AUTOMATED GAP-FILLING ALGORITHM FOR KINETIC DATA OF FINGER MOVEMENT: PIANIST HAND MOTION CLEANING USING SPATIO-TEMPORAL IMPUTATION

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INTRODUCTION

Notably, kinematic data are essential to examine various aspects of the piano performance as "art," including the levels of individualized techniques by a professional pianist, etc. For relatively accurate data acquisition, the approach of marker-based capture is employed. However, missing data points during capturing and incorrect embedment of pre-defined body models during data processing seems to be inevitable drawbacks due to the nature of finger movements of piano performance. Therefore, we propose a specialized framework for cleaning hand motion data without an explicit hand model by applying general imputation and interpolation techniques.

METHODS

We captured 86 trials (about *20sec* each) of performances of a pianist. We attached 54 (4mm diameter) reflective markers to both hands and fingers (Figure 1). We used eight infrared cameras to record kinematic data at 120Hz. We separated 9 trials and randomly erased 10% of the data for the test. In addition, the velocity of each key depression is recorded with the recordable piano (Yamaha Disklavier C7). The average missing ratio was 19.6% for the fingertips and 14.6% for all data points. The imputation procedure consisted of four steps: 1) Points on the back of the hand are imputed with iterative linear imputation (MICE) [1], and we transform the all points according to the back of the local hand coordinate (Figure 1). 2) Outlier detection was performed. Points with longer or smaller than 20% of segment length or points with large covariance in Elliptic Envelope [2] were removed. 3) Spatial interpolation: For fingers, we iteratively applied radial basis function interpolation. We interpolated a point per step, and the orders were determined by considering the degree of freedom of the finger movement. 4) Temporal interpolation: Temporal cubic split interpolation were used to smooth the unwanted fluctuation.

We evaluated the reconstruction error of the missing points in mean square error (MSE) and the Pearson correlation between the vertical velocity of fingers and the recorded note velocity. The maximum velocity for 0.3*sec* before the key depression was used.

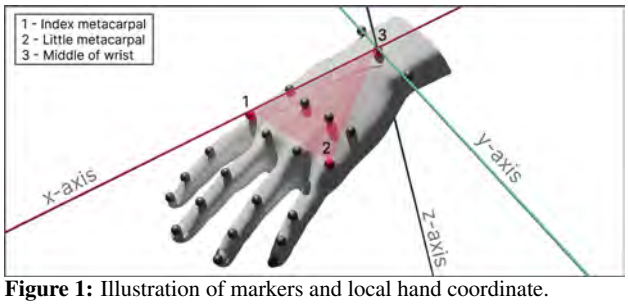

Figure 1: Illustration of markers and local hand coordinate.

RESULTS AND CONCLUSIONS

Our framework not only imputes all missing points, but also reduces reconstruction errors significantly as shown in Table 1. Although the velocity correlation in our framework is somewhat lower than that in the raw data, the imputed data preserve the natural movement of the keystrokes welgiven that it contains significantly more imputed keystrokes (260 additional imputed keystrokes). Our framework is generally applicable because it operates without a prior model and requires only a very small data set.

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Table 1: Evaluation Results. The unit of MSE is *cm*

	Reconstruction Errors				Key Depression Velocity Corr.		
	Average MSE	Backhand MSE	Finger MSE	FingerTip MSE	Correlation	p-value	#N note
RAW	-	-	-	-	.622	1.43e-7	1224
MICE (Baseline)	1.904	1.160	2.595	2.531	.270	.0296	1484
Spatial Interpolation	2.007	1.160	2.793	2.157	.156	.214	1484
+Temporal Interpolation	0.698	0.437	0.941	0.761	.553	1.76e-6	1484