Steps towards a communicative build methodology

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Slide 1 - Some Steps Towards a Communicable and Transferrable Build Methodology

For most of you listening, this instrument needs no introduction. As you know I have been working on it for a number of years, its based on an autoharp type zither - the reverse action keyboard damping mechanism is the most significant innovation in my work, although during the coming prototype build I intend to innovate significantly on the instrument itself.

After a number of years of prototyping I want to begin by reflecting on the resilience of the prototypes that I have created, most particularly prototype 3 which has proved extremely robust and prototype 5 which is improving since I worked on again this Spring.

Slide 2 - Prototype 3 is played by my daughter Lucy; she is a recently graduated physics student and grade VIII violinist - so a fairly mature musician. Lucy inherited this instrument in 2015, its had countless hours of playing from both myself and Lucy - over the last 2 years Lucy has played it in a Ceilidh band on a weekly basis. You can see the date of completion of this instrument, and the striking thing about it is that it really never goes wrong - the only thing is that the hinged damper mechanism that you can see in the picture on the left sometimes slips open, and its tricky to realign it. This was redesigned the next prototype.

Slide 3 - Prototype 4 was a virtual instrument only, it begun as a 3d drawing that you can see on the top right of this slide - every single part in the mechanism is drawn to scale. This one 3d rendering file allowed me to fabricate all the parts that you can see in the subsequent pictures, through the process of computer navigated cutting, using milling and laser based machines and eventually also 3d printing.

Slide 4 - Prototype 5 was made using all of these fabricated parts Its been played by me since it was finally completed in 2015. Like prototype 3 it really gets some hammer; during term time its played every week in ACMG and in the world music band, and I generally take every opportunity to showcase it. Generally prototype 3 was more reliable; Prototype 5, until recently, had a habit of breaking pulley strings, and the mechanism was more difficult to access. Quite often this happened immediately before concerts which was never pleasant, so in Spring of this year I reworked the mechanism so that it was more like prototype 3 in terms of its workings and its access, I also added added sealed bearings as pulley wheels which significantly improved the lightness of the keyboard - I believe it now has the same reliability as prototype 3.

Slide 5 - So. Having spent a number of years now developing prototypes (with at least two of them proving quite robust) and publicizing the instrument I can report that it does attract attention - and from across the world. On average I get about 2 approaches per month from people enquiring if I am now making and selling the instruments. So not a huge demand but definitely continued and ongoing interest.

But the first step is not to build instruments to sell, but to communicate with instrument makers how to build it. At the moment these potential customers eventually seem to be buying variations of the Newton formulation - a very similar invention to mine, but with an inferior keyboard (at least from the perspective of a pianist). There is currently a two year waiting list for Newton harps at D'aigle for example. Now I have no objection to the Newton formulation, I consider all the reverse action inventors as kindred spirits, but I do want people to experience my instrument, not something that is "a bit like it". The fact is the Newton formulation is very easy to understand and build, so it of paramount importance in the next build that I begin to develop a methodology that allows me to communicate with instrument makers effectively.

Slide 6 - Here are the steps I decided on to accomplish this

Firstly, to study how instrument makers communicate with each other.

Slides 7-9 follow slides

Slide 10

So I enrolled on a part - time evening class at the International School of Violin Making in Newark. I embarked on this together with my wife Rachel - she has been a long time collaborator on all my instrument making ventures, and she's a really good violinist - having two of us meant that we were able to share the driving and we were thoroughly enjoying the programme until it was interrupted by lockdown in March.

On the bottom right you can see the kind of layout of a typical classroom. It's small student numbers and everybody is working at slightly different stages with one tutor circulating, advising, demonstrating and approving progression to subsequent build stages(or not) as the case may be.

Slide 11 - This is what I spent the first semester making. There was no written resources within the classroom to accomplish this, it was all communicated verbally, and step by step, employing various block planes, chisels of various types, spoke shaves, gouges of various gauges, hand stitched rasp, scrapers, knives and hand saws. All of these need to be maintained razor sharp, and the ability to accomplish this is a whole rite of passage by itself. The classes are very relaxed and some people progress faster than others. The protocol works like this - at each stage you have to seek approval from the tutor, who will inspect your work microscopically - it needs to reach a satisfactory standard of finish and accuracy before you can proceed to the next stage. This really teaches you the level of criticism that you need to bring to your own work. For reference, I think its about the same level of accuracy as my 3d printer - around .2 of a mm.

Slide 12

This is my wife Rachel's scroll - annoyingly slightly further ahead than me, and the band sawing is a lot braver and closer to the line.

One thing that I never realized about the setting of the neck of a violin is that it is designed to be removed and reset after a period of about 30 years, at which time the instrument is deemed to be settled. It had never occurred to me before to think of servicing in such a long-term fashion - the relevance of this will become clear later.

The first semester really changed me as a woodworker - before this time my go to tools were almost always power tools, now I think its the opposite, but I think its also made me a better machinist - I get better results when I do use power tools.

Slide 13

At the end of the first semester the whole atmosphere of the classroom suddenly changed to two hours of silent concentrated technical drawing. This change was communicated through just two sheets of A4 paper. The diagram on the left gives all of the reference measurements - scaled to allow accurate drawing to take place. The methodology on the right contains step by step instructions, though it does contain some technical reminders - mostly to ensure that the correct amount of care is given - note step 2 - Draw around the templates with a scriber - a pencil and then again with a scriber. Both sides of the mould.

You can see that the sheet is taken directly from the degree first year - and I think that we would give similar precautionary reminders at this level.

Slide 14 - This is what this process looks like. A line is drawn between the two pegs drilled through the plywood, onto which the plastic template is secure.. You can see that it is really a half a template which needs to be turned in relation to the pegs twice on each side of the plywood.

Slide 15

Lets look at a couple more aspects of the method - points 4 and 5. - the instruction is simply to saw out within a millimetre and to finish with a rasp. There isn’t any further technical instruction. All the detail is communicated within the classroom. Once a mould is made it can be used to make many instruments, but if I did need to make another, I believe that I could make it from just these two sheets.

Slide 16 - So from these 2 solitary sheets of paper - this is what you are making - You can also see when I finished it - it took over a month.

Slide 17 - this is a close up - you can see I didn't rub out all my lines, despite the instructions, handy for this presentation. The lines define everything.

Slide 18

So lets attempt to extrapolate what I learned from these experiences with respect to the aims of the next build.

Slide 19

One. the principle of economy

Slide 20

Two - don’t communicate the detail of technical approach unless there is a pitfall - something that absolutely needs to be remembered.

Slide 21

Three - do communicate the sequencing.

Slide 22

four. To remember that I don’t have any templates to start from, so the creation of any jigs or templates needs to be included in the methodology.

Slide 23

I have attempted a manual previously as part of the PhD - it was never a central part of the study, just a proof of concept really. To what extent did this work satisfy these aims?

Slide 24

The build manual example that I made sought to illustrate how to make the lower action only. We will just at the slides for section 1.1

Slide 25

This view from the 3d rendering tells us what the lower action consists of

Slide 26-27

Commentary follows slide

Slide 28

Front view - note that this is a 3d view. It doesn’t represent something that I am expecting to make though, but a pre-existing part that needs to be altered.

Slide 29

Finally - this separated 3d view of the two components one made, and the other an altered, pre-existing part. I can still recognise what these images mean, but they are acting more like an informal sketch for me, prompting me to remember the rendering that I undertook in practice. Its definitely not a instrument making manual as I came to understand it.

Slide 30 is a one-one drawing of the same parts designed for print and exported in the form of a pdf - this is also the basis for the kind of data that needs to be fed to a CNC or a 3d printer.

Slide 31

These two pdfs are actual keys to these files which were divided up by the depth of the wood to be cut.

Slide 33

So these are the kinds of artefacts that I produced to function as a manual What does this add up to?

Slide 34

I produced a lot of useful artefacts, but there isn’t anything that can immediately be picked up and understood by an instrument maker - its all too esoteric, and most crucially there is no sequencing.

Slide 35

So this is the first aim of the new build

but we also need another set of aims - that define the design priorities of this particularly build more closely. These are slightly different to any previous prototype.

Slide 36

We can encapsulate this as; to be propagating an instrument that is worthy of such a methodology

Slide 37.

The design criteria are somewhat different to previous prototypes.

First. The instrument needs to be settled, not a prototype

Slide 38

Second. It needs to be at least as reliable as the current successful prototypes, particularly prototype 3

Slide 39

Third. The keyboard needs to be adjustable, and it needs to allow for variety. The key drop on prototype five was 10mm. This is more or less the industry standard for a keyboard. On prototype 3 however it was 12mm. Even after several years of playing prototype 5 and fixing the keyboard this years so that it worked to a much higher standard I still think that I prefer the slightly unusual feel of the prototype 3 12mm drop. The fact that it is non standard proves the desirability of producing a tuneable keyboard if possible. Neither prototype 3 nor 5 allowed for this possibility. A further level of flexibility in keyboard design is that I intend to change my approach to key coupling with respect to the dampers. On previous prototypes the number of keys has increased from 12 to 17 - but I produced separate pulley systems for all of the keys irrespective of whether or not they were doubles. This meant a considerable increase in complexity of the mechanism as the keyboard expanded. A more sensible approach might be to couple keys together, like on an accordion; this would means that there would only ever have to be 12 pulley systems, and in principle it would mean that you could vary the range of the keyboard as a potential customer prefers.

Slide 40

Fourth. Bearing in mind the experience of the 30 years before the resetting of the neck on a violin - the keyboard needs to be considered from a perspective of long-term maintenance.

Slide 41

The key property to identify. All moving parts are subject to wear, and at some time are likely to require maintenance.

Slide 42

But how often do you require maintenance. I decided that this might range from say 30 years for replacement of the key springs to pretty regularly in terms of setting the pulley tension and the key drop. In order to assist this I developed three different levels of fixings. The image is a shouldered bolt and the "nut" is a flanged timber insert that you tap directly into a bore hole. It - means that you can screw a bolt directly into the wood - ideal for parts that need to regularly come apart or to be tuned with no wear caused. As you will see Two of these now handle the key drop and return making it completely tunable. I do like working with these parts, but the disadvantage is that they are heavy when compared to a wood screw or glue.

Slide 43

So when deciding how to fix things we must first think how often it is likely to need access and maintenance. If it doesn't need to come apart, it should be glued. A wood screw can come apart but it shouldn't be used on parts that need regular maintenance or movement because wear is associated with every disassembly. On the keyboard base layer you will shortly see that the pivot base is screwed into the keyboard base. This means that the key springs can be removed and replaced. However, bearing in mind that this is likely to be a very rare servicing event I have blocked these into three rows of 6 per pivot base platform, meaning that all six springs will have to be replaced at once. It saves a lot of weight overall though, because 12 screws are used for the whole keyboard as opposed to 36, should we choose to allow access to individual key springs.

Slide 44

Lastly, this keyboard needs to be fashioned using easily acquired parts that I can direct an instrument maker to. It cannnot for example use keyboard springs reclaimed from a particular make of keyboard.

Slide 45

This is the proof of concept model made before embarking on the complete keyboard build, to be completed from the new manual. Spot the new keyboard spring - its a humble clothes peg! You can see the shouldered bolts either side of this pivot. The back one defining the drop distance, and the front one defining the return point. These are always accessible and alterable using an allen key. The key itself is designed to be separated from the clothes peg (the spring). In the model I did this with screws, but a bolt and timber insert is used in the actual build.

Slide 46

The two keys are coupled together as proof of concept that this is possible and that the key tip weight remains approximately the same for both keys. The peg on the other side (that I forgot to photograph - darn it) has been broken and reformed using shearing elastic, so that it doesn't add to the overall resistance. Overall it feels good.

Slide 47

Having completed this model successfully, I then turned my attention to a complete manual and build sequence, there are two pages which define how to make the white keys, this first page defines how to make the range from C to E. All the measurements are provided in 2d profile. The entire length of the key stem is not depicted in the drawing because it would render the key areas to be represented too small in the drawing. but it is clearly defined in the measurements. All the necessary measurements to make these keys including the depth of the wood are defined. I was able to take this page to violin making class and ask for feedback from my tutor. After some consideration she confirmed that all necessary information was present on the sheet and that she would be able to make the keys as depicted.

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This second sheet depicts the remaining white keys. Like the previous range they are designed using a mirror symmetry.

Slide 49

This slide depicts the finished measurements of the black key. I deliberated as to whether to provide a method for this, but decided to simply define it by the measurements. There are a number of ways to achieve the finished result; at the time of prototype three I used a belt sander to put the slopes into the keys. For prototype 5 I used an angled band saw. In the latest round I have used knife, chisel and scrapers.

Slide 50

In all cases - the simple instruction which accompanies these three sheets in the method is simply to make keys and keyboard base layer as depicted.

Slide 51

The second instruction on the method puts into practice the design thinking allowing necessary access to parts for servicing, against weight constraints as discussed earlier.

Slide 52

Here is the parts depiction for the keyboard base layer. This specifies two different depths of plywood and a suitable 12mm stripwood to start from.

Slide 53

Here is the finished part. If we relate this back to the model on the right you can see that the key spring (the clothes peg) was simply glued down at this stage. In the finished part on the left three plywood pivot bases are screwed to the base plate. Each will hold six keys. The different screw positions reflect the fact that the black and white keys will have different pivot points and so are positioned differently on the pivot bases.

Slide 54

The keyguard blocks are attached from the reverse side of the base plate, so the attachments don't interfere with the timber inserts.

Slide 55

At the moment the screw positions on the pivot bases are noted but not defined in the method. I worked these out as I put the part together by placing six clothes peg springs on each - aligned according to the different black and white key pivot points. If this becomes fixed, I will define it, but for this time around the simple reminder in the method did actually stop me from drilling these in the wrong place and having to remake the pivot blocks.

Slide 56

Some instructions don't need drawings. The pivot blocks in instruction 3 are defined through measurements only and are made from 12 by 12 millimetre stripwood. I first bandsaw these to within a millimetre and then machine them on the belt sander, I have added a 90 degree guide to this to ensure parts are kept completely square to the sanding face. For end grain machining remains my first choice, but only if I am sure that I can get a square presentation.

Slide 57

The distances in instruction 4 are depicted in two ways

Slide 58

Firstly as a table

Slide 59

And secondly as a drawing

Slide 60

Next we have to make a jig. This jig will ensure that all of the pivot blocks are attached at exactly the same points on the keys. The 3d rendering shows the black key held in the jig. The pivot block will fit into the space provided.

Slide 61

Here is the instruction

Slide 62

The white key pivot block is slightly more complicated.

Slide 63

Here are the parts

Slide 64

because of the different dimensions of the white key stems the jig has to be made to fit around the largest - the D key. But side movement of the pivot block by a fraction of a millimetre is not important - only the pivot point along the length needs to be fixed.

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This is the white key pivot block jig depicted with a white key underneath it. Again - the pivot blocks will fit into the space and be attached to the key

Slide 66

Here are the instructions for putting all of this section together. Note that the keys are bolted to the pivot blocks, but everything else is glued to the pivot base. This means individual keys can be removed as necessary, but the key-spring assemblies are in groups of 6 for maintenance purposes.

Slide 67

Note the sequencing here. Pegs are glued to the pivot block only after they are successfully drilled and fitted with timber insert bolt retainers.

Slide 68

Finally in this section of the presentation - here is the peg jig that allows the pegs to be glued accurately to the pivot block. There are 27 steps in all including making all the jigs necessary for the work on the model to be transferred to a keyboard accurate to .2 of a mm and we have looked at the first 10 of these steps, but the whole file is to be found within a pdf that accompanies this presentation.

Slide 69

For the last section of this presentation, I want to show some techniques of hand tools that have allowed a pleasing improvement in accuracy in making this keyboard, even though lockdown restricted the quality of wood that I could source. Firstly measuring, I have four different sizes of square and a range of rulers, metal and plastic. Here I am marking with a sharpie, to be followed with a pencil along the same line - this rendered on both sides of the wood. The picture on the right shows the wonderful Japanese saw which gives even cleaner cuts than a band saw.

Slide 70

In these pictures I am using knives to chamfer the edges of the keys right down to the lines.

Slide 71

And then removing shavings along the centre with a chisel to meet the bottom of the chamfered edges.

Slide 72

Here I am taking shavings off in the corner of a white key and finishing with a square file

Slide 73

Finishing with a scraper and most important measuring - measuring square, and measuring width and depth with the verniers.

Slide 74

The keyboards for both prototype 3 and 5 took a long time to finish at this point. In these builds, I rendered the keys using bandsaw, belt sander, files and sandpaper. They weren't bad - but when they didn't fit in the final jig it took a deal of time to figure out why and to sort them out. But this keyboard right after completion of the last key, went click and fitted into the jig perfectly. It was a real eureka moment for me - I knew my technique had progressed. In this picture you can see the keyboard in Keyboard Jig 2 where the fractions of millimetre key spacers have been added. The keyboard will be glued with these spacings fixed.

Slide 75

So to conclude. Compared to the 8 steps on worksheet 2 for violin making my procedure has 27 steps. However I do think that it satisfies all of the aims that I set out with respect to communication.

Slide 76

I'm giving short instructions. I am making notes of pitfalls but otherwise I am not touching on technique. I am thinking a lot about sequencing steps and I am including all of the steps to make the required jigs within that sequencing.

Slide 77

With respect to the second set of aims really I haven’t got far enough to be able to evaluate honestly whether the new keyboard hits the mark.

Slide 78

I can look at all of these steps and I have demonstrated in this presentation where and how I am applying them

Slide 79

I can definitely say that the keyboard will be fully adjustable thought its life and it will be easy to access for maintenance.

Slide 80

Thats most of the principles - I just have to evaluate whether it works on a harp properly

- and the biggest question. The clothes peg as a keyboard spring - will it prove to be durable enough? I have certainly played with the model a lot, and it seems to be holding up. And we know that the object is very durable in the function that it was designed for.

Slide 81

Finally, its definitely the case that I have made a considerable leap forward in terms of confidence in workmanship

Slide 82

And I am closer to being able to generalise principles for pedagogy. Teaching people how to innovate on musical instruments and to be able to communicate their ideas effectively.

Slide 83

Thanks for attending this presentation everybody. I hope you have enjoyed it, and I hope you enjoy the change in the weather that is forecast. We really could do with some sunshine