BellSim: a 21st century bell simulator

by Dr Adrian West CEng MIET

I have to admit that even after many years of tower bell ringing, I'm still apprehensive about teaching new learners the art. Those first few pulls at backstroke often involve the new learner not pulling correctly, causing the rope to coil loosely downwards on top of us and requiring rapid intervention. I also find that many new learners think bell ringing is difficult and pull so hard that I have to jump on the sally to save the precious stay.

Even when the first rope-pull steps are out of the way, constant vigilance is required to make sure the rope remains under control, often involving rapidly assisting or taking over from the learner and recovering the bell to the set position; it can be a rough action which can be quite off-putting to the beginner.

Towards the back end of 2019, I was teaching our youngest daughter Zoe to ring. While she was making good progress towards rope handling, her confidence was beginning to fail, and I was fearful she would give up and walk away. So, from this point I mused that there needs to be a better way to teach bell handling that removes the fear factor and promotes confidence so that the crucial steps of controlling the bell and rope can be successfully achieved.

The COVID-19 pandemic started in February 2020 and my professional work in electrical engineering consulting dried up completely, leaving plenty of time to consider what could be done to ease the new learner teaching process.

I decided that there were three basic requirements:

- To be able to quickly stop the bell rope motion at any time on demand by the instructor.
- The ability to run the rope at a much slower speed so that the learner could get used to the arm motion.
- To entirely remove the risk of a broken stay.

Clearly these requirements could not be met using an unmodified tower bell, so a new approach was required.

Throughout my career as a chartered electrical engineer, I have gained some considerable expertise in high power, high performance electric motors, associated power converters and industrial control equipment. It seemed a good fit therefore to use this expertise in the design of a completely new simulator mechanism.

I came up with a simple design where the bell rope is wound around a small drum which would be driven by a high performance servo motor and mechanical gearbox. The drum would rotate forwards and reverse to exactly replicate the motion of a real bell rope. A strain gauge loadcell would be used to accurately measure the bell rope force.

The bell, clapper and rope motion would be entirely modelled in software by solving the equations of motion in real time. The software models would be forced by values of gravity, friction, rope force and clapper strike action, such that the rope position and speed exactly match an equivalent real bell. The requirement was that any ringer operating the simulator should feel they are ringing an actual church bell.

Freed from the physical constraints of a real bell or a swinging weight equivalent, rope motion can be stopped at any point, the simulation slowed down and the stay replaced by a software equivalent which could be easily reset.

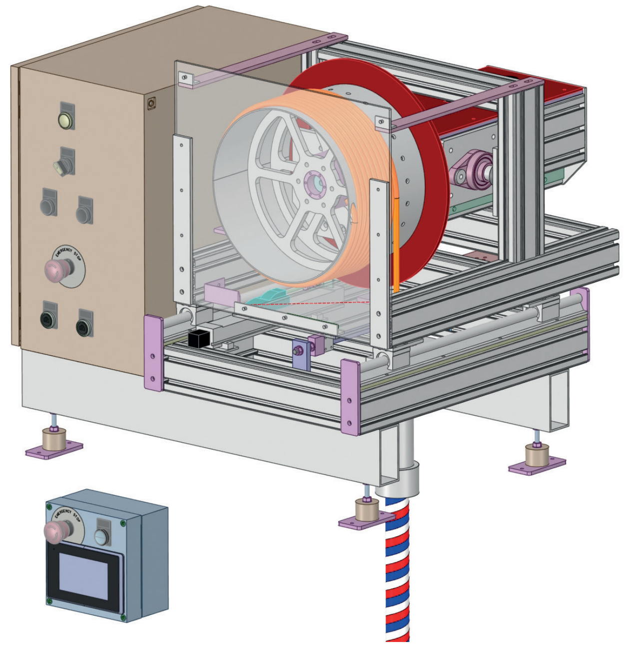
Equations of motion of the bell and clapper were required and a quick internet search yielded a published document by Frank King on the excellent **ringing.info** website. Dated August 1994, the document included detailed equations of motion from which modified versions were used for the working software.

The sixth bell at Whalley Parish Church in Lancashire was initially measured and relevant data computed for the bell software models including total mass, centre of mass length and inertia for both bell and clapper. Some considerable time was spent designing further system software models using the bell data to check feasibility before committing to design, procuring parts and manufacturing.

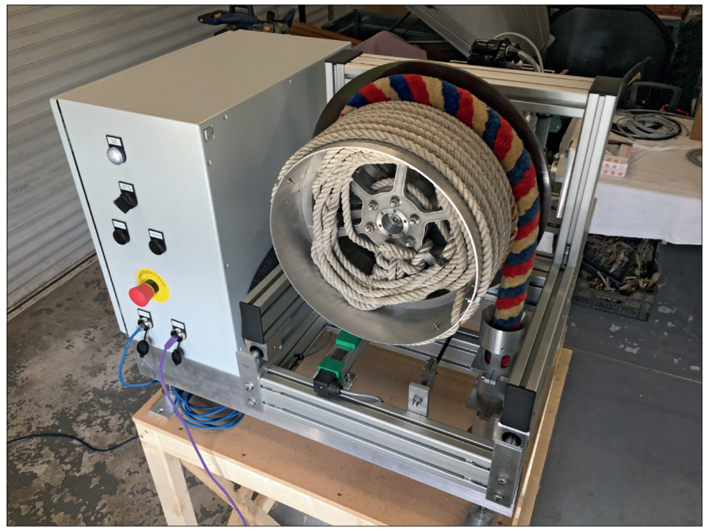
The device frame was constructed from extruded aluminium machine building sections to produce a strong assembly to handle the rope forces. A sliding carriage was devised to ensure correct helical winding of the rope on the drum and this was driven by a second stepper type motor to provide the correct rope winding pitch. The main servo motor was mounted inside a pivoting frame, anchored with the strain gauge load cell to measure the rope force.

A control box was constructed to industrial automation standards to provide good reliability and included a safety relay with hard wired push buttons to immediately stop rope motion when operated.

A low-cost industrial touch screen mounted in a small box located close to the ringer provides the main user interface for controlling the simulator (now named BellSim). A wireless interface with a small push button fob allows convenient start and stop if required while teaching.

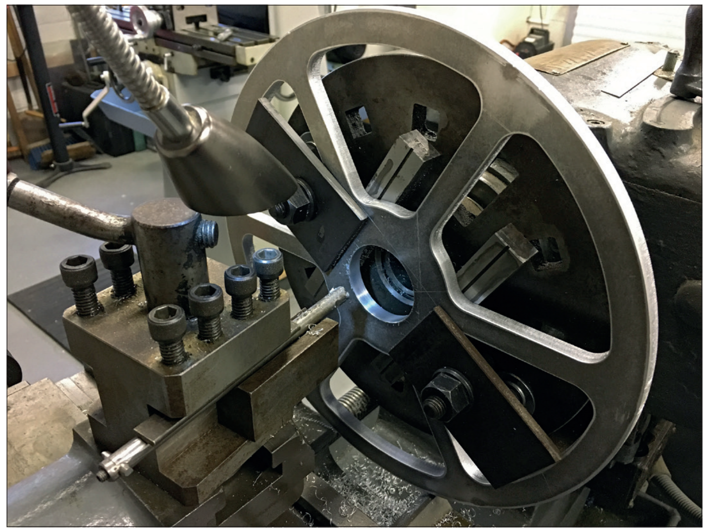


CAD diagram of the BellSim R2 with HMI

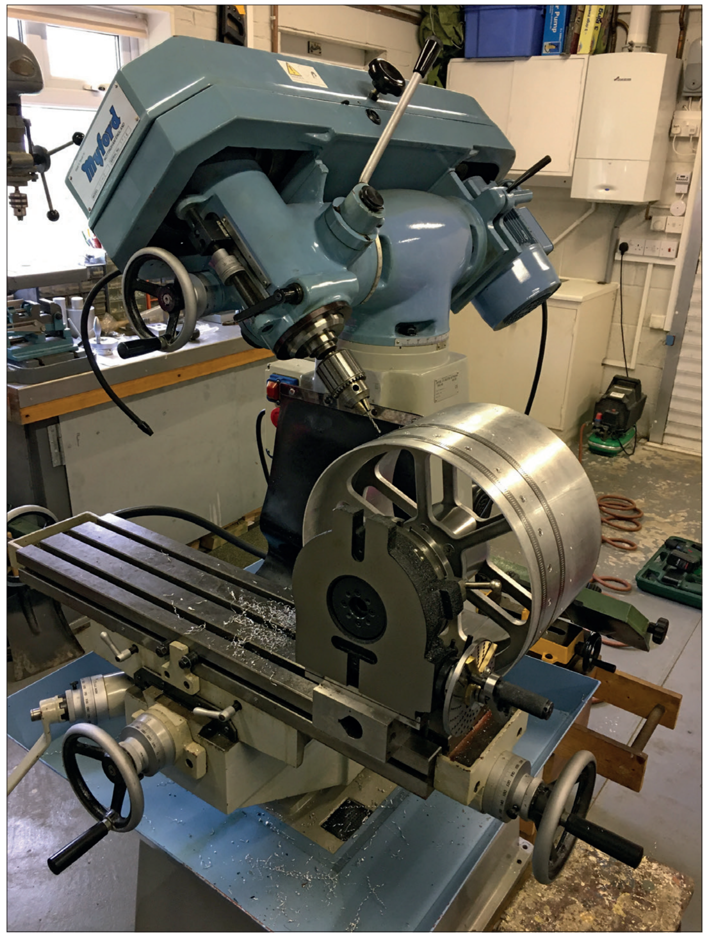


Front view without polycarbonate guards showing trial fitting of the rope on to the drum. Rope tube, sliding frame position sensor and local user controls shown

Rear view of BellSim showing main motor pod, motor cooling fan, rope force load cell, tie rod and amplifier



Early manufacturing showing lathe faceplate work machining the laser cut rope drum flanges



Early manufacturing showing precision drilling of the fixing screws to attach the rope drum rim to the flanges

The simulator provides a strike signal when the software simulated clapper contacts the bell and an isolated interface was designed to connect to AbelSim, the popular PC based ringing simulator. I constructed a wireless footswitch array to provide an additional start/stop and allow full control of AbelSim while ringing BellSim.

All the eight Whalley bells have now been measured, drawn up in 3D CAD, parameters computed and entered into BellSim. Early trials have been extremely successful with a ringing experience closely replicating a real tower bell. A bell can be rung, set at handstroke, set at backstroke, rung up, rung down and chimed in the down position. When ringing up the clapper can go up wrong unless the correct rope checking technique is used just like a real bell. A whole host of other features are featured including automatic rapid stop on software stay break or if the ringer fails to let go of the sally, ringer efficiency and performance measurement – a feature list too long to include here.

In total around 1,300 hours of time over 18 months have been dedicated to the device including: comprehensive software modelling to check feasibility, bench testing, 3D CAD drawings, electrical schematics, part manufacture, part procurement, frame assembly, control panel wiring, software coding, general assembly and system test.

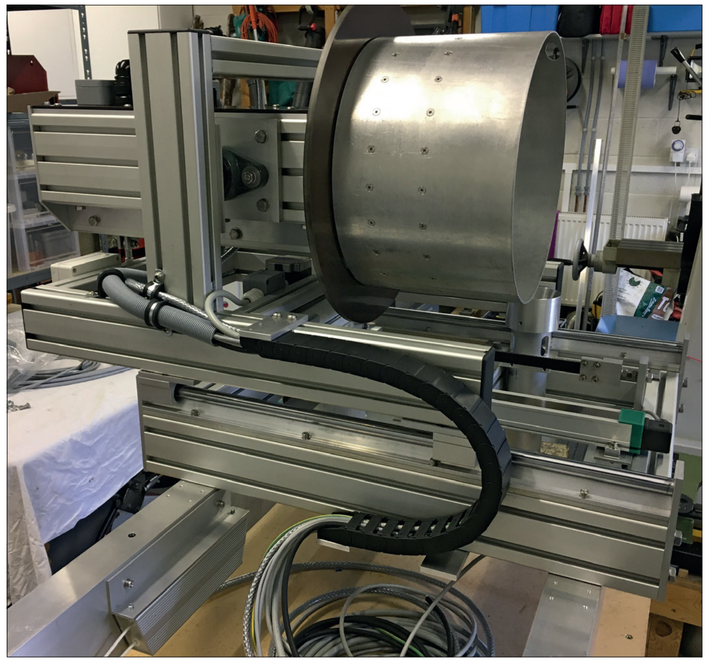
The three requirements listed above have been fulfilled and my daughter Zoe is back on track learning bell handling skills on the simulator with increased confidence. We had a training session the other day and she is close to achieving rounds on six based on a simulation of the second bell at Whalley together with AbelSim.

BellSim can handle up to thirty different bell sizes and characteristics, all selectable from the touch screen. So, after the training session, I switched to Whalley sixth and rang a course of Cambridge Surprise Major before automatically parking the rope out of sight and retiring for a beer.

For further information including a comprehensive list of features and a short video of BellSim in action, please find this on my company website at **www.opusds.com/bellsim**. If anyone is passing Whalley and would like a demonstration or a ring on the simulator then please get in touch. All feedback is welcome, both good and not so good. My contact details are on the website.

I believe this device may be a world first as a true *simulator* for English church bells, but if any reader knows different then please let me know.

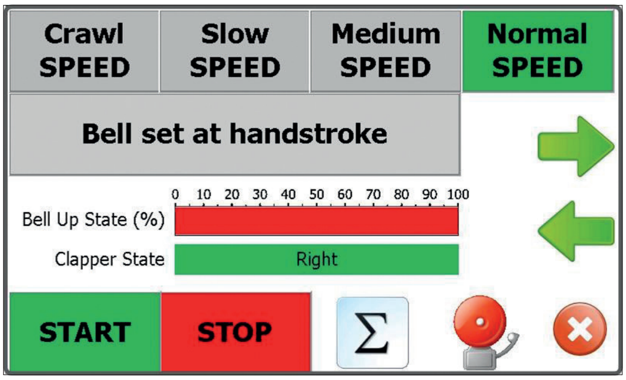
My thanks go to John Pilkington, then Ringing Master at Whalley for allowing access to the tower for the early measurements of the sixth bell and also for donation of a used bell rope.



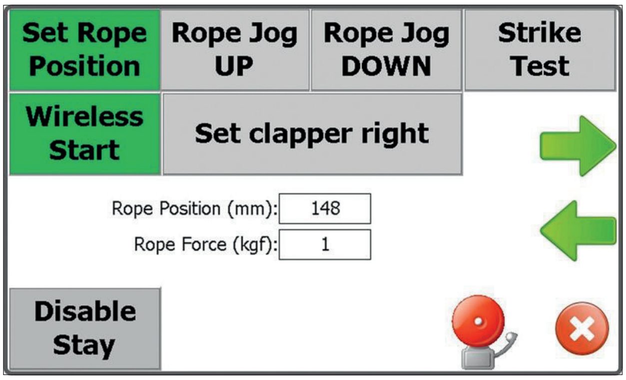
Side view during construction showing sliding frame at the extreme rear position. Energy chain shown with wiring on to the sliding frame. Rope drum shown with fixed rope flange

BellSim: the user interface

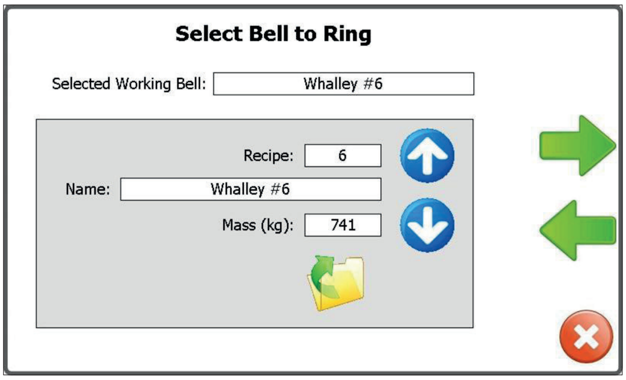
The image below shows a general view of the BellSim test ringing environment. It shows the complete setup of the simulator beneath the drum with the rope, BellSim touch screen, wireless foot switch array and computer running AbelSim together with a camera view of BellSim in the attic above. To the right are examples of the touch screen interface and the various options that are available with BellSim.



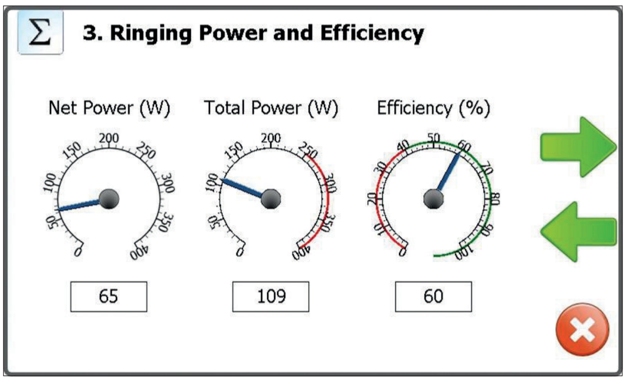
The main operation page for BellSim. Buttons allow start / stop of Bellsim. Selection to start with the bell set at handstroke, set at back stroke, bell down or park the rope out of reach. Four bell speed selections. Indications for bell up / down state and clapper right and wrong



The auxiliary control page for BellSim. Allows positioning of the tail end for correct rope length. Setting the clapper right or wrong on start-up. Enabling wireless start/stop control of BellSim. Stay disable button, rope position and rope force indicators



Menu selection of up to 30 different bells to ring. The complete set of eight Whalley bells have been entered and are ready for selection. Weights shown are total including headstock and fittings.



Gauges showing ringer efficiency based on a course of Grandsire Triples rung on Whalley #6 bell