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Ballet E-learning using fuzzy set induced posture recognition by piece-wise linear approximation of connected components

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ABSTRACT

The paper proposes a novel strategy of ballet e-learning for novices in remote areas. The present work is concerned with a training dataset of thirty four different ballet postures, obtained from images of trained dancers. A four-step procedure is primarily followed to extract features from the training images describing a specific posture *p*. First, the acquired images of *K* trained dancers of a specific posture *p* are pre-processed. The connected components (CCs) of the pre-processed images are then identified, followed by piece-wise linear approximation of their respective boundaries. After that, the internal angles of the polygonal boundary are used to characterize features of the given posture. This is repeated for all images of *K* trained dancers, all performing the given posture *p*. The merit of the paper lies in recasting the problem of selecting the CC boundary points for polygonal approximation as an optimization problem. The inter-subject uncertainty observed in the feature values extracted from the pre-processed images of a large number of experts/trained dancers, all executing the same posture *p*, here has been modeled by Gaussian fuzzy membership curve. The class of an unknown posture (obtained from the image of a novice) is determined by computing the support of each known posture class to the given unknown postural expression. The class with the maximum support (above a pre-defined threshold value) is declared as the conqueror. Experiments undertaken reveal that the accuracy of recognizing an unknown ballet posture of a novice, captured by a stereo camera, by the proposed stratagem is as high as 91.23%.

1. Introduction

Ballet is an artistic dance form, executed with music using distinct and highly formalized set of steps and kinesics. Originated in Italy in the fifteenth century, ballet was eventually spread to France in the seventeenth century. The present form of the dance is a result of cultural transfusion, especially from countries like France and Russia. However, the genre has a widely common standard of movements and a strict canonical manner of choreography in contradiction to the unrestricted manner of contemporary dance. Though it has been widespread in most modernized countries in the twenty first century, the rural areas are still deprived of this specialized dance form.

Current trends in all educational domains progressively make use of digital 'e-learning' technology to help novice/learners world-wide (specifically, the remote areas) to gain knowledge through Internet with interactive, self-directed learning experiences [46,47]. The 'e-learning' environment allows the learner to modulate the speed of learning, and also provides flexibility in selecting the learning sessions based on his/her personal choice. It supports the self-control over the sequence and depth of the topics to be explored by the learners based on their intrinsic motivation. A similar type of approach is followed in [46], where the authors have implemented a system for e-learning of tennis. Here, different swinging motions of the players are recorded using Nintendo Wiimote acceleration sensing device. The squared sum of the 3-axis acceleration data is taken as a relative timing reference. In the final stage, *k*-nearest neighbor is used to classify the unknown swinging motion. In another work in [47], web-camera based procedure is implemented in order to provide guidance for the robotic operation of endoscopic surgery.

The inherent advantage of e-learning lies in the effective gain of subject-specific knowledge through interactive multimedia which cannot be proficiently achieved by printed text and images. This is mostly compelling for dance education, where printed texts can never effectively reproduce the information captured by actual sequential execution of dance postures. E-learning of dance thus can efficiently balance the trade-off between the textual information of dance postures and the interactive multimedia representations of dance material.

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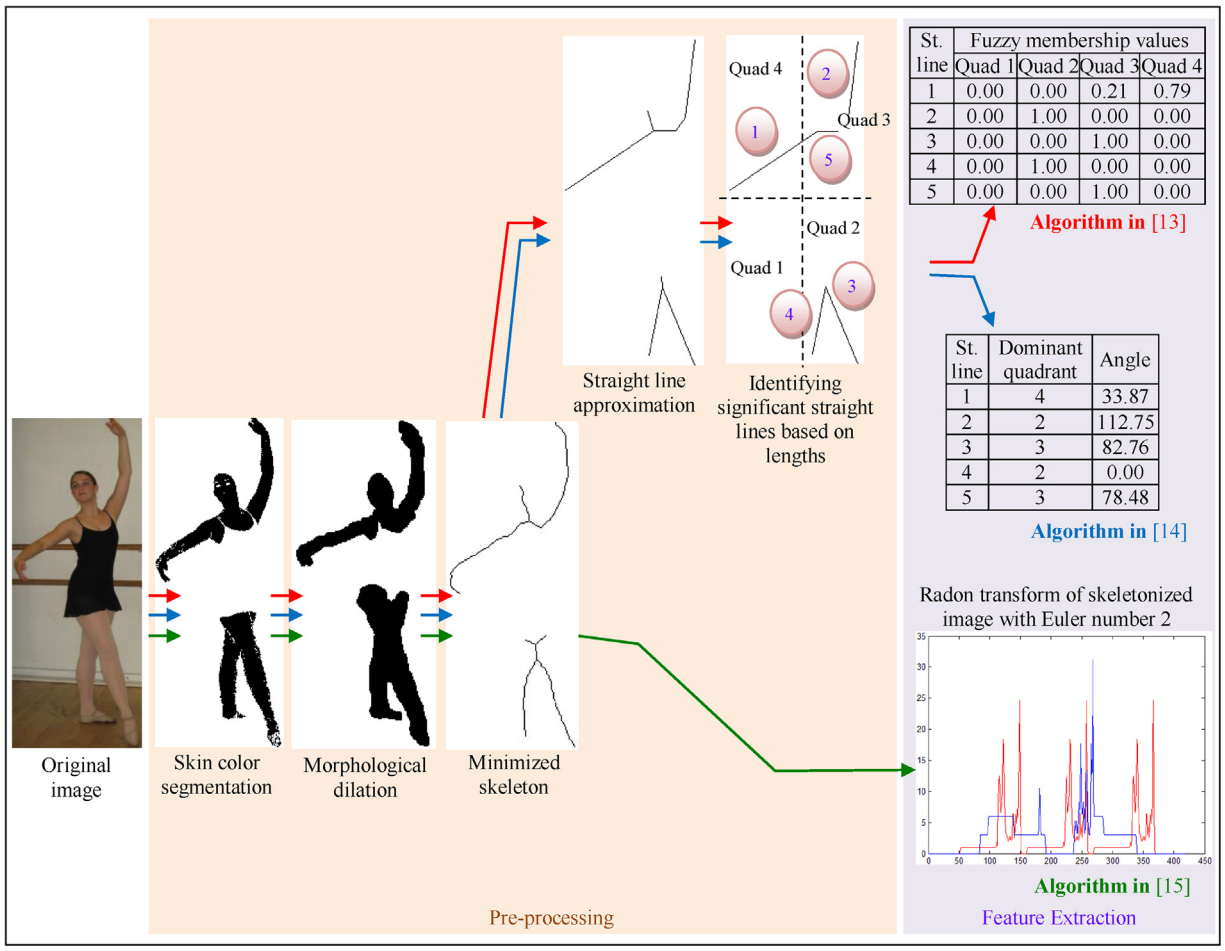

Fig. 1. Posture recognition policies proposed in [13–15] for 'Croise Devant' posture (red, blue and green arrows indicating the steps of algorithms proposed in [13–15] respectively). (For interpretation of the references to colour in this figure legend, the reader is referred to the web version of this article.)

The paper proposes a novel approach of ballet e-learning for novice/learners of remote areas. The merit of the paper lies in jointly satisfying two objectives of dance e-learning.

1. It helps a novice of remote area to identify, and thus execute, the dance postures obtained from sequential frames of a video. The video may be obtained from internet or from renowned dance school.
2. To identify the degree of accuracy in postural execution by a novice, a two-step procedure is followed.

(i) The postures of the novice are first recorded by single stereo-camera, placed nearly parallel to the body plane, during execution of postures following that of video frames.
(ii) The captured images are then processed to recognize the posture executed by the novice. If it results in the same posture of the respective video frame, the proposed methodology is also able to indicate the degree of correctness in postural execution.

It is evident from the above discussion that one significant issue of the work is to correctly identify the posture executed by a learner from the captured image. For recognition of unknown posture of an image, we have constructed a training dataset, consisting of postural features extracted from different images of all concerned postures, executed by a number of experts. To accomplish this, all the training images of a specific dance posture p (of trained dancers/experts) are first pre-processed. The *connected components* (*CC*s) are then identified from the pre-processed images. To extract features from the *CC*s, the *CC* boundary is piece-wise linearly approximated by a sequence of N (pre-defined) straight lines. Here lies the importance of the paper of formulating the problem of piece-wise linear approximation of a *CC* in optimization setting. The objective here is to optimally identify N boundary points of each *CC* such that on joining these N points (in proper sequence), the resulting polygonal boundary will closely approximate the true *CC*. Any well-known optimization algorithm could be used to solve this optimization. However, we have selected *artificial bee colony* (ABC) due to its established performance in the optimization domain [1,2]. Next, the set of N internal angles obtained from the approximated polygonal *CC* boundary (with N straight lines) are used to represent the given *CC* in the feature space. A training dataset of a specific posture p is finally created by the postural features (i.e., N internal angles) extracted from the recognized *CC*s of pre-processed images of dance experts, all executing the same ballet posture p. This process is repeated for all postures considered in the paper.

The present work aims at e-learning of thirty four ballet postures from the respective features of the trained dancers in videos. However, the postural features greatly depend on the physical states of the trained dancers. For example, different trained dancers exhibiting the same posture p (of a specific video) may have diversities in their postural features (i.e., the N internal angles of the *CC*s extracted from the respective images). Experiments undertaken with a large number of trained dancers, all executing same dance posture, reveal a small but random variation of their postural features around specific fixed points. *Fuzzy set* is here used to capture the uncertainty present in the given postural expression