FUTURS FANTASTIQUES

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Grand Auditorium

Peter Broadwell, *The Pianolatron: Processing Thousands of Digitized Player Piano Rolls for Analysis and Interactive Playback*

So yeah this is a project that has the piano respond is part of a much larger project that is focusing on a collection of more than a thousand digitized piano rolls, player piano rolls from approximately 1900 to 1930. These are some of the primary contributors although there are many more.

This is a screenshot of the app if there's time at the end I'll do a demo you can also go to the URL anytime to try it out it is still in beta but it's coming along, just quickly this is the view of the app this is a piano roll that's being played.

They're pretty easy to read with this color coding, the green perforations on the left side are controlling the volume of the notes on the left half of the roll and the green perforations on the right side are controlling the volumes of the notes on the right side of the roll, and the notes here are color coded as a blue is soft and red is loud.

So just to discuss the relationship of this project to AI it's important to keep in mind that piano rolls are a type of computing data medium, they're a relative of the punch card, and that has a long history perhaps it's one of the oldest data storage and programming methods and media going back to the Jacquard loom if not earlier.

So it's a pretty straightforward transition to make a piano player piano system based on punched cards as well a continuous feed in this case. As a quick historical digression our piano roll is also featured in a prominent 20th century invention that is spread spectrum frequency hopping radio that was originally invented to avoid having torpedoes, torpedo radio guidance systems be jammed during the Second World War, and the original idea was that the torpedo and the ship would both have these player piano rolls basically running and that would determine which frequency to use at what time so then they wouldn't be jammed. The inventors were Hedy Lamarr who's a famous Hollywood actress and George Antheil who was a composer who also was very interested in mechanical devices for composition. Contrary to what Antheil said the reason the piano torpedo system never really saw use was actually it's very difficult to synchronize two player pianos that are in different places from each other. And Antheil found this out firsthand when he wrote his belly mechanic which was premiered about a century ago here in Paris, that originally called for an unlimited number of player pianos that were supposed to be synchronized but eventually were replaced by four pianos played by actual humans. And here's a

photo of Antheil climbing into his apartment above Shakespeare And Company because he had forgotten his keys.

So in the remaining time I'll just discuss a few of the computational challenges we approached we encountered with this project and how they relate to AI. I think the important thing to keep in mind is that this is using computers to read computational data, data that is already somewhat computational even if it's an analog format, so it's a little different from handwriting text recognition or OCR.

So even in the case of hole detection it can be very simple to just threshold around something that's circular and say that's a hole it usually works things that are like holes made by insects are usually detectable, sometimes they're shaped like pump on the mascot of the Musée d'Orsay (anyone been there recently? okay just thought I'd bring that up). There are some extra challenges though segmentation can be a challenge especially so continuous notes are denoted by holes being very close together, but if a piece features lots of staccato very fast notes the thresholding model may not properly segment them which is what has happened with this roll, this is the performance of Schubert's Erlkönig which if anyone's played it they know it has a lot of very fast rapid notes. We're working on ways to fix these fairly rare cases that involve basic thresholding, we instead of looking at using a hard-coded number which would be this green line we're looking for this local minimum denoted by the red line which reduces the false continuations.

Another fundamental challenge is to reproduce the expression system and the expressions that were encoded into the rolls via the holes on the left and the right margins as I've just discussed before this really comes down to a question of whether you try to model every individual component of these reproducing systems there's an extra challenge that a lot of the original recording systems were lost to history between the world wars, so they're all somewhat speculative and highly refurbished in modern versions.

What we decided to do was to take a more numerical approach and we used as a ground truth these hand nuance curves these black stenciled lines that were actually stenciled onto the rolls in the early 1900s when they were printed, and you can see these green lines on the outside are the results of our emulation of the systems that we think were happening (the pneumatic mechanisms that we think were causing these, producing these). These are actually showing the volume levels (it's a little hard to read but it's showing the relative volume levels on both sides of the keyboard. And we've gotten pretty close I think you can see they correspond fairly well so that's the level we're working at). But again these are nearly computational; nearly binary or digital encodings but they're not quite, so it's an interesting domain to be working in.

Another challenge this briefly that we encountered was actually just finding where these columns of holes actually are, because some columns don't have any notes in them because not every roll uses every node on the piano, so basically it involves counting where all of the holes appear and then trying to find a fundamental

frequency to find the exact distance between columns. So we run a fast Fourier transform on that. 99 of the time it works but there are strange corner cases: in this case we have a spurious peak in our frequency spectrum here which gives us the wrong width for the columns. This is the correct one. We have ideas about how to fix this but we haven't actually completed it yet and when it doesn't work it really doesn't work, it sounds terrible. But for about 99 of the rolls they already work.

A final challenge is just related to the fact that a piano roll has no capstan system to regulate the playback speed, so as the roll accumulates on the take-up spool it accelerates, and this actually happened during the recordings as well so we need to model it otherwise our playback will be much too slow by the time we get to the end of the roll. And this is fairly easy to model of based on the fundamental physics, but it turns out that there's a lot of variation in and what actually happens during the playback based on things like humidity and the other aspects of the system of the particular playback machine that you're using so what we've been doing is running some using some data science approaches to basically compare what an unaccelerated roll would sound like to actual recordings of refurbished player pianos playing those rolls with the acceleration that they exhibit and we match them together using some frequency spectrum matching, we use a dynamic time warping algorithm to do this kind of map matching.

And we're able to get a pretty good view of the sampled velocities across the playback time of a particular roll and so we can basically find some consensus numbers for the average acceleration rate for a particular type of a roll. As a bonus we also get the starting velocity of the roll which was not really something that could be mechanically determined by the manufacturers then, which is also part of why the torpedo would never work but we're able to get this information up for particular rolls.

And now briefly I'll try to just give a demo I don't think there's going to be the audio will work but I'll just give a brief demo of the app playing a roll maybe you'll be able to hear the audio from here. And I'll just turn up as loud as I can. We can also turn on the color coding, and we can switch to a different roll this one rolls in a different direction and we can skip to different places in the performance and everything is too slow we can speed it up. So, that's the app: I encourage all of you to try it out at your leisure.

Thanks for your time and attention.