**Movement morphemes underlying classical dance: A computational approach**

**Mira Berthold**[1], Maximilian Stasica[1], Martin Puttke[2], André Seyfarth[1]
[1]Lauflabor Locomotion Laboratory, Institute of Sports Science and Centre for Cognitive Science, Technische Universität Darmstadt, Darmstadt, Germany
[2]DANAMOS®, Berlin, Germany
Email: mira.berthold@stud.tu-darmstadt.de

## Summary

The concept of basic movement principles – so called *morphemes* – underlying classical dance has previously been established using intuition and experience of dance professionals. This work provides a computational framework to kinematically separate the seven morphemes and identify them within a multitude of dance movements. Moving further, we aim to convert the framework into a tool usable by practitioners. We envision to utilize the knowledge gained to establish movement morphemes for a broader purpose up to the complete human movement system.

## Introduction

The canon of classical dance is a set of well-defined movements that requires year-long training to master [1]. Albeit the great diversity of movements in dance, it is theorized that all the movements of the classical canon rely on combinations of seven basic movement primitives – called *morphemes* [2]. While previous findings support the idea of these morphemes [3,4] they have not yet been mathematically formalized. We therefore propose a computational approach to distinguish these morphemes based on biomechanical parameters.

## Methods

Kinematic data were calculated from distinct labelled repetitions of the seven morphemes, which were collected from N = 8 participants. These data were then used to train a support vector machine (SVM) based on the MATLAB Classification Learner tool to distinguish between the different morphemes. The Cubic Gaussian SVM classifier showed the highest level of accuracy ($p_{Correct}$ = 95.1 %) in the training set. The SVM was then tested using a set of kinematic data obtained from repetitions from five different ballet jumps – namely sauté, petit pas jeté, changement du pied, tour en l'air and sissone ouverte par developpé – as well as a pirouette and a battement. The SVM was tasked to label each singular movement with the most prominent morpheme. The labels assigned by the SVM were then compared to labels provided by an experienced dance teacher. The test-movements were performed by N = 21 participants ranging from students to professional ballet dancers and children from a ballet school. Note, that due to the varying levels in experience not all variations could be performed by every participant.

## Results and Discussion

Due to an ambiguity in the data used in the training set, producing a strong tendency towards the 7$^{th}$ morpheme, the scores for the 7$^{th}$ morpheme were not deemed reasonable and were therefore not considered in the labeling process. After this decision, the trained SVM correctly identified 42.9 % of the movements used in the test set (Table 1). Correctness was assumed, if the SVM assigned the same label as the expert. The expert pointed out that while the morphemes 3-7 may seem the most prominent visually, every movement tested relies on a sufficient execution of morphemes 1 and 2. This is reflected in the overall high scores of these morphemes. Currently, the classifier seems to struggle with the 4$^{th}$ morpheme and the sissonne ouverte par developpé. This could be improved by assigning different weights to the supporting and the free leg.

**Table 1**. The averaged scores assigned by the SVM. The automatically assigned labels are marked with circles, while the expert labels are depicted in **bold**. Higher labels denote a better fit of the movement to the category.

| **Morpheme** | **1&2** | **3** | **4** | **5** | **6** |
|---|---|---|---|---|---|
| Battement | -1.3 | (**-1.2**) | -1.9 | -2.5 | -4.1 |
| Sauté | (-1.7) | -2.5 | **-5.4** | -2.3 | -2.6 |
| Tour en l'air | -1.4 | -6.5 | **-5.5** | (-1.1) | -2.1 |
| Pirouette | -2.3 | -13 | -5.9 | (**-0.7**) | -5.9 |
| Changement | (-1.4) | -8.2 | **-4.8** | -1.6 | -1.5 |
| Petit par jeté | -1.7 | -10 | -6.6 | (**-1.4**) | -3.5 |
| Sissonne ouv. p. dev. | -3.2 | **-19** | -8.4 | (-1.0) | -9.8 |

## Conclusions

While the classifier correctly labeled 42.9 % of the movements, it deviated from the expert-labelling in 4 out of 7 test cases. The algorithm therefore needs improving with regards to the training set and improved decision boundaries of the SVM. Further, differences between the supporting and the free leg should be considered in the classifier.

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