

3D Visual Feedback in Learning of Piano Posture

Javier Mora¹, Won-Sook Lee^{2,*}, and Gilles Comeau³

¹ SITE, University of Ottawa, Canada
jmora091@site.uottawa.ca

² SITE, University of Ottawa, Canada
wslee@uottawa.ca

³ Department of Music, University of Ottawa, Canada
gcomeau@uottawa.ca

Abstract. An overlooked, yet essential problem in piano practice involves body posture. Bending the back, leaning towards the keys, lifting the wrist and other improper positions are usually noticed by piano teachers when instructing their students. If they sit too low, fingers will feel the burden of static arm weight; if they sit too high, the playing might become rigid with tension in wrist and shoulders. In this manner, visual feedback can help in realizing potential problems when playing the instrument. This paper discusses an innovative application of the techniques used for the 3D visualization of piano performances in any possible view, with the purpose of comparing them to a good model of someone playing the piano. It includes the capture and reconstruction of the 3D motion and posture of a professional piano player so that it may be compared against the posture and movements of students, by overlaying 2D videos of their practice session at the piano.

Keywords: 3D Visualization, motion capture, piano pedagogy, piano posture, visual feedback.

1 Introduction

Piano Pedagogy is the field which refers to the interactions between an instructor, a student and a musical instrument with the objective of the instructor teaching the students how to properly play the piano. These interactions are quite diverse and consist of verbal communications, auditory perception, visual demonstrations, physical interaction and an instructor's feedback based on audio and visual inspection and verification of the student's performance. In the last few years, the field of piano pedagogy has gradually been opening up to innovative advancements in technology in order to enhance the learning experience.

In recent years, video cameras have entered many music studios in order to support and facilitate the various interactions coming into play during a music lesson. Newsletters for piano teachers have regular columns on technology [1] with titles such as "The Video Camera: A Teacher's Best Friend". Teacher training manuals [2]

* Corresponding author.

devote whole chapters to new technology. It is now certain that the video camera and the advancement of technology have expanded the traditional piano teaching approach by enriching and diversifying the teaching tools available [3].

Professional piano teachers still rely extensively on visual observation of posture and gestures to help their students improve their performance. Experts in piano pedagogy are recognizing more and more the benefits of using visual technologies to monitor the upper and lower parts of the body, arms, and hands of piano students during live performances [4]. Such monitoring can assist piano teachers and students in evaluating piano playing more efficiently, either in real-time through instant replay [5, 6] or in delay-time through post-analysis of the performance [7].

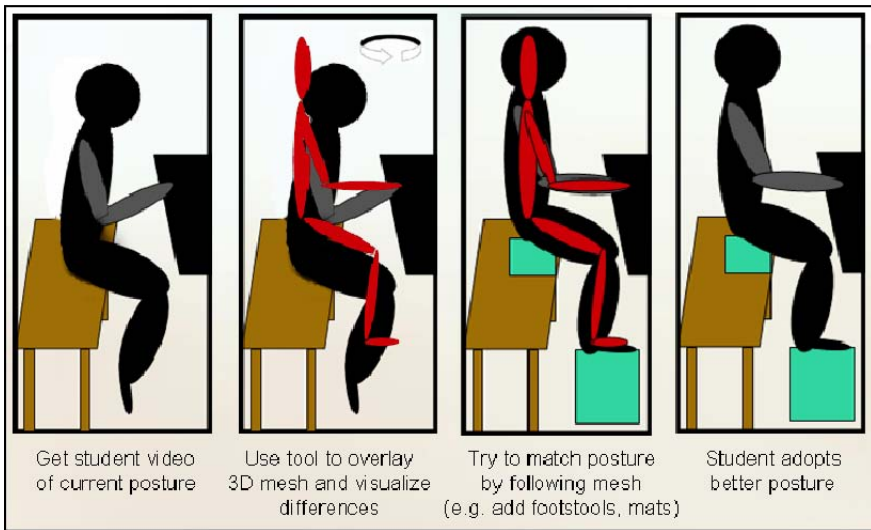


Fig. 1. A video shows incorrect body alignments of a student. By overlaying the 3D mesh of a proper posture, the student is able to visualize the mesh in any view and adopt a better posture at the piano.

In recent years, we have witnessed significant advancements in human-computer interfaces and interaction capabilities. In addition, advancements in 3D video technology, motion capture (MoCap) and Virtual Reality (VR) have led to a richer user experience and discrete analyzable interaction between humans and computers. So far, to our knowledge, no research has attempted to use the playback of motion capture data from professional players for piano posture lessons. It is the aim of this research project to come up with creative methods that will provide the piano instructor and the piano student with a rich and unprecedented experience in understanding correct piano postures with the support of a 3D reconstruction model.

As shown in Figure 1, the idea of the project is to provide a tool that when used, relevant posture suggestions can be determined by comparing the student posture on video, with a 3D mesh representation of a good posture. The tool helps the user visualize these differences in posture and once they have been observed, the student may proceed to make the necessary adjustments [8].

Existing research has shown that learning from self-observation through video has positive effects on a learners' skill acquisition and that video playback can support cognitive processes. This 3D pose information augmented project builds on this research to develop a tool to be used in a user friendly way during a lesson. In a particular scenario, a student's performance is recorded during a piano lesson. Through its replay, the teacher and the student can then analyze body postures and movements by comparing them with a superimposed 3D mesh of a correct posture.

2 Piano Posture

Before students develop their own unique technical habits, they should be introduced to basic knowledge of piano posture. Prof. Hao Huang [12], from Scripps College, explains some of the principles of position which affect motion. Huang suggests that bench levels must be adjusted so that forearms are lined up with the key beds, that is, slightly below the surface of the keys themselves. Students should sit towards the front edge of the bench in order to emphasize the balance and body orientation in leaning towards the keyboard. It is also important to sit far enough away from the keyboard that elbows find some latitude of motion, so that they do not keep bumping into the torso as arms cross the body. The ideal shoulder position is achieved not so much by pressing shoulders down, as much as bringing them back and away from the neck. If feet are not touching the ground, an unbridgeable chasm is created between the body and the keyboard, affecting body posture. As shown in Figure 1, the use of gym-mats or footstools could be used to cope with this problem.

The use of this 3D visualization project may offer a technological aid in enhancing the education of piano posture. By overlaying the 3D representation of a proper posture on top of a student's video clip, visual comparisons can be made and proper posture adjustments can be adopted by piano students.

3 3D Feedback of a Good Model

This 3D learning project includes a set of areas that deal with different technologies utilized in this approach:

- A. Motion Capture: method for cleaning and reconstructing the captured data, minimizing errors caused by missing information, reconstruction of the skeleton and its conversion to proper BVH format.
- B. Features and User-Interface: deals with the display of the BVH skeleton and 3D data, overlay of AVI videos, and the implementation of additional features to the interface.

3.1 Motion Capture

A VICON MX 3D Motion Capture System [9] was used to record the posture and movements of a professional piano player. The system consisted of eight infrared cameras which captured the 3D position in space of the reflective markers positioned along the body of the pianist. As shown in Figure 2, there were on average 79 markers

across different trials in order to record the position of relevant body components. Trials included drop and rolls, slurs, legatos, staccatos and scales. Taking into account MoCap reconstruction requirements, markers were positioned following the educational advice of a professional musician and Eutony therapist.

The captured data goes through a labeling and cleaning process. That process includes fixing broken trajectories, removing flickering, crossovers, and phantom markers caused by noise, minimizing clothe movements as well as errors in camera calibration. A low-pass filter is used to block unwanted high-frequencies that represent spikes in the trajectories.

The skeleton is reconstructed using a VICON anatomical converter that notes the position of the markers and estimates the position of the skeletal joints. The output of this reconstruction is a set of ASF/AMC motion capture files, in which the ASF file contains the skeletal information while the AMC file contains the motion information. Using Autodesk | Alias MotionBuilder [10], these files are subsequently converted into a BVH format that encapsulates the ASF and AMC data into one file.

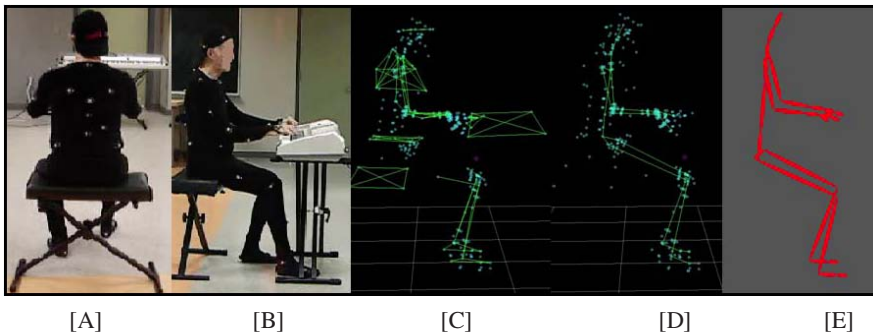


Fig. 2. [A] Back view of subject and its markers. [B] Data is acquired via Motion Capture System. [C] Markers are cleaned and labeled. [D] Anatomical converter estimates joints. [E] Data is converted to .BVH to use with tool.

3.2 User-Interface

Display of BVH Skeleton and 3D Data. Figure 3 provides a sample BVH format hierarchy. This ASCII file is easy to read and it is supported by many motion capture devices on the market. This format can store motion for a hierarchical skeleton. The motion of the child bone is directly dependent on the motion of the parent bone. In this sample, the bone “Hips” is the root of the skeleton. All other bones are children of the bone “Hips”. The rotation of the “LeftHip” is added to the rotation and translation of the root “Hips”, and so on. At the beginning of the BVH file, the skeletal hierarchy is described by using matching opening and closing curly brackets. After the last curly bracket, the motion data is presented.

BVH files can be loaded onto an MFC/Open GL application from the Game Developer Magazine [11] that keeps track of the loaded bones, their movements and their displays into the drawing scene. The application source code is expanded and modified in order to incorporate the relevant features of the project.

```

HIERARCHY
ROOT Hips
{
  OFFSET 0 0 0
  CHANNELS 6 Xposition Yposition Zposition Xrotation Yrotation Zrotation
  JOINT LeftHip
  {
    OFFSET 3.5 0 0
    CHANNELS 3 Xrotation Yrotation Zrotation
    JOINT LeftKnee
    {
      OFFSET 0 -13.4 0
      CHANNELS 3 Xrotation Yrotation Zrotation
      JOINT LeftAnkle
      {
        OFFSET 0 -16.0 0
        CHANNELS 3 Xrotation Yrotation Zrotation
        End Site
        {
          OFFSET 0 -5.23376 0
        }
      }
    }
  }
}
...
}

MOTION
Frames: 19
Frame Time: 0.0333333
0.00 48.1698 0.00 0.91267 ...
...

```

Fig. 3. Sample BVH file

Overlay of AVI Videos. The implemented framework for this project incorporates an OpenGL rendering scene in which a plane is drawn on the background of the scene. 2D videos in AVI format captured at the piano studio are edited, resized and texture mapped into the plane. In addition, frames are loaded and played back to the user. This feature enables the user to appreciate the difference between the captured video and the 3D mesh that is rendered on top of it.

Skeleton Individualization. Not all students have the same body lengths and proportions; therefore, the tool provides a way to edit bone lengths on-the-go and adjust the body size of the 3D mesh to that of the video. Each bone is labeled and identified with a unique number that can be referenced through the interface. This permits each skeletal bone length to be adapted according to the user's needs.

Since the BVH skeleton is organized in a structural hierarchy, modifications to the length of a parent bone will automatically update the relative 3D position of any children that the modified bone may have. These length modifications can be saved as a new BVH skeleton file that is particular to an individual person. As a result, these new generated files can later be reloaded and re-used for new individual comparisons.

Additional Features. In case of the mesh occluding parts of the video, setting transparency values permit users to adjust the opacity of the mesh so that they are able to see-through the representation. Custom video loading permits the user to browse and select a particular video for the purpose of posture comparison. In addition, custom animation loading permits the selection of different BVH files that contain different piano performances.

Since pianist students may be wearing different color of clothes every time a video is taken, the color of the mesh is also changeable as to avoid confusion in colors when overlaying the 3D mesh on top of the video. The type of the mesh can also be toggled from a wired to a solid representation based on the user's choice. In addition, a "Lights ON/OFF" feature activates the OPENGL `glEnable(GL_LIGHTING)` command in order to toggle between focus on the video and focus on the mesh.

4 Results

As discussed earlier, building on existing research has shown that learning from self-observation through video has positive effects on a learner's skill acquisition and that video playback can support cognitive processes. When piano method books are introducing piano position, they almost always show a drawing of a 90 degree hips-leg-knee angle as shown in Figure 5. However, the use of this tool, along with our motion capture, helped us realize that the posture in this joint actually presents a slight decrease on a right angle due to pianist comfort, as observed in Figure 4.

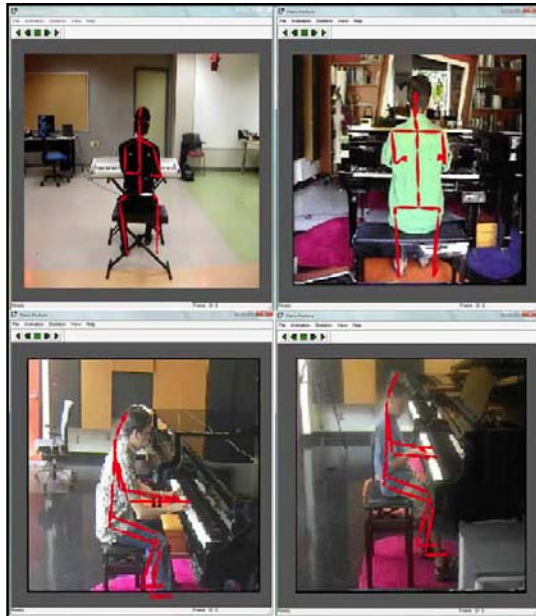


Fig. 4. A variety of experiments with different piano players were realized. The red mesh corresponds to the MoCap data that is overlaid on top of an AVI video captured at the Piano studio. The mesh can be seen from any possible angle (e.g. side, diagonal, back, top views).

The ability of the tool to reposition the mesh 360 degrees on each axis permits the user to explore the different views of the mesh in order to analyze the proper posture to adopt at the piano. For instance, as shown in Figure 4, the user is able to evaluate the posture from the back view and the side view. It enables zoom in/out to focus on particular joints and body alignments for better visualization.

A second motion capture session allowed the acquisition of new data concerning proper body positioning at the piano. The obtained information permitted the realization of experiments and the expansion of posture data that is useful for comparisons and analysis. The tracking of body markers on a different subject allowed the verification of general body postures consistently perceived on different professional piano players. The resulting information was presented to a university class in order to undergo a user study and obtain professional feedback.

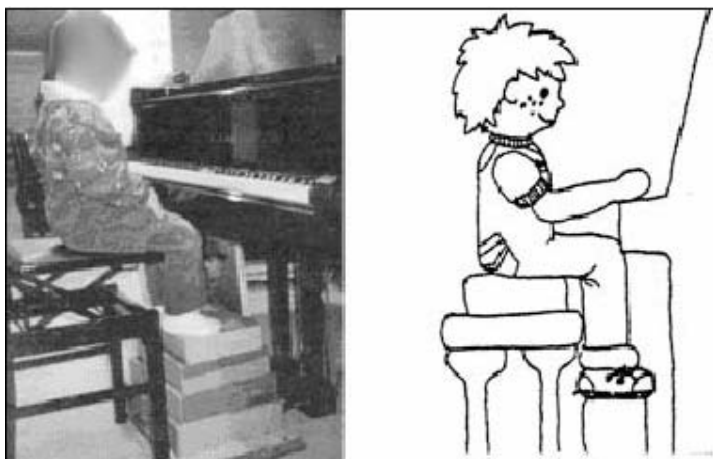


Fig. 5. Common ninety degree angle assumption on hips-leg-knee alignments [15]

5 User Study

In order to acquire relevant feedback about the usefulness of the described tool, the software was presented to eighteen students of a 4th year undergraduate piano pedagogy class at the University of Ottawa's Department of Music. Most of these students had been practicing piano for over 10 years and also had experience teaching piano to young children. Their tutoring experience ranged from a few months to many years. On average, they had taught three to five years through part-time private piano lessons.

Some interesting comments and critiques were raised during the presentation. In summary, the interviewed students believed that this tool can be perceived as a fun attractive way to capture apprentices' attention, and that it permits to teach children acceptable postures at the piano. However, they were mainly concerned about the usability of the tool's user interface. They believed that the tool's navigation was time-consuming and that it required considerable effort from the user to get relevant information. This may become an obstacle that affects time constraints during piano lessons. The students would have liked a higher variety of presets that may facilitate and speed up the navigation.

The software 3D mesh limits itself to a skeletal representation which cannot match the same amount of information complexity to that of a full 3D body mesh representation. However, the students excitingly appreciated the fact that they were able to observe body positions and have accessibility to comparison capabilities. This feature makes a strong impression that facilitates the comparison task when users need to check body postures. In addition, the interviewed students also thought that it would be interesting to focus analysis on hand posture and capabilities of zooming the loaded videos.

The surveyed class proposed a method for integrating the developed tool into piano teaching. It would involve the development of a set of different piano exercises that

students could perform. The resulting recorded videos could then be play-backed and compared against a good 3D mesh model in order to assess the properness of the students' performance. Pre-recorded movements could also facilitate further comparisons with the 3D model.

Above all, the class valued the quality of the acquired motion captured data, and they believed it is of great value for the purpose of studying good piano playing posture. The sort of tracked information that the reflective markers captured provided valuable information to piano pedagogy itself.

6 Conclusion

The capture of a proper body posture at the piano, through the use of motion capture systems, can provide quality information to students who want to enhance and correct their position when playing the instrument. In this paper the capture and reconstruction of 3D individualized skeletal information was displayed through an interactive user-interface that permits the comparison of piano postures in any possible 3D angle.

The idea of using MoCap technology to capture posture data and impose it above a range of available studio videos proves an innovative application to enhance and offer an extra pedagogy tool for piano teaching.

Future work would include user studies such as experimentation in the piano studio with students. This could be a launching point to numerous future experiments including: user studies to compare multiple experts to see if there is indeed a common posture that experts use; studies to learn if posture is dependent on the specific piece of music being performed; studies to learn whether student posture is improved using the system; and, implementation of visualization techniques to aid in discerning differences between student and expert.

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