# Generation and Visualization of Tennis Swing Motion by Conditional Variational RNN with Hidden Markov Model

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## Abstract

In tennis, mastering the appropriate swing motion is important because we transfer the energy from our body into the ball via the racket to generate speed and spin of the ball. For learning motion, the system that makes a player follow recorded teacher motions was proposed and this method is more effective than the traditional coaching (Todorov et al., 1997). However, some limitations exist for this system. This system used pre-recorded motions but the tennis swing has too much variety to be recorded because players have to adjust their motion into the hitting point. Moreover, the direct comparison between motions is difficult because a motion is the sequence of high dimensional data.

To overcome this problem, we propose a conditional generative model that generates a teacher swing motion for the hitting point specified by the user and encodes a motion into a trajectory in low dimensional latent space for easy comparison between the teacher's motion and that of the user. In particular, we extend the variational recurrent neural network (Chung et al., 2015) into the conditional model (CVRNN) to generate swing motion conditioned on the hitting point. And, we integrate the state sequence of the motion (ex. split step, forehand backswing, backhand backswing, forehand forward stroke) into this model as observable variables to promote transition of the motion because motions generated by the CVRNN stacked at the forehand backswing and the CVRNN couldn't generate various swing motions (Fig. 1). Moreover, we combine the hidden Markov model (HMM) into this model and the HMM aligns the state sequence in an unsupervised way. The CVRNN and the HMM are trained iteratively.

In our experiments, 64 forehand and 60 backhand swing motions of Roger Federer, variable-length sequence of 3-dimensional coordinates of 17 joint's positions, and the hitting point for each swing motion were used. Our results showed that the CVRNN with HMM generated various swings (Fig. 1). Moreover, the CVRNN with HMM encoded the swing motions into entangled trajectories in the low dimensional latent space for different types of the swing motion (Fig. 2). These results implies that the CVRNN with HMM might be used for generating various teacher swing motions and encoding a motion into a easily comparable trajectory in the low dimensional latent space.

**Keywords:** tennis swing, visualization, generative model, neural network

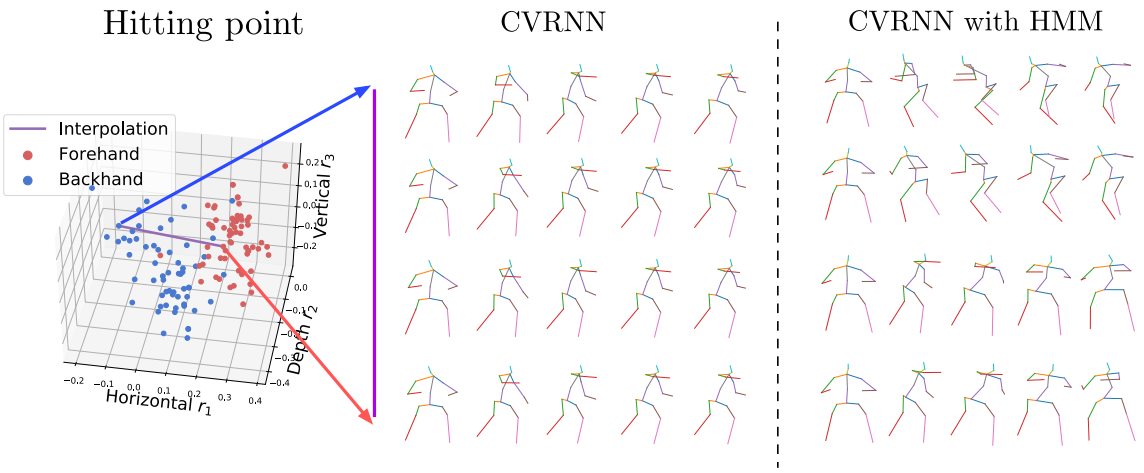
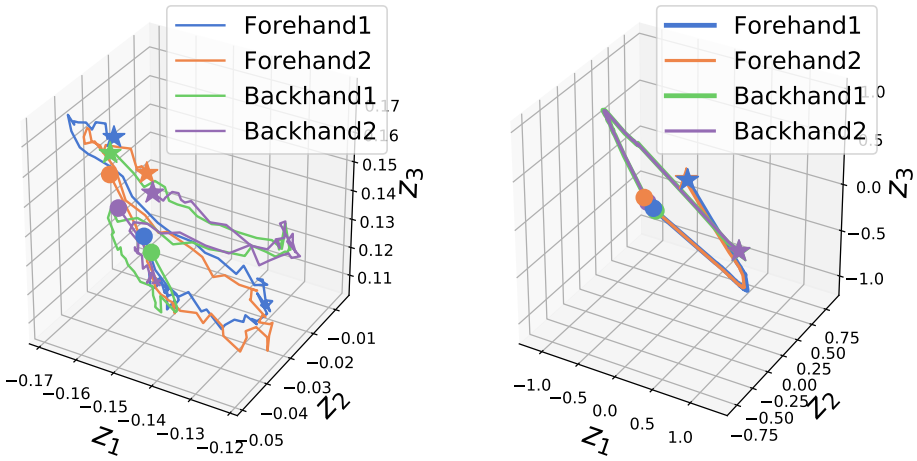



Figure 1: Generation of swing motions by the CVRNN and the CVRNN with HMM.




($a$) CVRNN ($b$) CVRNN with HMM

Figure 2: Trajectories of the encodings of swing motions in the latent space. Note that the circle is the start point of the motion and the star is the end point of the motion.

## References

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