Feature Extraction of a Synchronized Swimmer from Underwater Videos

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Vision-based feature extraction of a synchronized swimmer doing *figures* was done in the hopes of correcting and improving a synchronized swimmer's ability to do *figures.* Extracted feature through image processing techniques plays an important role in understanding the synchronized swimmer's body kinematics and dynamics.

In gathering data, two cameras were used to video capture the swimmer's movements. One was stationed at a calculated distance above the water, and the other camera was placed underwater directly above the other camera. In this article only the underwater feature extraction of the three figures synchronized swimming, Porpoise, Neptunus, and Ballerina, and the essential image processing techniques used for the feature extraction were covered. The results showed that empirically extracted threshold limits for the skin region produced smooth feature extracted foregrounds.

Keywords: feature extraction, *figures* synchronized swimming, Porpoise, Neptunus, Ballerina

1. INTRODUCTION

Control, stability, and movement coordination are the main criteria set in assessing the performance of a *figure* synchronized swimmer. Moreover, correct transition of steps is critical in order to smoothly perform each *figure.* These criteria can be evaluated in aerial and underwater views.

Aerial and underwater perspectives of the synchronized swimmer doing figures serve as a gauge for the coach/trainer to completely assess the coordination of movements of the swimmer. But often, only the aerial view of the synchronized swimmer is available to the coach/trainer to assess the swimmer's movements. Hence, application of underwater vision and analysis of the swimmer's body kinematics have the potential to evaluate the swimmer's performance more rigorously.

The swimmer's body kinematics involves calculation of angles, velocities, accelerations of specific body segments. Body segments that are essential are the shoulder-hip segment, hip-knee segment, and knee-ankle segment. With these information and measurements, detailed analysis of the swimmer's movements is possible.

But calculation of these parameters can be done in different ways. Among these is the use of vision. In this study, video cameras were

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used to capture images of the swimmer in aerial and underwater environments. This was conducted without markers attached to the anatomical landmarks of the swimmer, i.e. shoulder, hip, knee, and ankle. However these body segments are not easy to feature extract.

Color is widely used in computer vision for feature extraction and classification. But most of the studies that utilized color segmentation techniques were conducted in aerial view. Meaning, air is the medium in which light travels as it is reflected from the surface of the object being considered to the camera which would then digitally store this information and further image process it using a computer. Although there are some who utilized color in underwater imagery such as Marcos et al., who used color for the feature extraction of coral reef components (Marcos et al., 2003), and Chambah, et al. who used Automatic Color Equalization (ACE) as enhancement for automatic live fish localization and recognition (Chambah, et al., 2003). Still, this type of studies is not comparable to the number of studies that had been conducted in an aerial environment.

In this paper, color segmentation technique is utilized to capture the skin region of the swimmer's body performing three different figures in an underwater environment. Thus localization of the body segments in underwater view is possible. Although body kinematics is essential in order to analyze the swimmer's movements, this can be achieved only if the two perspectives, aerial and underwater, are combined to make a meaningful assessment of each transitional movement made by the swimmer. However, this paper is limited to the feature extraction of the swimmer's body only in the underwater environment, hence, calculations and measurements are not included.

In the following subsections some properties of color and the HSV color space used will be discussed, and a short overview of *figures* synchronized swimming is shown. Section II illustrates the methodology used in this study. The presentation of results and discussion can be found in Section III. And to end this paper, a brief conclusion will be provided.

1.1. HSV

In computer vision, color information of an image is contained in a point called "pixel". In each pixel in HSV (Hue, Saturation, Value) color space, chromaticity (or colorfulness) is represented by hue and saturation, while intensity by brightness.

Colors are modeled or represented in color spaces to meet some standards. Some color spaces are set according to how humans perceive color, and one of these color space is HSV (Marcos et al., 2003). This simple reason motivated the authors to use HSV color space instead of RGB (Red, Green, Blue) color space since HSV color space better corresponds how people distinguish color which is necessary in skin-color selection.

In order to illustrate the HSV color space refer to Fig. 1.

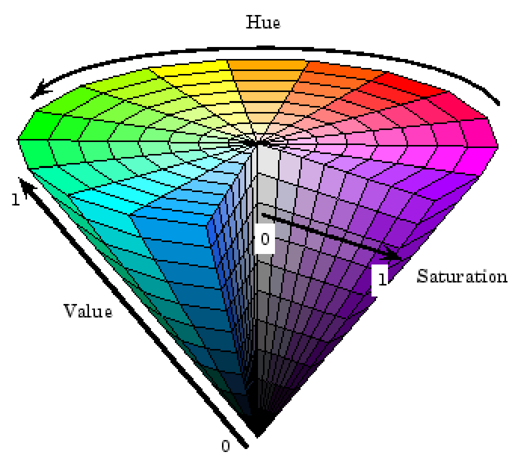


Figure 1. HSV Color Space (MathWorks, Inc, 2009).

As the value of hue varies from 0 to 1, the colors vary from red through yellow, green, cyan, blue, magenta and back to red. As the value of saturation varies from 0 to 1, the corresponding colors vary from unsaturated (shades of gray) to fully saturated (no white component). A faded color is due to a lower saturation level, meaning, the color contains more grey. And as value (brightness) varies from 0 to 1, the corresponding colors become increasingly brighter as shown in the above figure (MathWorks, Inc, 2009).

1.2. FIGURES SYNCHRONIZED SWIMMING

A *figure* is a combination of basic body positions and transitions performed in a manner and order described by the Federation Internationale de Natation (FINA) Synchronized Swimming Manual for Judges, Coaches and Referees. Body positions and transitions are the two components that define *figures.* Transition is a continuous movement from one body position to another (V. Jasontek, 2006).

Figures should be executed in a stationary position, or “on the spot”, and should also be executed in a controlled uniform motion and as high enough from the water’s surface as possible (V. Jasontek, 2006).

In this study, 3 kinds of *figures* were analyzed. These are: (a) Porpoise, (b) Neptunus, and (c) Ballerina. The transitions of each enumerated *figures* are illustrated in Fig. 2. Refer to the FINA Handbook for the detailed description of each illustrated transitions.

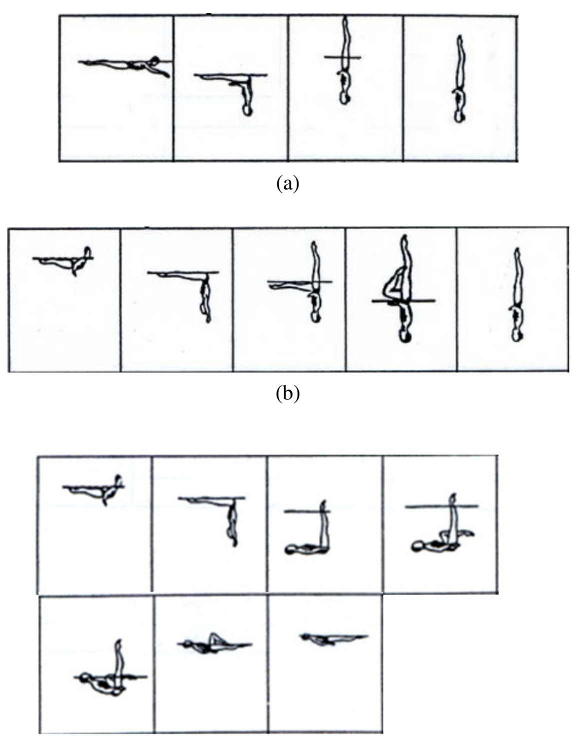


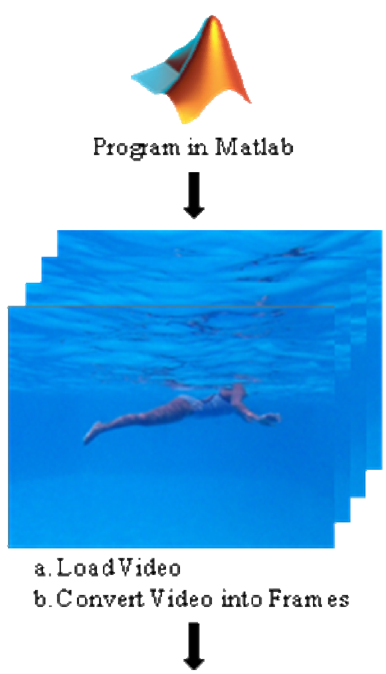
Figure 2. Figure Transitions of: (a) Porpoise, (b) Neptunus, and (c) Ballerina.

2. MATERIALS AND METHODS

A member of the *synchroswan* team from the Philippine Amateur Swimming Association (PASA) participated in the actual video recording of this study. This was conducted at the Rizal Memorial diving pool area at approximately around 9 a.m. every Saturday. The swimmer performed the 3 *figures* previously discussed. No markers were used during the recording process to minimize motion restriction. For the Porpoise and Neptunus video clips, the synchro swimmer wore a black bathing suit with black/white head cap, goggles, and nose clip. And for the Ballerina video clip, the synchro swimmer wore a blue bathing suit with red head cap, goggles, and nose clip. This set of outfit is required in figures synchronized swimming.

There are two cameras used to video record the *figures* done by the swimmer, one for the aerial view and the other one for the underwater view. The two cameras were set to video record in 320x240 resolution at 30 frames per second (fps). And they were placed at a calculated distance above or below the water level of the pool, and were oriented so that the sun's rays were directly toward the swimmer to maximize the presence of ambient light. Although there were two views to consider, only the underwater component will be discussed in this paper.

The authors used MATLAB® software as a tool to feature extract the contour of the swimmer's body given the underwater video footages. The flowchart as presented in Fig. 3 illustrates the flow of the program.



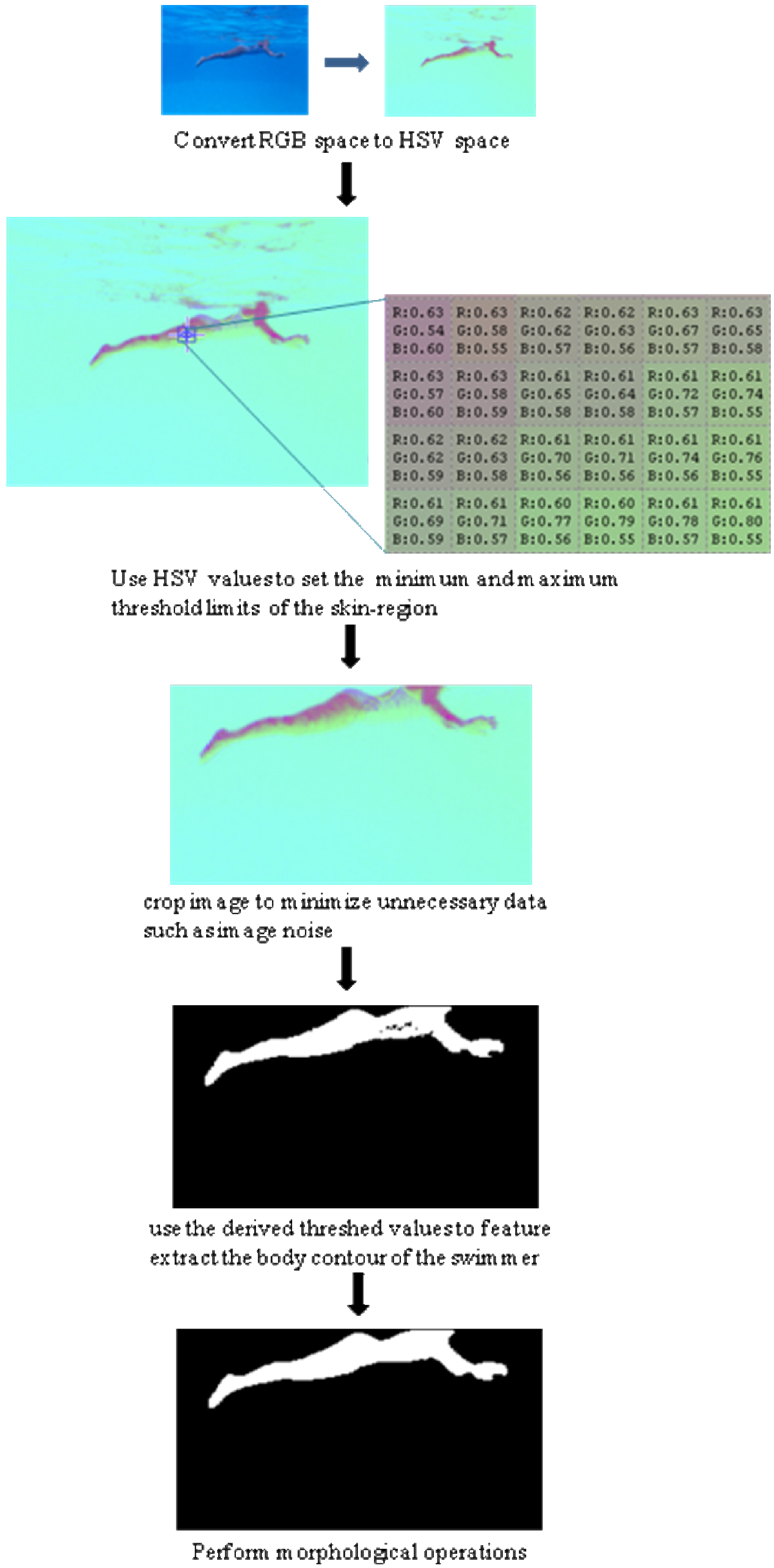


Figure 3. Flowchart of the Program Run in MATLAB®

The step-by-step procedure illustrated in Fig. 3 was utilized for the three video footages that contain the three *figures* being considered, i.e., one video footage for every *figure.* Results are shown in the following section.

3. RESULTS AND DISCUSSION

In this section, segments from the image processed videos are presented. These segments are the same transitions as illustrated in Fig. 2. Figures 4, 5, and 6, show the frame transitions of the feature extracted synchronized swimmer doing Porpoise, Neptunus, and Ballerina, respectively.

Notice at frames 163 and 199 of Fig. 6, that the left hand has been disconnected from the body. This is the effect of varying illumination underwater producing shadows at varying locations as can be seen in Fig. 7. The feature extracted anatomical parts were also dependent on the empirically extracted threshold limits.

At frames 303 and 348 of Fig. 6, the effect of internal reflection is clearly visible near the water's surface. Since the color of the reflection is somewhat similar to the skin-color region, it became visible on the binarized equivalent of the image frames.
Assessing the performance of the program used, the quality of the feature extracted images is satisfactory. The total image processing time of 82.069 seconds for the whole 12 second video of Ballerina can be further improved to optimize the program. But overall, the results here are promising, and can be incorporated with the aerial view counterpart so a detailed analysis of movements can be done.

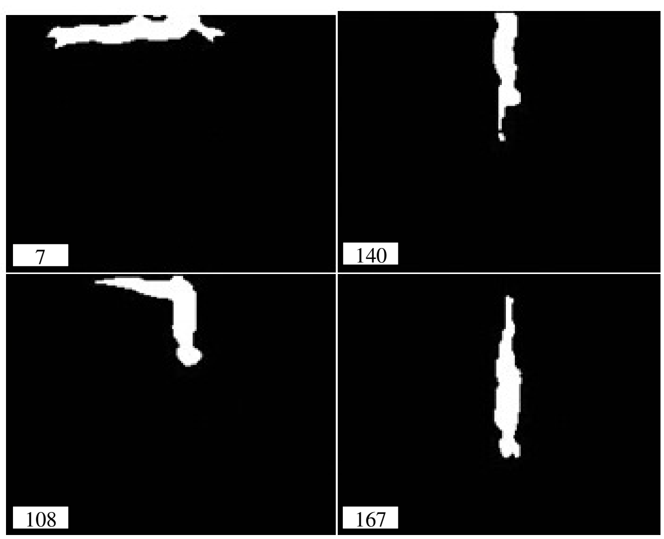


Figure 4. Transitions doing Porpoise *Figure* (frames: 7, 108, 140, and 167).

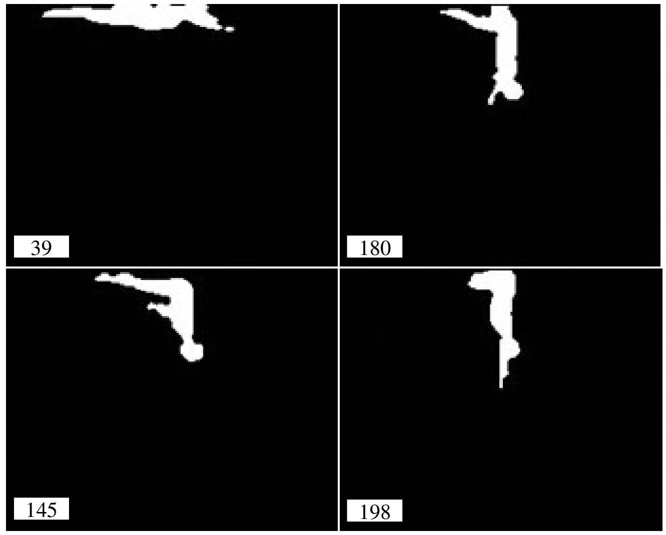


Figure 5. Transitions doing Neptunus *Figure* (frames: 39, 145, 180, and 198).

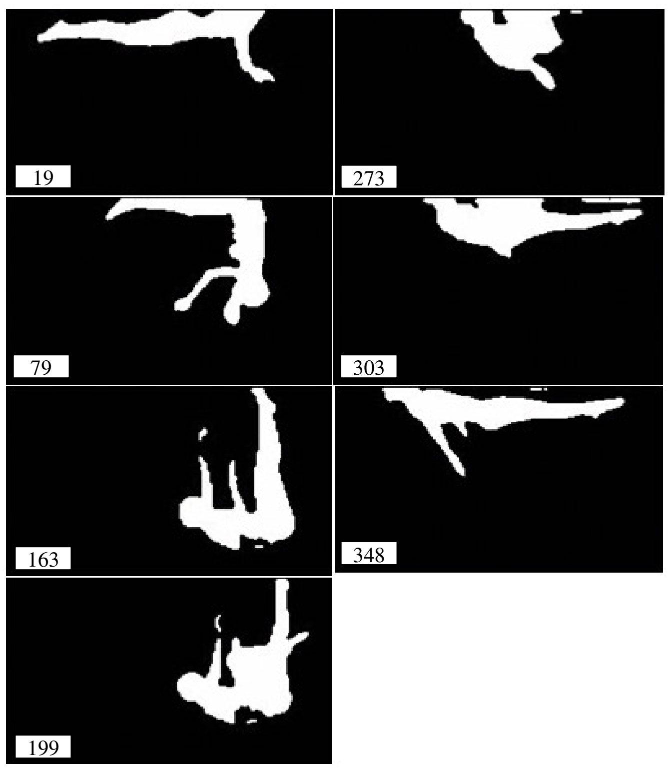


Figure 6. Transitions doing Ballerina *Figure* (frames: 19, 79, 163, 199, 273, 303, and 348).

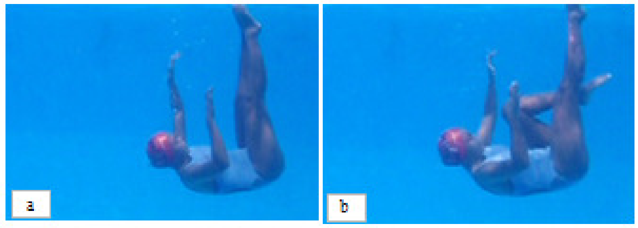


Figure 7. Ballerina Video Footage of Frame: (a) 163, and (b) 199.

4. SUMMARY

The paper “Feature Extraction of a Synchronized Swimmer from Underwater Videos” presents an image processing technique for feature extraction. The technique allowed the authors to filter the effects of noise due to internal reflections from the surface of the water and they were able to show that empirically extracted threshold limits for the skin region produced smooth feature extracted foregrounds. The work may play an important role in understanding the synchronized swimmer’s body kinematics and dynamics, and hopefully to provide greater objectivity in judging this sport.

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