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Real-time simulation of ancient piano actions: a step towards the technician's experience

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Historical context

Everyone knows the modern piano as a standardized instrument, built almost exactly the same all over the world. Today's concept of nationalistic piano schools is merely based on piano technique, but not on the instrument's design. This used to be the case when the major pieces of today's repertoire were written. Roughly speaking, German music was played on different instruments than those used for French or Italian music. One of the earliest distinct schools, equipped with the so-called "german actions" appeared in the second half of the 18th century. In this kind of action (Figure 1), the depression of the key (1) causes the hammer (2) to be propelled towards the strings thanks to the pawl (3) which flips the hammer shank.

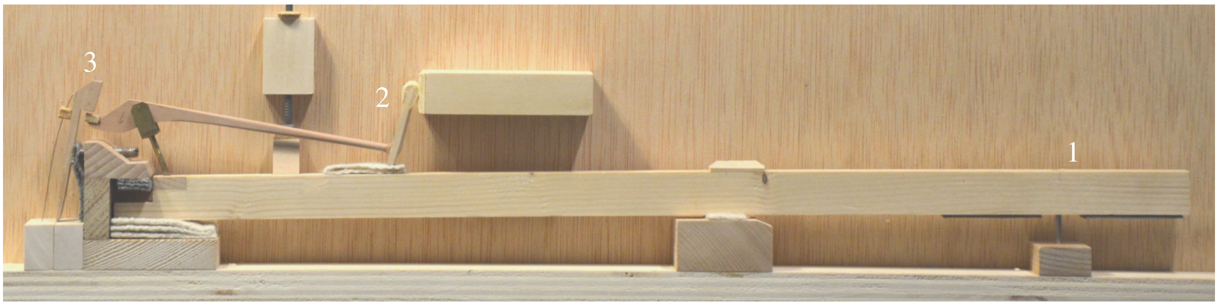

Figure 1: A reproduction of a *fortepiano* action found in the instruments of Conrad Graf.

These actions were very simple and varied only slightly in design during the time they were used. It is only in the late 19th century that they were abandoned and replaced by more complex and powerful actions. Only one of its components, the pawl, has shown a noticeable evolution in shape. The pawl of the first instruments, mainly represented by the maker Johann Andreas Stein, was mounted vertically, with a notch at 90° (Figure 2, left). Somewhat later, another more inclined version appeared, generally associated with the name of Anton Walter. In his action, the pawl is inclined and the angle of the notch is clearly less than 90° (Figure 2, right). The exact reason for this morphological evolution is still strongly debated among piano makers and musicologists. A real-time multibody model could provide some clues to this musical enigma.

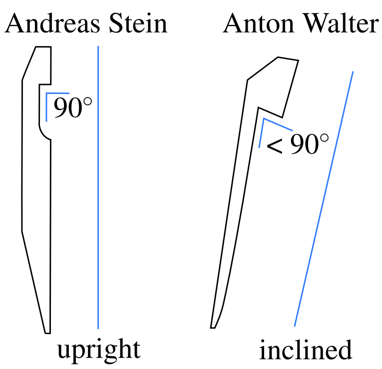

Figure 2: Two pawl designs

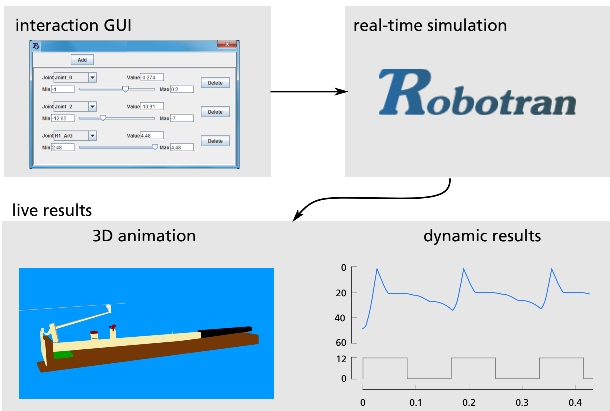

Figure 3: Virtual tuning environment

Objectives

In previous works, multibody modeling has proved to be useful when evaluating the influence of some regulation parameters on the behavior of ancient piano actions [1]. Although computational time was not a primary aim, it soon became clear that it was a strong limitation when analyzing the behavior of the model. In practice, piano technicians continuously change the regulation parameters incrementally until the action shows the desired behavior. In a simulation context, such approach seems currently unavailable in literature. Attempts have been made to obtain real-time simulations to enhance the performances of haptic keyboards, but this has implied a too great simplification of the model [2] or hasn't been completely finished [3].

A simulation of piano actions in real-time with a graphical user interface for online interaction is under development (Figure 3). The goal is to allow modifying parameters on the fly to mimic the piano tuning performed by the technician. Based on our recent experience in robotics and vehicle dynamics, we are confident to achieve a real-time virtual tuning interface (Figure 3) fully developed in a C environment for the piano action model of [1]. For the robotics and vehicle applications, no simplifications in terms of degrees of freedom or constitutive laws were necessary to reach real-time computation. This is possible thanks to the compactness of the Robotran symbolic model [4], the performance of C language and graphical libraries. The use of a suitable integrator, able to deal with stiff equations and model non-linearities is also of prime importance.

Illustrative result

A version of an action with the upright pawl has been presented in [1]. The influence of the horizontal position of the pawl on the force with which the string is struck (Figure 4) is an enriching result. This is also a good image of the sound amplitude produced by the impact. In this virtual experiment, the key is always struck with the same input. A negative displacement value (Δx) means that the pawl is shifted to the left with respect to a well regulated action ($\Delta x = 0$).

This result shows the interest of our approach in two different ways. First, it reveals the great sensitivity of the pawl on the action's behavior: a displacement of 1 mm can cause a loss of force of approximately 50 %. Secondly, these results have been obtained through distinct time-consuming simulations. The envisaged real-time tuning environment (Figure 3) will allow us to perform these virtual experiments in a continuous manner, just like piano technicians would do it.

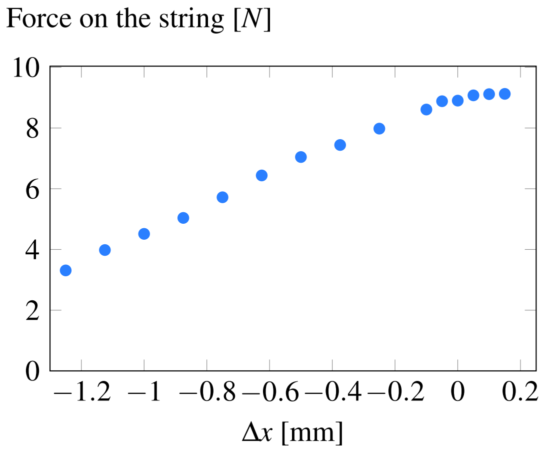

Figure 4: The relationship between force on the string and the position of the pawl is quasi linear.

References

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