Proceedings of the International Symposium on Music Acoustics
(Associated Meeting of the International Congress on Acoustics)
25-31 August 2010, Sydney and Katoomba, Australia

Mechanical Pipe Organ Actions and why Expression is Achieved with Rhythmic Variation Rather than Transient Control

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PACS: 43.75.Np 43.66.Ww

ABSTRACT

Whether mechanical organ actions allow organists to control the way in which they move the key and thus influence the transients has been discussed for many decades and this is often given as their main advantage. Some characteristics of mechanical pipe organ actions, notably pluck (the initial resistance felt as the pressure difference across the pallet valve is overcome, and which, due to flexibility in the action, also results in the pallet not starting to open until the key has moved a significant distance), make it difficult for the player to control the key movement and thus the transient. This project looks at how organists use rhythm and timing to play expressively. This can be through the use of deliberate "figures", or the player may be unaware that they are making such variations. These variations in style lead to clear groupings of the pressure rise profile under the pipe and thus limit the amount of transient control possible. Informal listening tests suggested that the transient variation measured were only discernable by the most highly trained listeners and may be less important than timing.

INTRODUCTION

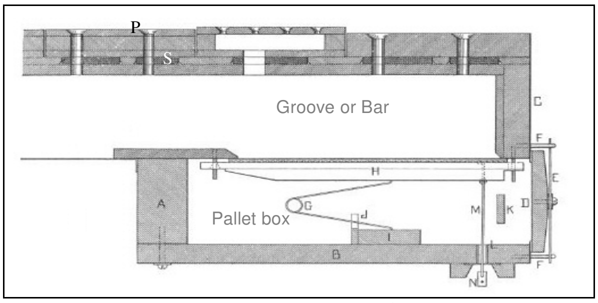
This paper is a progress report on a project funded by the Arts and Humanities Research Council at the University of Edinburgh. The project set out to investigate the extent to which organists use rhythm and timing to achieve expression on mechanical action pipe organs rather than varying the transient by the way in which they move the key. It is widely, but not universally, considered that transient control is a basic factor of organ playing. A number of prominent organists and builders, such as Noehren[1], disagree, but there is little published research.

This project originally started because of the construction of a number of large organs in the UK that have dual mechanical and electric actions. The curators of these organs reported that the mechanical consoles were hardly ever used suggesting that any advantage was not overwhelming. It also implied that there was significant unnecessary expenditure and also the probability that either or both of the actions were compromised.

The PhD[2] work that preceded this project concluded that players did not vary the way in which they moved the key to a significant extent.

BACKGROUND

The bar (groove) and slider windchest has existed more or less unchanged for some six hundred years even down to the materials generally used.



Source: (Audsley 1905)

Fig 1 Cross section of a bar (groove) and slider windchest adapted from Audsley Fig CLIX. The significant parts are: N connected to the tracker from the key and pulling open pallet H via tracker M, compass spring G providing the closing force on the pallet, pallet box containing pressurised air, bar connecting all pipes played with one key, slider S shown open so that the pipe, planted in tapered hole P, will speak when the pallet is opened

The one characteristic that defines the nature of the touch of a mechanical pipe organ action is pluck (being analogous with the feel of the plectrum plucking the string of a harpsichord. It is also called "top resistance"). Pluck is caused by the pressure difference across the closed pallet (H). Fig 1 is a modification of an illustration by Audsley of a cross section of a bar and slider windchest[3]. The bar is the channel on which all the pipes for one note are planted. The sliders (S) are movable strips, usually of wood, that determine which ranks of pipes receive air from the groove by lining up holes in the slider with corresponding holes on the top of the groove. They move perpendicular to the plane of the diagram. The pallet box (ABDH) contains pressurised air whereas the groove contains air at atmospheric pressure. The net force of the pressurised air on the bottom of the pallet has to be overcome in order for the pallet to start opening. As soon as the pallet starts opening as the tracker (attached to N) moves downwards, the pressures on either side of the pallet start to equalise and the additional force reduces very quickly (Fig 2). The feeling has been likened to pushing a finger through a thin layer of ice.

It is unlikely that the original builders of the first windchests applied theoretical fluid dynamics to the design and it seems probable that the principal advantages were ease of construction, reliability, ease of repair and positive sealing of the pallet against the opening due to the air pressure in the groove thus reducing leaks. There have been various attempts over the years to reduce pluck by changing the design of the pallet, such as by using two opposing pallets to even out the force due to the air in the windchest, but none have endured.

Possible other advantages will be discussed later.

When a note is not sounding the pallet is kept closed by the force exerted by the pallet spring and the air pressure against its lower surface. As a force is applied to the key, the various action components bend, twist, stretch and compress until sufficient energy is stored to overcome the force keeping the pallet shut. As soon as the pallet starts to open (pluck is overcome) the effect of air pressure reduces and the pallet "catches up" with the rest of the action. This is illustrated in Fig 2.

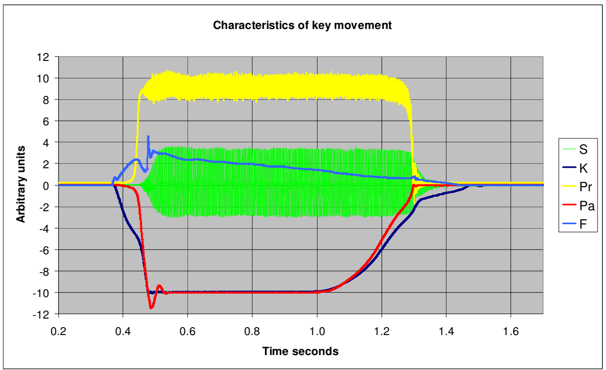


Fig 2. Graph showing key movement (K, dark blue), Pallet movement (Pa, red), wind pressure immediately under the pipe foot (Pr, yellow), force applied to key head (F, light blue) and sound recording (S, green) for a representative "slow" note on the model organ in Edinburgh University. To a constant time scale, but arbitrary units of magnitude.

The most important features of Fig 2 are:

- The key moves a significant distance before the pallet starts to open ~ 4 units
- The key slows down due to the increasing resistance as the action flexes (rollers twisting, washers compressing, levers bending etc.)
- When sufficient energy is stored in the flexed action (in this case after about 4.4mm key travel), pluck is overcome and the pallet springs open and catches up with the rest of the action
- As the resistance due to pluck is overcome the key increases in speed of movement as it is not possible to reduce the force being applied by the finger in the time available
- The air pressure in the groove starts to rise at the same time as the pallet starts to open
- The air pressure reaches a peak early in the pallet movement (after about 4.5 units pallet travel)
- The pallet starts to open at about 4 units key travel and the pressure in the groove reaches a maximum at about 5.7 units key travel out a total of 10. This is the only part of the key movement that could affect the transient and during this movement the pallet is out of control of the key.
- There is a delay before the pipe starts to speak
- The key is on the key bed and the pallet is fully open before the pipe has reached stable speech
- There is a delay before the pallet starts to close when the key is released (probably due to friction)
- Later in the release movement the pallet starts to close in advance of the key movement (due to air pressure)
- The pallet is firmly seated before the key has returned to its rest position (in this case the key has 2.3 units to travel until fully depressed)
- The sound envelope does not start to diminish until the point at which the pallet closes.
- The force applied increases until the pluck point when it reduces, although not suddenly, due to the airflow through the pallet opening applying a closing force to the pallet
- The force increases suddenly as the key hits the key bed.
- The force is gradually reduced but the key does not start returning until the force due to the pallet spring is greater than the force applied by the finger.

- There is slight increase in force as the pallet ”snaps” shut due to the flow of air through the opening . This helps to reduce leaks round the closed pallet.

The effects noted above were noted in every organ measured to a greater or lesser extent depending on the size and rigidity of the action and the magnitude of pluck, and even on a light, suspended action the effect of flexibility in the action is significant.

EARLIER MEASUREMENTS

Some tests were carried out using the University organist from Edinburgh playing the 1978 Ahrend organ in the Reid Concert Hall. This has a very light, suspended action. In the first exercise he played an improvised theme and was then asked to repeat it varying nothing but the speed of key movement. The measurements of the key movements are shown in Fig. 3 in which the curves are superimposed approximately at the pluck point. He felt that he had moved the key “five time faster” the second time (blue curve). Fig 3 does not show that the overall tempo was also faster with the fast key movement. Even on this relatively rigid action, the effect on key movement due to flexibility of the action before the pluck point (at about 0.4mm key travel) is apparent at the beginning of the key movement.

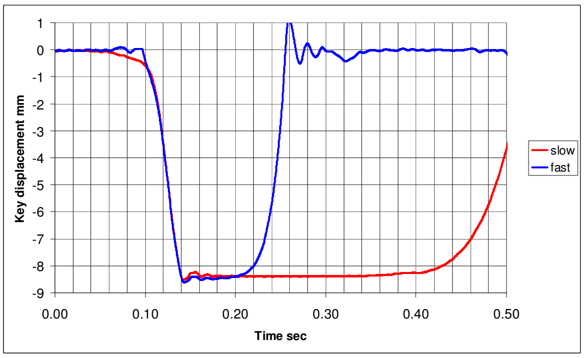


Fig 3. Key movement from two performances of the same theme. The player was asked to vary nothing but the speed of key depression, which he thought varied by a factor of five. Ahrend organ Reid Concert Hall, University of Edinburgh.

In the next exercise he tried to “accent” a note by hitting it harder. Fig 4 shows that again with the non-accented movement the effect of the flexibility of the action is apparent, but the post pluck movement is very similar in both cases.

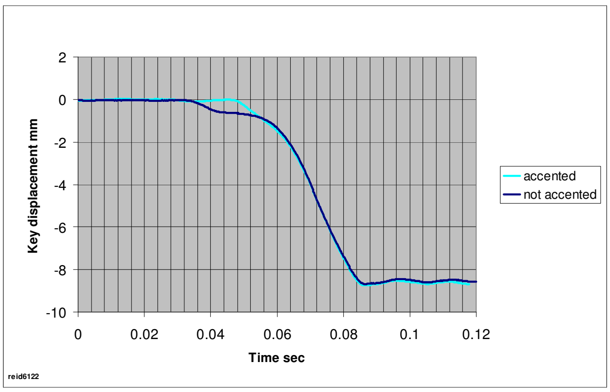


Fig 4. Graph comparing the same notes from two performances of the same sequence but with one accented by being “hit harder”. Ahrend organ Reid Concert Hall, University of Edinburgh.

A further test was designed to indicate the point at which the player perceived the note to start. He was asked to play in the two manners from Fig 3 simultaneously one octave apart. Fig 5 shows the two notes to the same time reference and indicates that the player perceived the start of the note to be the point at which the key started to move. This introduces a timing difference between the two notes of approximately 30ms as the pipes will not start to speak until after the pluck point at a displacement of approximately -1. The “slow” note will sound after the “fast” note and is also slightly longer by about 10ms.

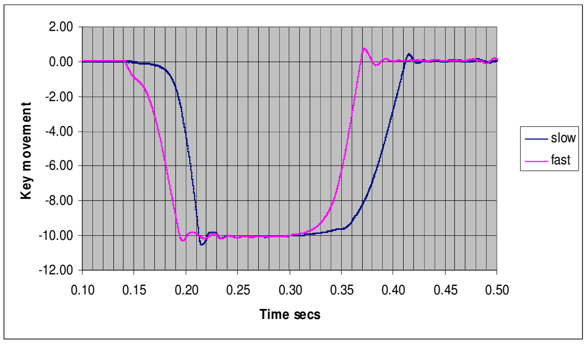


Fig 5. Two notes were played an octave apart, one with a “slow” and one with a “fast” key movement in order to establish the point at which the player perceived the note as starting. Ahrend organ Reid Concert Hall, University of Edinburgh.

CURRENT RESEARCH

Rhetorical Figures

A frequent comment by organists was that, even if it was possible to vary the way that they moved the key at the start of a piece of music, it was not possible to maintain these variations throughout a piece. One way to do this is through physical gestures at the keyboard based on the study of musical-rhetorical figures in German baroque music described by Bartel and others.[4] Speerstra[5] has studied these as part of his research into clavichord technique at the University of Göteborg. These are physical gestures based on Baroque figures that can be maintained throughout a performance.

Examples of Dr Speerstra’s figures are listed below with his descriptions and graphs of some of these showing the key movements, pallet movements, pressure rise in the groove and sound recordings. The measurements taken showed that phrasings closely followed the descriptions given, and some examples are shown below:

Transitus (Fig 6)

> Basically you are standing a certain amount of the weight of your arm on a stiffened finger with a relaxed elbow and moving from the first finger to the second without completely engaging the muscles of your arm that would lift it off the keyboard. This technique makes it easy to control heavy actions and you would expect this kind of paired fingering to have fast attacks for both notes and a longer first and third note a shorter second and fourth note and hopefully as slow a release as possible after the second and fourth note.

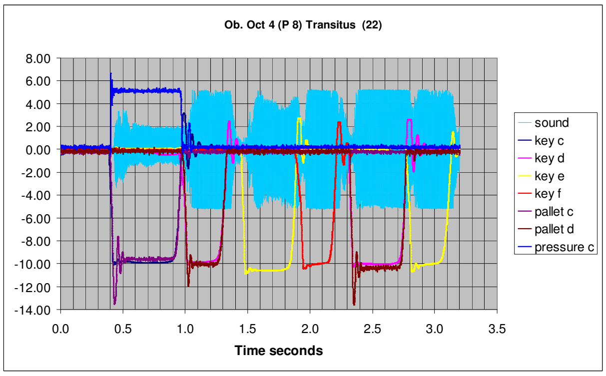


Fig 6. Graph showing the key and pallet movements. pressure in the groove and sound recording for a theme played with Transitus Rhetorical Figure. Örgryte Church, Göteborg

Suspiratio (Fig 7)

> It is a figure that starts with a rest followed by three notes, so the first note is now an upbeat and I would expect that there is a faster release after the first note and the second and third would form a pair much like the first and second in the transitus example.

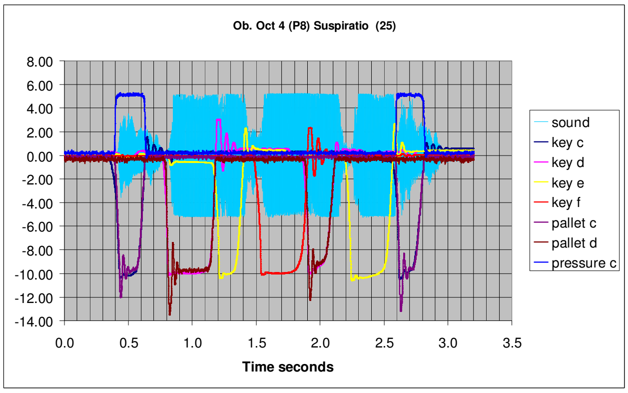


Fig 7 Graph showing the key and pallet movements. pressure in the groove and sound recording for a theme played with Suspiratio Rhetorical Figure. Örgryte Church, Göteborg

Portato (Fig 8)

> Portato [uses] separated notes but with slower attacks and releases.

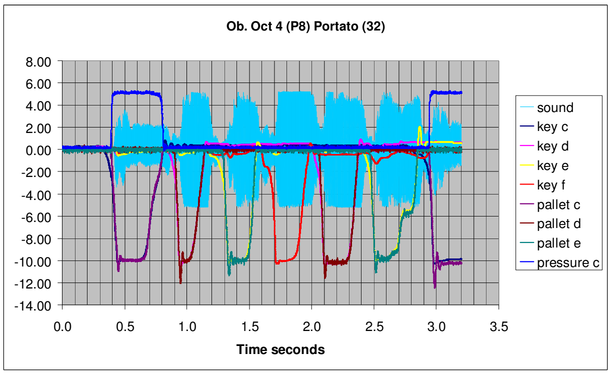


Fig 8 Graph showing the key and pallet movements. pressure in the groove and sound recording for a theme played with Portato Rhetorical Figure. Örgryte Church, Göteborg

Finger Technique.

> I think I tried to play with the fingers alone holding the arms off the keyboard and allowing the elbows to engage if they needed to. I didn't try to play in any particularly controlled manner so I expect the note lengths to be all over the place and the only thing I was trying to do was to play fast attacks.

To these can be added more familiar styles such as Legato and Staccato, although these may benefit from being more clearly defined.

Measurements were made of Dr Speerstra playing in these styles on the North German Organ in the Örgryte Church in Göteborg (built in the style of Arp Schnitger by the Göteborg Organ Art Centre [GOArt] as a research instrument). The key movement (middle C, D, E, F, pallet movement (C, D) and pressure in the groove of middle C (measured by removing the Principal 8 pipe) were measured as well as sound recordings being made. All magnitudes are to an arbitrary scale.

Fig 9 shows all of the key movements and pressure profiles for the Rhetorical Figures described above. Despite the low number of data points, it can be seen that there are two groups of key movement and two very close groups of pressure rise profiles. The graph has been produced to show the two groups superimposed within the group but separated between the groups. If the player perceives the note starting at the point at which the key starts moving there will also be time differences between the start of the notes. There is an initial pressure drop in the "faster" group. Full listening tests have not been carried out, but initial tests across a wide range of musical levels did not indicate consistent differences in transient between styles. This organ is unbushed and there is considerable action noise when keys are hit hard. This can mask the attack transient of the pipe, particularly close to the console.

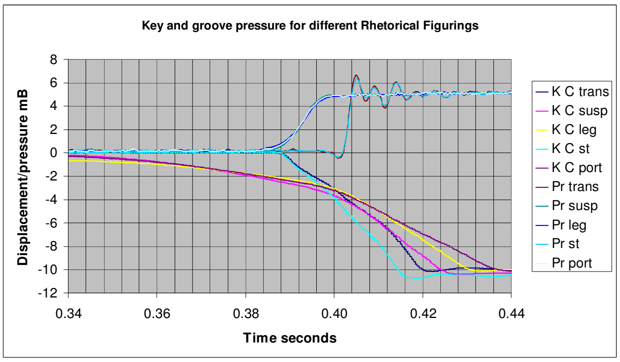


Fig 9 Graph showing key movements (K) and pressure in the groove (Pr) for the first note of a theme played with the Rhetorical Figures Transitus, Suspiratio, Legato, Staccato and Portato. Pressure curves aligned to highlight similarity. Örgryte Church, Göteborg

Other Styles

Measurements were also made on the copy of the Casparini organ of 1776 in Vilnius built by GOArt in Christ Church, Rochester, NY for the Eastman School of Music (ESM). A number of doctoral organ students played in styles of their choice that they considered resulted in variations of expression including different transients. They used their own descriptions of these styles and some of these were long and descriptive and cannot be incorporated onto the graphs. The pressure was measured directly under the pipe foot using a device made by the ESM Organ Technician, Rob Kerner and is not directly comparable with the previous example. The groupings of pressure rise profile have again been superimposed to highlight the similarities and the time scale does not represent a constant start point of the note. All recordings are of the same theme used in the previous exercise.

Fig 10 shows the measurements from the first student, CP. There appear to be three distinct groups with Group One being the left hand set of curves, Group Two the middle set and Group Three the right hand set.. The initial gradient of Group One shows some variation, but again, initial listening tests did not consistently identify differences even between the extremes of all groups. The other two groups are more closely matched. Note again the initial pressure drop in Group Three and the extreme pressure variation. There were significant variations in the overall tempo, length of individual notes, relative lengths of adjacent notes and overlap of notes.

The student's description of each of the styles is shown in the following tables:

Table 1. Descriptions of playing styles in Group One, Fig 10. Student CP

259	Classical Mendelssohn
260	Romantic pp
262	Romantic pp
265	Baroque, two beats per measure
269	Bach 1st inversion suspiratio
270	Legato

Table 2. Descriptions of playing styles in Group Two, Fig 10. Student CP

256	One accent per measure
257	One accent per measure
258	Classical Mendelssohn
266	Baroque one beat per measure
267	Baroque one beat per measure
268	Baroque two beats per measure
271	Harmonised

Table 3. Descriptions of playing styles in Group Three, Fig 10. Student CP

263	Virtuosic light fortissimo
264	Virtuosic light fortissimo

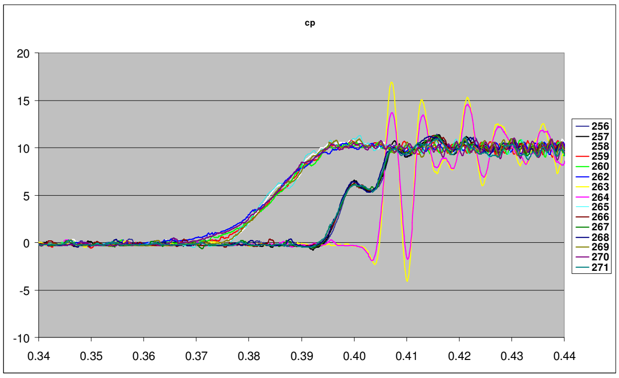


Fig 10. Graph to show groupings of the pressure rise immediately under the pipe foot of a theme played in a number of expressive styles as listed in Tables One to Three. Student CP on the Casparini copy in Christ Church Rochester, NY

One style, 266 and 268 - Baroque two beats per measure, falls into both groups one and two.

The key movements of the two extreme styles, Romantic pp and Virtuosic light ff, are shown below. Fig 11 shows Romantic pp (262)

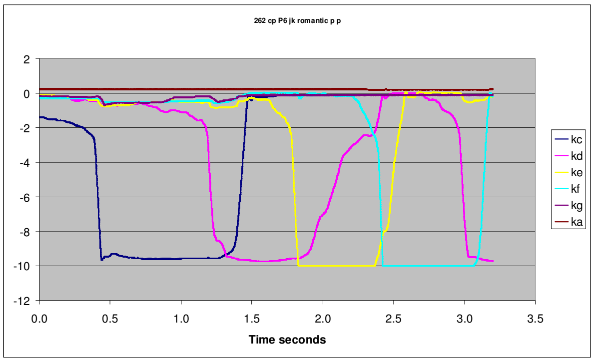


Fig 11 Graph showing the key movements of student CP playing in a style described as "Romantic pp". Casparini copy in Christ Church Rochester, NY

Fig 12 shows "Virtuosic Light ff" (263) to the same scale

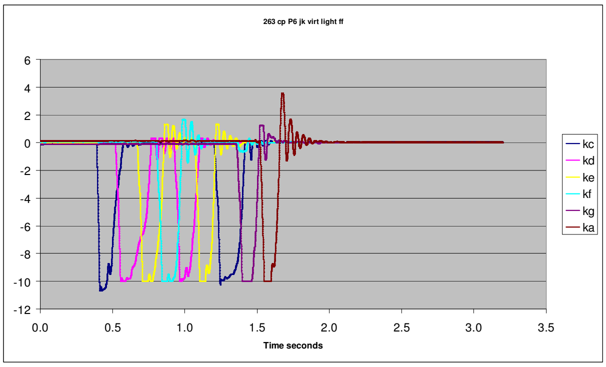


Fig 12. Graph showing the key movements of student CP playing in a style described as "Vituosic Light ff". Casparini copy in Christ Church Rochester, NY

Fig 13 shows the measurements from student LG. Here there are two groups for the Principal 8 alone, corresponding with groups one and two of CP's playing. The measurements from the plenum are not readily distinguishable from the Principal alone. These groups correspond with Groups One and Two from CP.

The descriptions of the styles are:

Table 4. Descriptions of playing styles in Group One, Fig 13. Student LG

274	Normal
277	Weight on 2nd
278	Weight on 2nd
283	Plenum equal accents
284	Plenum accent on 1st of pair
285	Plenum accent on 1st of pair
286	As 286 but faster tempo

Table 5. Descriptions of playing styles in Group Two, Fig 13. Student LG

273	Normal
275	Paired notes with more weight on 1st
276	As 275
280	Weight on 2nd, 3rd and 4th finger
281	As 281
287	Fast, stronger on 1st

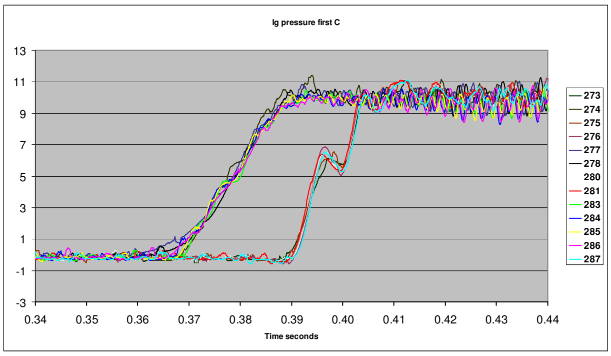


Fig 13 Graph to show groupings of the pressure rise immediately under the pipe foot of a theme played in a number of expressive styles as listed in Tables Four and Five. Student LG on the Casparini copy in Christ Church Rochester, NY

In the case of examples 277 and 278, "Weight on 2nd" there was a distinct elongation of the pre-pluck part of the key movement and the key and thus the pallet did not reach full travel. The pallet movements are shown in Fig 14. They show a shallower gradient at the start of the pressure rise. The two "Normal" playings are split between the two groups.

All of the six student subjects demonstrated what appeared to be significant groupings of pressure along the lines of the examples shown above.

Fig 14 shows the pallet movements from the measurements of LG (see Fig 13 for the pressure rise).

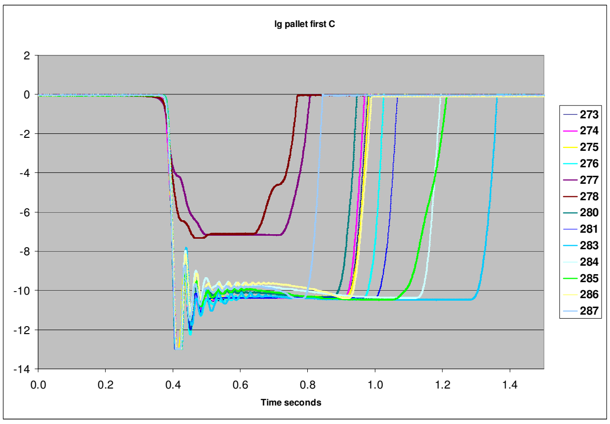


Fig 14. Pallet movements of the first note of a theme played by student LG in a number of expressive styles. There is considerable variation in the length of the note but little variation in the speed of movement during the critical phase just as the pallet opens and closes. Descriptions are given in Tables Four and Five.

Throughout this project, players have stated that even if there may be reasons why the attack may be difficult to control, it is completely possible to control the release. Fig 14 is representative of all of the subjects measured and shows very little variation in release. The one outlier, 285, is in the same style as the line that it crosses, 284, and may be considered an anomaly. The two notes in which the pallet does not reach its full travel are figures with the weight on the second note of the pair. It is not clear why the maximum movements are so similar, and may indicate a friction point in the action.

CONCLUSION

There is clear evidence that rhythm and timing are critical aspects of organ playing. In some cases it is as the result of deliberate and systematic efforts by the player as in the Rhetorical Figures and in others the player may be unaware of making variations.

There is some evidence that transient control is difficult to achieve by the inherent design of the bar and slider windchest. Variations in key and thus, to some extent, pallet movement fall into distinct groups, the reason for which is still under investigation but would appear to be due to fundamental changes in the way in which the finger initially contacts the key. The bar and slider windchest works against transient control but there is clear empirical evidence that players like mechanical actions. The immediate reason for this may be that it provides good tactile feedback. Other reasons for its endurance may include ease of construction, reliability and snap closing of the pallet to give a good seal

The project is continuing and, with the cooperation of our colleagues around the World, it is expected that a clearer understanding the important issue of the extent to which mechanical actions contribute to the organist's ability to play music on the organ will emerge.

[1] Noehren, Robert. *An Organist's Reader* (Michigan, Harmonie Park Press 1999)
[2] Woolley, Alan *The Physical Properties of Mechanical Pipe Organ Actions and how they Affect Musical Performance,* (PhD Thesis, University of Edinburgh, 2006)
[3] Audsley, George Ashdown. *The Art of Organ Building* (Mineola, Dover 1965 republication of 1905 edition, Dodd, Mead & Co)
[4] Bartel, D. Musica Poetica: *Musical-Rhetorical Figures In German Baroque Music* (University of Nebraska Press)
[5] Speerstra, Joel. Discussion with author