The pullometer challenge – part 2

Work done by others

I contacted all the people who responded to my original article, and who had worked on the pullometer. Here is a brief overview of what they told me about their work.

Jonathan Frye, in Glasgow, Scotland, opted for a Wii Fit board to measure the ringer's weight – motivated by affordability and portability. Last year he had already produced interesting traces that showed differences between ringers, but these were not correlated with what the bell was doing and he particularly felt the need to know when it reversed at the top of the stroke. He had experimented with gyroscopes and accelerometers (Wiimotes) but with unsatisfactory results, so he concentrated on the force measurement. He also wanted to correlate the force with the bell's path through a method, and with video of the ringer's action.

Since then he has developed a bell motion sensor using a 3-axis gyro/accelerometer with on-board processing, connected to a Raspberry Pi 3. He has developed a display with a bell image moving in real time, and also with bell position plotted on the same graph as force. He is working towards comparing the impulse in the 'check' and 'pull', as well as working out when the bell is changing speed (hunting up/down). With technical problems mostly solved he sees the main need as working on the presentation, and learning what it can tell us.

Adrian Nash, in Rotherwick, Hampshire, used adapted weighing scales. Last year he had produced results that showed significant differences between ringers, as well as noticing effects that he attributed to ringers bending their knees. Like Jonathan, he also identified the desirability of correlating the force with a video of the ringer's action.

During the year he made limited progress (not helped by his scales breaking) but his display now includes separate running averages for handstroke & backstroke, with max & min shown separately. His main challenge has been to identify the top of the stroke. He is now doing this with a higher speed version of the Bagley simulator interface that detects a marker on the wheel. That should also allow the pullometer to be more easily integrated into an existing simulator system using Abel (or similar). Most recently he is considering deriving everything (including the force) from measuring the movement of the bell.

Peter Budd, (who doesn't ring) has worked with Hamish Rankin (who rings at Bowdon, Cheshire) on sensing the bell movement with the types of MEMS chip used in mobile phones (he's tried more than one with different results). From these he can derive acceleration and hence force. His prototype interface displayed the force in real time in two small circles that showed handstroke and backstroke force separately. This approach relies on being able to calibrate the bell so that the 'normal' movement, due to the forces like gravity and friction that aren't of interest, can be 'subtracted'.

He met considerable problems with spurious signals, and experimented with other sensors to try to eliminate this. He also intends to experiment with measuring the force on the rope with a tension sensor inside the wheel (and correcting for the capstan effect).

Ian McCulloch, in Brisbane, Australia, hasn't been able to do any more since the work he had done last year measuring headstock movement and using a Kalman Filter to clean up the result, but he has made progress on modelling the dynamics of a bell and the dynamic forces due to the rope, and how this will affect a pullometer.

Richard Johnston, in Plymtree, Devon, had told me about his work before last year. He was detecting bell movement by sensing an optical pattern around the wheel rim using two closely coupled laser/sensor units. From that the height, speed and hence acceleration and force can be derived. Last year he said he had given up as he did not know how to handle the sensor timing noise errors computationally (a problem common to all electronic detection methods), but he has since become aware of standard industry solutions, and now believes his approach would be viable after all.

In addition, John Pereira reported in these pages (Letters p.1252) that 10 years ago he had measured weight variation using the resistance of carbon granules in a plastic tube (like an old-fashioned telephone microphone) under a board that the ringer stood on, but I have no information on any later work.

Where next?

Much progress has been made, with several techniques shown to be viable either on their own or in combination, but there is more to do. On the practical side, developers need to consider affordability, ease of installation, flexibility and usability, as well as performance. It will be interesting to see which approaches emerge as the most attractive for widespread use.

Usability is particularly important. As well as 'working', the tool must also be easy to use. It must not distract from the teacher's interaction with the pupil by the need to 'fiddle with the controls', and its displays must be easy to understand and interpret in terms of what the pupil is doing. User input will be essential to achieve this, and although some of the developers are themselves teachers motivated to develop a tool that they will find useful, I am hoping that there may be ways for other experienced teachers to provide input as well.

What is being measured?

With the ability to capture the data now established I expect more effort to go into how best to transform it into useful displays. For example:

The ideal would be to see just the force applied by the ringer. The Oswestry prototype detects more than this because it measures at the top of the rope. It compensates for the static weight of the rope but not for the dynamic forces caused by accelerating the rope's mass, so they are included in what is displayed. The extra forces are small enough not to interfere with detecting things like over pulling (compared to normal pulling) and gross differences between check and pull. But they are enough to mask things like the ringer having a slack rope, especially with a long draught. If the normal behaviour without ringer intervention can be reliably identified and subtracted from the measured force then the display should be easier to interpret, including detecting a slack rope.

Measuring variation of the ringer's weight doesn't give a pure force either since it includes forces due to body movement as well as the force on the rope, and since body movement isn't predictable those forces can't so easily be separated out. It might be possible to provide some compensation based on a 'normal' action but how useful it would be remains to be seen. Inertial forces will be greatest when ringers move their bodies as well as their arms, which heavy-bell ringers routinely do, so this aspect isn't something that will 'go away' even for a ringer with a good style. It needs to be understood so the results can be properly interpreted.

If the force is derived from measuring the bell's movement, the inertial and gravitational forces on the bell are far bigger than those applied by the ringer, so it is essential to separate them out. Fortunately the inertial and gravitational forces are regular, so it should be able to be capture them by measuring a free swinging bell. Even so, subtracting two large numbers to get a reliable value for the difference is not always easy if the signals include measurement errors.

How to present the information

What are the most effective ways to present the results? As well as basic plots of force against time and/or bell position, would other presentations be useful? For example:

- Would it be useful to 'replay' the movement of the bell and/or ringer with forces superimposed?
- Would it be useful to display rope velocity as well as force? This might make it easier to understand a learner's failure to match the speed of the rope, which is a common cause of dropped bells and/or floppy ropes.
- Would it be useful to display the total energy added and/or lost at each stroke?
- How much easier to interpret would a display of pure rope-end force be, compared with a display including other dynamic effects that the user has to allow for?

As well as transforming the raw data to make it easier to use, there is the equally important need to develop our knowledge of the pullometer's practical potential. It is a completely new type of tool and we need to learn how to use to best effect. It is quite likely that in the process we will learn some unexpected things about what really happens between a ringer and a rope. Some developers have produced what seem like counter-intuitive early results, so it is quite possible that even those of us who have thought quite a lot about ringing technique, and are well versed in the underlying physics of forces and motion, might learn some things that we didn't expect.

This learning will require practical experience, of what works and of what doesn't work, and about how to integrate it within the overall teaching process. From that we should be able to develop advice and guidance so that ringing teachers at large, and not just a few enthusiasts, are able to benefit from using a pullometer. If you would like to be part of this process in any way, please get in touch.

The remaining challenge

The second part of the Pullometer Challenge, to demonstrate 'marketability', is still open. It requires demonstration of a pullometer that meets all the requirements set out in the original challenge (feasibility and marketability):

- Demonstrate feasibility – Build a working pullometer that meets the following requirements:
  a) It can be installed for use with a normal tower bell.
  b) It doesn't have a significant effect on the bell's normal handling.
  c) It can show a graphical display versus time of the force that a ringer applies to the bell.
  d) Its display can be selected to show either a single trace extending over many strokes, or successive strokes (whole pull or half pull) superimposed.
  e) The display scale can be adjusted (manually or automatically) to show features of interest.
  f) It can store multiple force recordings and recall them for display.
  g) It can show two separate recordings together for comparison.
- Demonstrate 'marketability' – Show that the pullometer design meets the following requirements:
  a) It can be acquired at modest cost (target less than £100). (Components such as old computers that are widely available at no cost will not be included in the total.)
  b) The on-bell components can be easily installed on a designated bell (target under 20 minutes).
  c) Components in the bell chamber can be installed so that they are not vulnerable to damage when people walk around the frame and climb in and out of pits to perform routine maintenance or silence clappers.
  d) Components in the ringing room that may be vulnerable to theft can easily be removed for safe storage and quickly set up again when needed. (It is assumed that the bell chamber is locked and secure so equipment there can remain in situ.)
  e) There is a sustainable source of supply, ie one or other of the following applies:
  (i) The design is in the public domain, uses commercially available components and can be made using manufacturing techniques available to a competent amateur. Or ...
  (ii) If the developer is a sole supplier then there is evidence of capacity and willingness to supply a reasonable demand, and a credible assurance that in the event of not being able to supply the demand then condition (i) above will be met.

The remaining awards are:

- £500 to the first person or team to demonstrate a product that meets all requirements above
- An additional £250 if this is demonstrated before the end of June 2018

Some of the criteria for marketability may require a degree of interpretation, for example 'easily' and 'vulnerable', and the extent to which effective 'cost' is increased by the need to make components from parts rather than just install pre-assembled equipment.

The challenge is open to any design, whether based on the prototype that won the feasibility award or on some other approach or combination of approaches.

To discuss any aspect of this challenge, please contact me at: pullometer@jaharrison.me.uk. To apply for one of the awards and arrange an assessment of your pullometer, please contact me at the same address