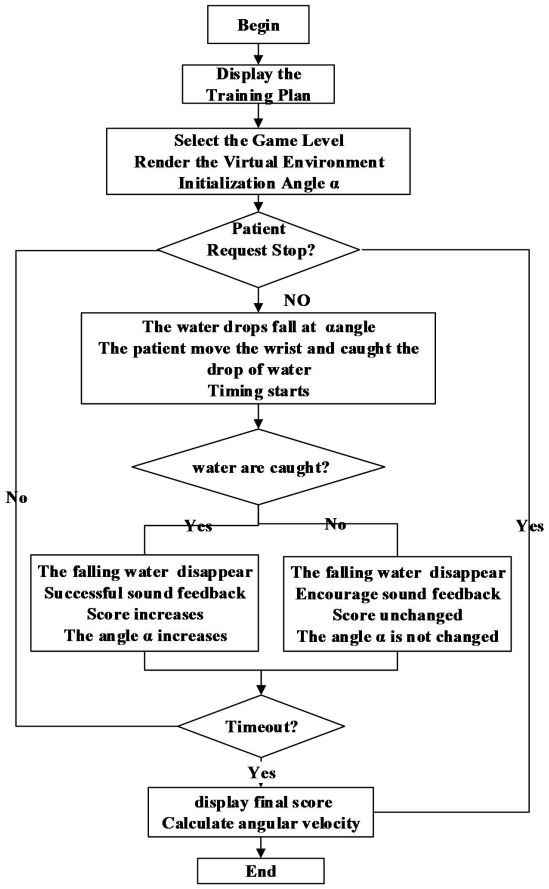


Figure 3: The flow chart of AR-based occupational therapy rehabilitation(water - droplet training game)

Before the game starts, the patients are asked to select a level of difficulty. The game level is designed according to velocity β and density θ of water droplets falling. At the same level, water drops at different angle α (the angle that the central axis that the connection line of water droplets to the starting point of the central axis).

### 3.4 Evaluation Scheme

Measuring the range of motion (ROM) is an important content in rehabilitation assessment. This study will be performed using patients with wrist injury to compare wrist ROM measurement in every stage. Specific details of this evaluation are as follows:

| | | | initial value | Assessment time | | | |
|---|---|---|---|---|---|---|---|
| | | | | Training for first week | Training for second week | Training for third week | Training for fourth week |
| ROM | Ulnar deviation | L | | | | | |
| | | R | | | | | |
| | Radial deviation | L | | | | | |
| | | R | | | | | |

Table 2 : The table of ROM evaluation

The patient is using the application, that this framework is applying to the Android platform and the rehabilitation data is collected by the sensor, for wrist rehabilitation. The maximum curvature of each wrist motion is tracked by a periodic record such as one week. Then, the relevant information will be filled in Table 2 to analyze the rehabilitation of patients.

## 4 Conclusions and Future Work

This paper proposes a novel framework for wrist-rehabilitation assessment and training that integrates AR technology with kinesiotherapy and occupational therapy in rehabilitation medicine. On the one hand, it is designed according to the special anatomical structure and physiological mechanics of the wrist and easy to use; On the other hand, it can offer real-time feedback of the wrist recovery by using sensors and ROM evaluation method. In the near future, more realistic training scenes will be rendered and more interesting games will be designed.

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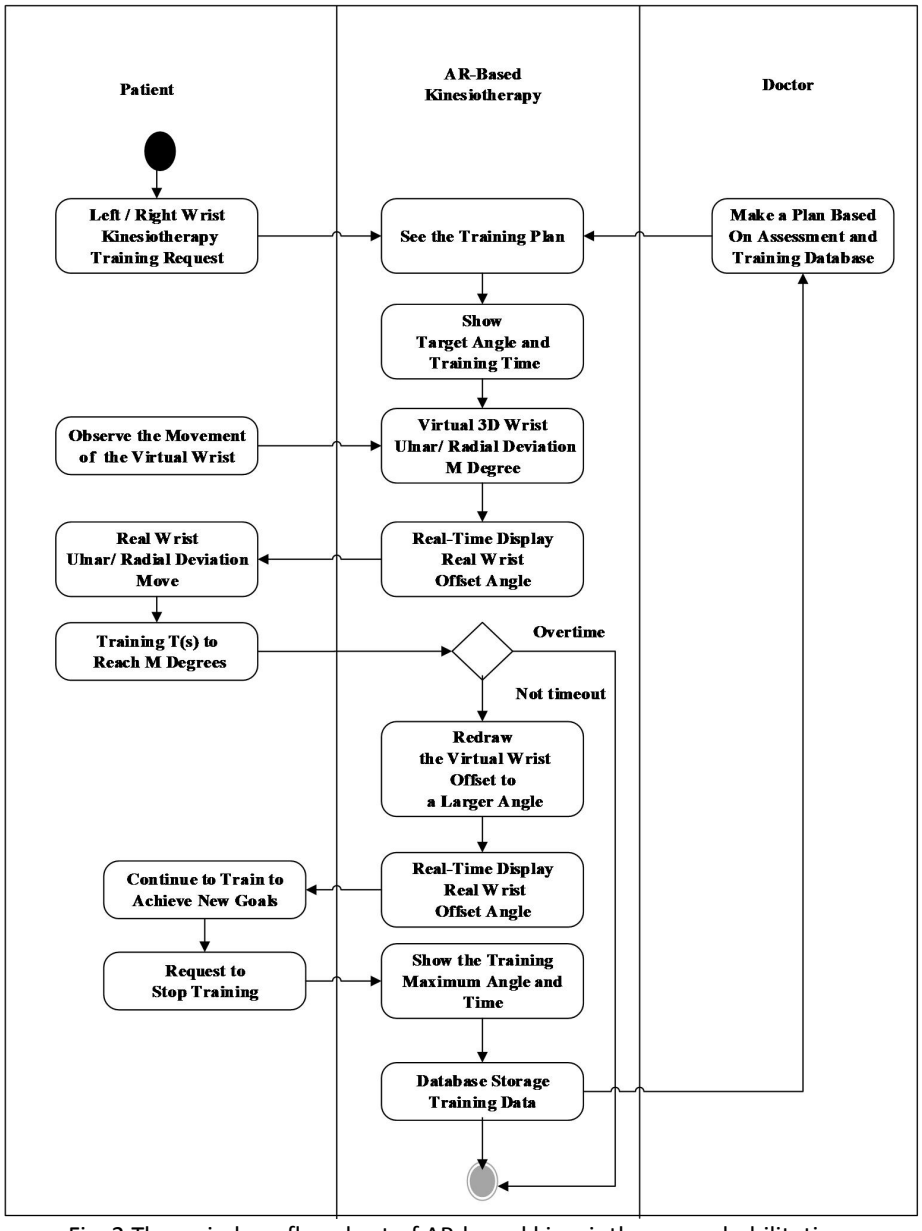


Fig. 2 The swimlane flowchart of AR-based kinesiotherapy rehabilitation