Didactyl: Toward a Useful Computational Model of Piano Fingering

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Abstract
A core competency in piano performance is determining optimal fingerings for a given musical passage. Advice on fingering may originate from a variety of sources—the composer, editors, teachers, and competing pedagogies. Fingering decisions are further complicated by questions of musical interpretation, ergonomics, cognition, and habit. Theoretically, the search space for an ideal fingering for a piano melody is exponential in the number of notes in the melody. Each finger is a candidate for playing each of *n* notes, implying 10^n distinct finger combinations could be used. Not surprisingly, then, an effective algorithm for automatically generating optimal fingerings has remained elusive.

As part of the domestic computer music market, which had sales of $384.6 million in 2010 [1], a slew of commercial piano tutoring systems ([2]–[12]) are currently available. Each of these systems has predefined curricula, affording students and teachers little flexibility to introduce additional content or to produce more customized fingering suggestions. (At least, none advertises such flexibility as a feature.) Our aim here, then, is to develop a useful, *general-purpose* model of piano fingering, which generates *customized* fingerings for *arbitrary* content. Availability of such a model will allow users to draw on rich sources of public-domain music, like the International Music Score Library Project [13].

From a research perspective, we strive to define and eventually to extend the state of the art in the computational modeling of piano fingering. Several studies have been published on this topic ([14]–[20]), but it is difficult to compare their results. Here we describe our initial attempts (1) to reproduce these published results, (2) to define evaluation corpora to allow comparisons between the models, and (3) to publish implementations of their approaches as open-source web services.

Indeed, in some cases, systems are not described in sufficient detail in the literature, so their published results are only approximated here. In these cases, we describe the difficulties encountered. Regardless, we expect our web services and evaluation corpora to reduce opportunity costs for future researchers working in the domain. We are already conducting experiments combining methods accessed through our RESTful interface.

Through this work, we hope to gain insights into the cognition of piano performance through the long-term development of our derived model and to shed light on aspects of piano pedagogy. A readily available computational model of piano fingering should also prove useful for composers to gauge playability of passages and for publishers and educators to rate the difficulty of pieces.

Prior Art

Parncutt et al. [15] develop the first computational model of piano fingering in 1997, restricting the problem space to include only short melodic finger-legato fragments played with the right hand. This model is later improved by Jacobs [16], who modifies the heuristics used and replaces the imprecise semitone measures in the original with physical distances. A simplified, but more individualized, approach is described by Hart and colleagues [17]. These early systems all use a similar dynamic programming approach.

Viana et al. [14] and Viana [21] describe a hybrid approach that starts with an "expert system," encoding "a limited set of the most common rules" for piano fingering. It fails over to a genetic algorithm only when none of the rules applies. Each "chromosome" becomes a sequence of fingered notes, and the fitness function becomes a minimized "fingering distance."

Kasimi et al. [18] later suggest an algorithm to determine harmonic fingerings for piano. Here a fingering solution for a passage is the sequence of fingering assignments required to make the necessary transitions from one set of sounding notes to the next set, and doing so with minimum cost. They include both "horizontal" (melodic) and "vertical" (harmonic) measures in their cost calculation. Like Hart et al. [17], they explicitly suggest customizing cost estimates, but they define heuristics for easy customization.

More recently, Yonebayashi and colleagues [19] have suggested an alternative approach based on hidden Markov models and "parallel to the principle of modern speech recognition." However, they revert to considering melodies only.

De Prisco et al. [20] apply a differential genetic algorithm in what they present as a general-purpose model of musical fingering. A "chromosome" is a fingering for an entire score while a gene is an individual fingering change. They use an adaptive network-based fuzzy inference system to serve as a fitness function, trained with "*triples* of consecutive fingering-changes" from fingered scores for piano, guitar, and accordion.

Biography

David A. Randolph is Principal Staff Software Engineer at Motorola Mobility and a PhD student in the Department of Computer Science at the University of Illinois at Chicago (UIC). His research interests include music computing, educational technology, natural language processing (NLP), and biomedical informatics. At UIC, he is advised by Prof. Barbara Di Eugenio and is affiliated with the NLP Laboratory.

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