Relating Superhuman Virtuosity to Human Performance

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Abstract :-

An exciting field of compositional endeavour is outlined in this paper. We focus upon transitions from human to beyond human performance ability founded in psychoacoustic measurement data. The challenge is to make such changes perceptually smooth and acoustically plausible. The point of greatest ambiguity and hence compositional tension is around the limits of what is humanly possible. Virtuosity contextualised accurately against human ability is much harder to design than bare feats of bravura. For convincing illusion an extrapolation of human performance characteristics to impossible tempi is necessary. This is by no means trivial given the context sensitivity of expressive deviations reported in performance research literature.

This compositional agenda is intimately linked to advances in computer music, through research into sound synthesis and the synthesis of human performance. Historical precedents in work of Nancarrow, Jaffe and others is highlighted.

Key-Words :- human performance, transhuman skill, limits of performance, computer music composition

1 Introduction

You have finally obtained the latest recording of acclaimed concert virtuoso Reilly A. Komputer. Music spreads over your expensive Ambidolbics system, evoking the best seat of the Vienna Musikvereinsaal. Reilly plays a wonderfully warm piece, very comfortable to the ear, what exquisite poise and feeling! You smile as the tempo is cranked up; this great virtuoso just couldn't stay calm for long. Gradually the accelerando is transforming the music to a moto perpetuo of rage. The notes are flying, fiery, flamboyant. You realise with a start that the speeds have already transcended the humanly possible.

This scenario is accessible with current technology given the use of a automated piano like a Disklavier. If Reilly was a violinist, such an illusion would likely require advanced sound synthesis. Developments in physical modelling could make such a composition renderable even for a string quartet or for an orchestral composition. Underlying all such work is the study of human performance, gaining data that can be extrapolated to inhuman tempi and densities of music whilst staying in touch with the human element.

This paper examines some background and approaches to the 'modulation of ability' illusion. We speak notionally of skill, yet our investigations can be widened to all sorts of human related parameters as targets for compositional study. We might wish to model the fatigue, the confidence, the proprioceptive sensations of the performer. We must also distinguish a particular focus of this paper, shifting rates of play whilst preserving sensible values in other qualities like expression, from the case where one moves from the human to the inhuman directly by also dropping all expressive deviations. All of the parameter spaces suggested by psychoacoustic data and models are up for grabs! One composer might aim to move from human to beyond human fatigue endurance, always maintaining a human tempo level. His rival could investigate the opposite, of human fatigue resources feeding inhuman tempi.

Complex models adopted from psychology and physiology will be multidimensional and parameters will show dependences. As composers, we may choose to hold some whilst modulating others. Human performance will no doubt take devious paths through the theoretical parameter spaces, paths we may match or pervert. There is no claim that movement cannot be discrete: continuous change in parameters may be useful for setting up illusions and ambiguities, but abrupt change has also proved a worthy formal device.

Previous effort in beyond human performance has achieved much working by intuition. This is a saving grace, for whatever models from the psychology of music a composer might attempt to ingest into his work, his experience as a human being would automatically allow (perhaps a more laborious, but still effective) adjustment of musical parameters to his ear.

The assumptions of this paper are such that we assume a sound quality comparable to acoustic performance for computer rendered music. Human performance informed data can still be useful outside such a scope, but the sense of illusion and tension at the edge of the superhuman will rest

upon an equivalent auditory experience to the traditional concert.

This paper will detail some sources of information for the composer of transhuman illusions in performance and synthesis research, some existing works in this category, and speculate about achievements to come.

2 The Limits of Human Performance

The trend of composers challenging performers seems a constant of musical history [16]. Look at Beethoven and Schuppanzigh or the virtuoso culture within which Liszt flourished. One only has to glimpse the dense notations of a new complexity composer like Ferneyhough to see how rigourously the demands in motor skill and concentration can be set forth for modern performers. Performers catch up: if in mid life, Nancarrow was complaining 'As long as I've been writing music I've been dreaming of getting rid of the performers' [12] yet by the time of his late fame he was accepting commissions from exceptional instrumentalists like the Arditti Quartet.

With a wealth of composers probing every instrument on the planet, a wealth of performers spending their lives in pursuit of mastery, a wealth of engineering effort that has stabilised many traditional instruments, has the cult of difficulty reached its limit? We must already be deep in diminishing returns? There is a similar controversy that arises amongst sports psychologists every Olympics. Will humans go on breaking world records? The issues take in drugs, genetics, technological improvement and the greater pool of potential competitors. Some predict near stasis now for most sports, others quote that a linear trend of improvement is still implied for decades to come [18]. Given the uncertainty over future athletic performance, let us not make the mistake of predicting the asymptotic limits of human musicians just yet. However, it is clear that there are levels of virtuosity that will remain outside human manipulation. Even Boulez could not write a pointillistic piano sonata that utterly disregards the time to move the hand from one location to another within the realm of physics.

It is taken as proven that there is room between ultimate human ability and human auditory capabilities- the Nancarrow Studies for Player Piano will do as the proof. No human will ever play Rhythm Study 3a, but one can certainly hear it and appreciate the distinct note streams.

Table 1 gathers estimates of the limits of human digital dexterity (mostly from the viewpoint of pianism), with some comparable figures. Where piano works are the target, they have been selected for a scale like toccata character, one note at a time, requiring a sustained speed over a number of measures. Ten fingered arpeggiation between hands in fixed position, glissando and chord onset asynchrony would offer faster mechanisms for playing, but are sidestepped in favour of the moto perpetuo etude.

Work	Speed	Hertz
Brandenburg no 5, 1st mvt harpsichord cadenza	demisemiquavers at 96bpm	12.8
Chopin Etude Op 10 No 4	Presto. SQ at minim= 88 per min.	11.734
Chopin Etude Op 25 No 11	Allegro con brio triplet SQ at minim= 69	13.8
Prokofiev, first piano concerto first cadenza	quintuplet SQ at minim= 88	14.67
Nancarrow Study No3a	SQ at minim= 120	16
Ligeti Etude No 10 (Bk 2) (performance instruction- at the limit of continuum)	triplets at 240 bpm	12
scales played by this author, realistic limit	demisemi at 112 bpm	14.93
'Typing world record'	37,500 key strokes over 50 minutes	12.5
'Typing speed record'- Stella Pajunas	216 words per minute- assume an average of four characters per word	14.4
piano trills [19]	12-14 notes per second	14
Toronto Conservatory Piano Syllabus 1986 (quoted in [16])	scales required at 500 notes per minute for level 12	8.34
Nancarrow timbral gliss, study 25 [12 pp 243]	175 notes in one second	175
drum and bass	semiquavers at 180 bpm=720 bpm	12
author - presto possible- one hand using quintuplets	120 bpm DSQ quintuplet	20
author- presto possible- using two hands in alternation	160 bpm DSQ quintuplet	26.67

Table 1- Estimated limits of finger repetition rates

All the human performances approximate the domain of haptic rates (below 20Hz). The limited evidence here does seem to suggest a peak of virtuosity for around 15 Hz for controlled scale figures in keeping with the toccata style.

3 Human Performance and Psychoacoustic Studies

There are a wealth of scientific studies the composer can turn to. [7] is a good starting point for current psychoacoustic research. For Ligeti's point of continuum, 20-60 milliseconds is often given for the minimum separation to differentiate musical sound events. The average listener would be able to hear a constant stream of onsets at a tempo from 1000- 3000 bpm. If our estimation of a maximum sustainable speed was that of constant demisemiquavers at 120 bpm, the performer cannot break the 1000 bpm event horizon! More likely timbre, overlap and especially reverberation give continuum, not human finger racing.

If a performer grows tired maintaining the demanding tempi near continuum, an accelerating performer will be more and more constricted by what has been called Fitt's law [10], that the time delay between productions must be proportional to the distance traversed and inversely proportional to the target area. This is critical not just to triggering events, but also in terms of the precision of pitch, dynamic and timbre. The design of the instrument is tangled up in this. The composer will observe that these problems of instrumental layout, performer fatigue and ultimately the human form itself, can be disregarded when a virtual instrument is involved, and are exactly the qualities we would bring back into our computer models in designing transhuman performance that correlates to human activity.

That our tradition of music has performances carry expressive deviations in note length, in pitch, in attack and any other parameter a performer can wring from their instrument to convey their passions, is a central area of study in the psychology of music [5, 11]. [26], whose subjects included Boulez, demonstrates how much human beings tend to deviate from strict time values- 'in five initial experiments we found that…our subjects exhibited systematic and substantial errors'. Such empirical investigation into expressive performance allows the application of data and models to synthesis.

As alluded to earlier, changing a global parameter like tempo cannot be done independently of associated context sensitive variables like degree of expressive variation, itself tied to the parsing of musical structure. These issues are broached with verve in [6].

The restrictions of instruments themselves are of compositional interest. We can detach the strictures of fingering from physical models of the instrument. Inspiring studies for the composer may be found in [13, 21, 24]

Studies of skill acquisition, motor skills and human performance provide good reading, though most are biased towards athletics. Composers may find a dearth of specific information on musical topics, but would certainly be able to obtain interesting introductions to fatigue, concentration or training [8, 17, 25].

4 Precedents

Nancarrow's painstaking work with player pianos is the forebear of all future work in this field. He explores complex tempo ratios rigidly in his more abstract studies, but also recreates performance liberties. As an analyst notes, 'the player piano has always been for Nancarrow an opportunity to achieve rhythmic deviations Western notation does not easily acknowledge' [12]. For tight mathematical forms mechanical precision is requisite, but 'the late unmetered Studies 41, 45 and 48 approach a chaotic rhythmic energy close to that of free improvisation'. Given the many years of piano roll punching, the dedication to make expressive corrections by hand is apparent.

The fact that fast note streams blur into continuous texture has been utilised by composers for some time. [4] gives a wonderfully pertinent quotation from Ligeti in this regard, the Hungarian master discussing Continuum- 'A harpsichord has an easy touch; it can be played very fast, almost fast enough to reach the level of continuum, but not quite (it takes about eighteen separate sounds per second to reach the threshold where you can no longer make out individual notes and the limit set by the mechanism of the harpsichord is about fifteen to sixteen notes per second)'. This puts Ligeti's estimation of the discrimination of the ear (in the case of a harpsichord sound) at about 50 mS. Whilst the harpsichord cannot continuously pluck a single string at this rate, it is certainly obtainable by arpeggiation.

With his incredible enthusiasm for Nancarrow's work it is unsurprising that Ligeti has his own player piano works. Most are conversions by Jurgen Hocker of extant piano etudes, works that might be said to stretch the demands on human pianists to the limit (once again in musical history…). Two quotes from [28] concern us. On the tenth etude involved in table 1, 'the ultra-rapid repeated notes of which are a test of the piano

mechanism as well as the pianist- Ligeti asks here for 'almost the speed of Continuum". On the fourteenth etude, the only work conceived originally for player piano, Toop writes 'It is precisely the humane and humanist dimensions that Ligeti's studies add to the mechanical intricacies of his models that underpin their aesthetic status'. Such human related mechanical virtuosity is a theme in deep resonance with this paper.

The overloading of performers, the overstretching of humans to their limits is a central concern of the new music movement of complexity, one of whose most famous exponents is Ferneyhough. The discoveries and compositional practises of this field can be invaluable to any composer seeking some base of knowledge of human performance limitations. [9] reprints the introductory notes of Casandra's Dream Song - '…some of the combinations of actions specified are in any case either not literally realisable (certain dynamic groupings) or else lead to complex, partly unpredictable results…such divergencies and impurities as then follow from the natural limitations of the instrument itself may be taken to be the intentions of the composer.'

Ferneyhough works with human beings so that he might 'take advantage of these human qualities and limitations through careful, well-thought-out compositional strategies'. His understanding of human performance limitations are necessarily highly advanced. See the same paper, pg 13 for a marvellous diagram of the care that has gone into the potential fingering of what looks on the surface like a very difficult figure for the violin.

We can move beyond instrumental composition to the possibilities of computer sound synthesis. David Jaffe's Silicon Valley Breakdown [3, 15] (amazingly from 1982, very early in the development of physical modelling!) provides a wonderful example of a work taking immediate advantage of sound synthesis innovation to explore virtuosity with musicianship. The delay line string algorithms give a consistent timbre to the piece, and we hear a twenty minute confrontation of bluegrass and more abstract material. Whilst the string model is not incredibly realistic, it has the virtue of forming a consistent and interesting timbre through the twenty minute piece, with a strong sense of ensemble.

Interaction between computer and human is not prioritised in this paper, but refer to [23] for a good introduction and some sample works. Imagine though the possibilities of a computer learning the performance character of a human performer as they duet. Within the concert, the computer can extend the virtuoso's techniques beyond their abilities. Since realtime versions of the technologies demanded by transhuman performance are likely to arise after non real-time rendered examples, advances will naturally extend to live interactive works. For the ultimate computer takeover, the technical challenge of modelling a *specific* Stradivarius during a concert is formidable.

5 On Creating New Works

Let us lay down some practical notes about creating transhuman works respecting humanity.

We should be avaricious for human performance data. Composition will respect acoustics and psychoacoustics and gain principle inspiration from each new scientific study of human musicians. Physical modelling sound synthesis is the most likely provider of acoustic quality rendering appropriate to these aims.

Even without advanced models of performance, the composer still has access to a superior technology; his ears. Whilst the work may be laborious (think of poor Conlon punching rolls day after day) modern software can speed it up somewhat, and hand made expressive deviations can be added to humanise inhuman playing. Computer music composers have often added noise to onset times, amplitudes etc. to simulate expressive performance. As a first approximation this technique is very useful, but would not match real statistical analyses or the hierarchic judgements of human musicians.

Is human performance data compromised by working to the average virtuoso? A composer can gain revenge by parametrising their transhuman modulation of ability, and playing various forms to experimental test subjects. The most effective illusion to the largest audience would determine the final form for the composition.

Realistic animations are produced from motion tracking data of human subjects. Transhuman pieces could be based upon data gleaned from a specific virtuoso. Measurements taken of the expressive performance characteristics in the human range would be extrapolated into inhuman skill levels. If the human part was recorded, spectral modelling techniques on the source instrument plus room response information could provide the continuous acoustic signal data for the humanly impossible sections. Otherwise, performance data captured would inform rendering across the range, using a physical model.

It would be a wonderful task for an animation studio to construct a feature based on motion tracking of a human musician, with motion character then extrapolated in places to inhuman speeds. Transhuman music would then retain the feature of a physical performance so vital sometimes to audience response.

Recently, this author has composed two computer music works that explore transhuman (solo string) performance by the construction of large (1 gigabyte) sample databases. This approach is not recommended, not least for the timescales involved in the laborious database construction, but also for its lack of legato and deeper expressive facility in sample playback. Physical modelling would be the venue of choice for future experiments.

The same sort of comments as attend to the limits of the human body can be transferred to a discussion of the limits of mechanical instruments. A prime reason that physical modelling is promoted in connection with the artistic desires for transhuman illusion is because it may remove mechanical limitations. Physical models have the potential to give us new physical instruments, a horn that no human lung could blow, a cello with an infinitely long or circular bow so that a down bow can extend forever. Instruments of common type can be slowly morphed into one another by changing their physical characteristics during performance. A single virtual piano can play with any fundamental frequency, so even the discrete 88 piano keys are sublimed. The computer can resonate a tube above the highest harmonics excited by a French horn player. Extension of range with continuous timbre is a massive increase in compositional space. These sorts of tricks are fantastic aspects of working with physical models, but their real compositional power could be in sheer surprise. Imagine hearing what you think is an upright piano tuned in equal temperament slip into a mean tone tuned grand.

We have blithely skipped over the massive research area of physical modelling, and the control of physical models. There is no space to review references here, but the reader might find two recent papers linking synthesis and control systems of bowed string models interesting [20, 27]. With its intimate connection to the physicality of musicianship, physical modelling is already well within the ballpark of human performance. The human player as low level manipulator of their instrument is intimately tied to the higher level concepts of expression and musical feeling.

It would not go amiss to mention that the use of physical models in this work also introduces the timbral possibilities of ensemble morphing, with consistent but innovative extrapolations of real instrumental sounds. We have often restricted the discussion to single virtuosi since they are enough of a challenge on their own at present, but ensemble works are also of great potential interest. Models of ensemble [1, 2, 14, 22] are further sources for compositional parameterisation of human character, in this case, limits and behaviours of human music groups set against transhuman ensembles. Disturbing the character of ostensibly human ensembles is another great way to find new unexpecteds in composition.

6 Conclusions

Reading the patterns in a pinch of salt I confidently predict: in one hundred years time, composers with sensationally accurate computer instruments at their disposal will write transhuman works that smoothly flit between the ludicrously virtuosic and the look then play one note mentality of a beginner sight reader. Subtle deliberate mistakes will be engineered into the most exquisite and impeccable climaxes, and the critics will judge the work by the flow of its argument within multiple established models of human to inhuman transformation. God forbid that a reactionary punk movement rise from the underground promoting the extreme case of modelling failed composers and drunk orchestral musicians.

By gaining knowledge of the limits of human motor ability and characterisation of emotional expression those qualities become potentially tractable parameters in composition. Just like in any parameter space, compositions are surely wise to not always use the extremes, but to modulate from state to state. Limit information will be absolutely critical to allow artful transformations between the human and the inhuman.

Who can predict where genetic manipulation and cybernetics might take human performers, or what virtuosic demands by future composers will turn out to become second nature another generation on. The computer rendering revolution in acoustic music is perhaps lagging behind the recent blockbuster movies of the computer graphics world, but should pay exceptional dividends to composers willing to engage with its thorny technical and aesthetic issues.

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