# The pullometer challenge – update

It's a year since I travelled to Oswestry to try out the system that won the feasibility part of the pullometer challenge. In my subsequent article I described what other people working on a pullometer had done.

Since then I have received several updates from developers. I had one device to try out and but for a combination of illness and travel schedules would have been able to try out another one too. I have not yet been asked to assess any device for the final challenge.

Kim Quinn's article (page xxx) adds a new dimension by describing some capable hardware that is available off-the-shelf, so it may be timely to give a review of the problems that developers have to overcome in order to make a pullometer widely available as a useful teaching aid.

On the hardware side they need to find a technology that will reliably measure the physical interaction between the bell and the ringer, typically by sensing what the bell and/or ringer are doing. Then they need to find a way to make a device available, affordable and practical to install in a typical tower.

On the software side they need to extract valid data from the raw measurements, to transform it into useful information related to the skills of ringing, and to present it in a way that teachers and ringers can readily interpret.

## Technology

Sensor technologies so far considered to extract data from the bell/rope/ringer include:

- Inertial sensors on the headstock or wheel
- Weight sensor under the ringer
- Tension sensor that the rope passes through
- Tension sensor embedded in the rope
- Optical motion sensor around the wheel

In theory everything can be derived from the bell movement but it requires a lot of calculation. Measuring tension (or weight) is more direct, but still requires unwanted effects to be removed. And even when the force is known, for most purposes it is necessary to measure the bell's movement in some way as well, notably to know where it is relative to the balance point.

Cheap solid state inertial motion sensors (solid state accelerometers & gyroscopes) are now available, and they have attracted a lot of interest.

## Affordability & practicality

Developers using inertial sensors have built their own combinations of sensor chip, processor and communications. For them to make a device based on that widely available they would either have to put it into production (like David Bagley and others with simulator sensors) or rely on people who are good with a soldering iron and making things doing the assembly themselves.

The device that Kim Quinn has used offers a possible alternative that could be bought off the shelf and used with suitable software to provide a pullometer. However in UK it costs around £160 – well above the target price in the Challenge.

Getting information from a headstock mounted device is another technology problem. The Oswestry prototype used wires, but wireless is better. Bluetooth and WiFi are both widely supported but might not be reliable to go direct from bell to ringing room in a tower with several intermediate floors. One option might be a wireless link from the bell to an intermediate unit in the bell chamber, with a cable downstairs.

A rope tension sensor is less likely to be available off the shelf, and so would need to be assembled – by the supplier or by the buyer.

Weight measurement devices are readily available off the shelf. Their diagnostic use is limited without accurate information about what the bell is doing, but 'zero installation', and the ability to move it between bells (or towers) could give them a role as basic 'overpulling' meters.

## Data analysis

There are two problems. The first is that whatever you measure will contain errors and 'noise' – spurious variation that doesn't reflect the underlying physical reality. There are many mathematical techniques for dealing with that – so you need to find the right combination that will work with your data. You can download a lot of that software for the device that Kim Quinn used.

The second problem is that what you can measure mostly isn't what you are interested in – the force applied by the ringer – but something related to it – say the rotation of the bell. They are connected by simple equations but the ringer's force isn't the only thing causing the bell to move. The weight of the bell has a much bigger effect, and as the graphs from the Oswestry device showed, so too does the the weight and inertia of the rope. Either these need to be eliminated in some way or the result must be presented in a way that enables the user to discount the effects.

## User interface

When you are confident that what you are measuring is a reliable indication of force, the key question is how best to present it. That's not about technology, it's about how the human brain explores and interprets information, and especially about what someone teaching a ringer is likely to be looking for, and why.

We don't yet know all the ways in which a pullometer may be used but we already know some of the problems that it could help with. Broadly there are two cases. In one case the tutor knows what the pupil is doing wrong, but explaining it in words doesn't get through.

A classic example is a pupil who pulls much too hard 'because the bell keeps dropping', when in fact the pupil is causing the bell to drop by checking it without realising. The tutor's words don't register, because they conflict with what the pupil is feeling. In this case the pullometer can help by showing the pupil what he/she is actually doing – notably applying force too early, while the bell is rising, and so stopping it too soon. So it helps to overcome the communication barrier.

In some cases the tutor can see that something is wrong but isn't quite sure what. Seeing the movement of arms, hands and rope may give some clues, but to interpret what is happening requires knowledge of the force as well. In this case the pullometer helps by giving the tutor an understanding of what the pupil is really doing – an essential first step to being able to help.

There are many aspects of handling where vision might lead to a suspicion, but where knowing about the force can make it much clearer. For example:

- Stroke length – How far is tension maintained on the down stroke (efficient pulling) and how soon on the up stroke is contact made with the bell (effective feeling)?
- Smoothness – Is there a jerk as the rope tightens, or at the top of the stroke, and how even is the force during the rest of the stroke?
- Consistency – How much variability is there over a period of ringing? How well does the rhythm recover after a disturbance?
- Manoeuvring – Is excessive force used to make places and dodges, possibly overshooting and inducing more excessive force?

Typically after recording a piece of ringing the tutor will want to scan through all of it looking for 'interesting' bits to home in on. This requires some sort of overview showing many strokes, coupled with a more detailed display, and the ability to move easily between the two. How many strokes to show in the overview is a trade-off – too few and it will require excessive scrolling to find things, too many and there might be too much loss of detail. It may be sensible to give the user a choice of scale.

Some problems may be resolved just by inspecting what the pupil does on individual strokes, but often the insight will come from comparison – either comparing what the pupil does at different times (as he/she tires during a touch, or from lesson to lesson) or by comparing what the pupil does with what the tutor does.

Comparing two strokes may seem simple but it's more than just plotting two lots of force against time. There are two complications. The first is that the duration of individual strokes varies – with the speed of ringing, and from blow to blow (for example when changing place).

The second is that the bell goes (or does not go) past the balance by differing amounts, and this is critical in terms of understanding both the bell's behaviour and the force used by the ringer. Developers have tackled this problem in several ways - by distorting the time scale to fit, by adding markers to show the balance point and where direction reverses, or by basing the display on angle rather than time.

## More than force?

Force is how the ringer influences the bell, hence it is the primary focus. But applying force is a means to an end – making the bell behave as intended. There may be related properties that could help understand what a ringer is doing to the bell, for example, energy. Raising a bell increases its energy. Ringing slower or quicker increases or decreases its energy. Overpulling continually injects and removes energy wastefully. So being able to view the bell's energy, as well as the force applied to it, may help tutors and ringers to gain useful insights.

## The remaining challenge

Of the four original awards, one is still open – £500 to the first person or team to demonstrate a product that meets all functional and marketability requirements. The additional £250 award for doing this before June 2018 has lapsed.

John Harrison

*Requirements restated on page 2*

## The requirements

To win the remaining award of the Pullometer Challenge, the successful device must satisfy all of the original requirements for both 'feasibility' and 'marketability', which are repeated here:

- 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.

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.

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