Expression control in automated organs and its perspectives for preservation of the past

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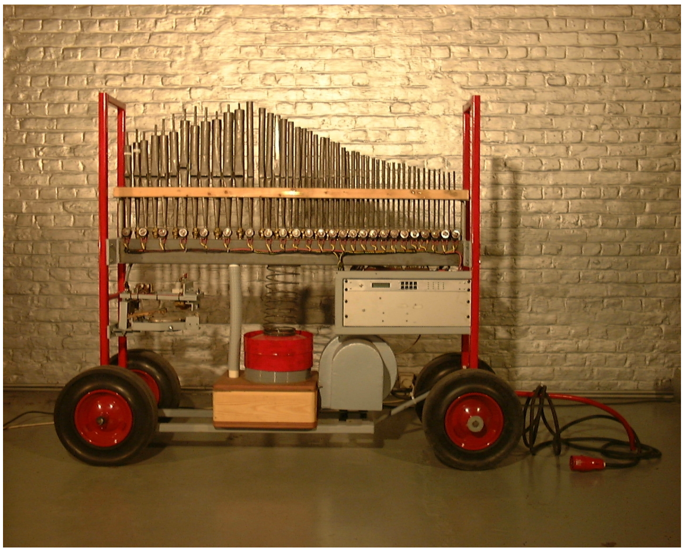
The practice of automating musical instruments is in no way recent, and in fact might very well be just about as old as the history of that class of musical instruments where many mechanical parts, levers, wheels, bellows, hammers are used to control the actual sound sources. We all know watchmakers and their skills in the construction of musical clocks. On a very large scale – the principles being the same – we can also refer to the vast tradition of carillons on belfries and some church towers. Before the advent of electronic circuitry, musical automata, orchestrions and barrel organs were built using mechanical or pneumatic principles. Up to the 19th century, the pinned barrel was the device of choice to program the music into the automaton. With the 19th century came the advent of pneumatic principles. All the automatic instruments made at that time (the antique Limonaire organs, Pianolas, Mortier organs, Decaps and many more) use paper rolls or cardboard books for programming and are pneumatic. By nature they are, just like their purely mechanical ancestors, binary machines: a punched hole in the roll is a note-on, no hole is a note-off. Musical expression – apart from the precise placement of tones in time, or overall control of the wind pressure – is left out altogether from these designs which is what explains the very mechanical character of the music produced. Although it is not impossible to implement gradual and nuanced control using pneumatic technology (and many attempts to do so have been made, sometimes with reasonable results), it is only since the advent of electromechanical or electropneumatic devices and particularly micro-controllers that this has become common practice amongst modern automated instrument builders. Instrument automation has been keeping us busy since the early 1970s, and in this paper we will concentrate on some aspects of expression control applied to organ building. We will try to give a broad overview of technologies and approaches applicable to organ-type musical automata with expressive possibilities way beyond the simple, if by no means trivial, note-on, note-off that has plagued automata for way too long. All the technologies described above have been put into practice in one or another of the 47 musical robots – not all organs of course – that currently make up the <M&M> robot orchestra.

The first organ building project we undertook started off one day somewhat by accident. Elders from the protestant church in the Brabantdam in Ghent decided to get rid of the 18th century organ in their church, since the cost of real restoration was outrageous. They happened to know us as an instrument builder and offered to sell it to us for the symbolic sum of 100 Euro. So we did, and we were left with the remnants of a complete organ... Most of the wood pipes had been either attacked by worms or severely affected by mould. The lead pipes had been stacked horizontally for many years and thus we found that all of them had been almost completely flattened. Only the vox humana register, with its short resonators and thick pipe feet, looked more or less intact at first sight. When opening these pipes however, we noticed the havoc wrought by tin pest: all the parts where covered with a thick layer of lead oxide. After a tedious restoration session on this register, we got all the pipes to speak again and we took up the idea of automating it. <Vox Humanola> was about to be born.

The wind is generated by a Laukhuff radial compressor, controlled with an electronic motor controller such that wind pressure (nominally 12mBar) can be brought under precise computer control. As in other early designs, we copied most elements from traditional organs and provided bellows, believing they were required for wind stabilisation. Later we discovered that we could easily manage without bellows, as long as the motor control was well designed as an auto-regulating system. The wind chest, made of steel, is populated with direct-acting solenoid valves with varying orifices (3 to 10 mm). These industrial valves required some modification to make them suitable for use in a musical instrument: they were noisy when active. To suppress the clicking noise, we cut of a slice off the ferromagnetic anchors and glued a round piece of felt in its place. The return springs were replaced with also less powerful types. The solenoid valves could now be switched under computer control. We finally succeeded in making this register sound in all its ancient glory again.

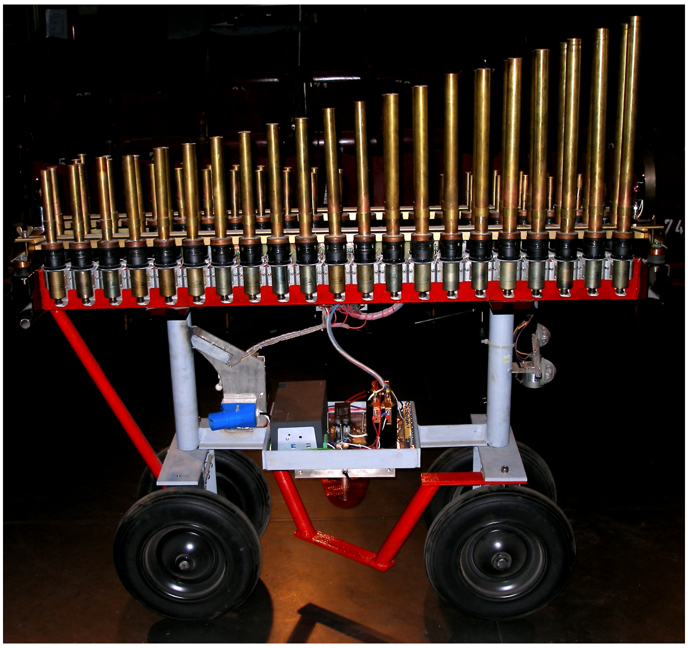


The second register we recycled consisted of small tin/lead pipes and was made into our <Piperola> robot, along similar lines. Only the lowest octave uses closed pipes, the higher ones being open. Here we added a nice pressure tremulant, working on the bellows directly using a heavy solenoid. Operational wind pressure for piperola is 10mBar. A special feature is that the construction of the tremulant allows it to work as a wind source when the motor is switched off. Thus pretty staccatos become possible.

The last automaton we derived from this 18th-century organ became <Trump>. In this case, taking into account the completely ruined state of all the resonators on the trumpet pipework, we decided to design something more original. We modified the scaling of the register in such a way as to obtain a gradual shifting formant over the compass of the instrument. To homogenize the sound output, we placed all the pipes in an exponential horn, the low pipes in the apex, the high ones close to the mouth. Here we no longer used any form of bellows, and neither did we used industrial solenoid valves. Instead, we applied flat pallet valves here, mounted inside the wind chest. The wind pressure was set pretty high at 20mBar and the intonation of the pipework was adapted accordingly. Needless to say, this is a rather loud instrument.

One day, we got an offer for a bunch of wooden open organ pipes, presumably made by Oscar Van Peteghem. They looked as though they could be restored and only 4 pipes needed to be remade in order to make a reasonably useful automaton limited to the low register. This became <Bourdonola>, our first pedal register:

We modified the pipes later to yield a more string-like sound, by placing harmonic bridges over the flues of the pipes, a common practice in the 19th century. Although mounted on wheels, transportation is often a problem as a truck with a high internal height is required for the longest pipes, which have a length of 2m80. Taking the pipes out for transportation is possible, but always leads to problems with tuning and intonation after reassembly.



After all this, it became about time for a more adventurous undertaking: what about a percussive organ, where each pipe would get its wind from its own bellows? This was the idea behind <Puff>, which sounds more or less like an extended system of pan flutes. Moreover, this was the first organ module we designed with equal temperament quartertone tuning. All the pipes where made of hardened brass in the style of ordinary penny whistles and can be overblown if enough wind pressure is generated. The individual bellows are made from pyrex glass cylinders with a well-fitting plunger made of carbon compound. The plunger is set in motion under the action of a hefty tubular push-type solenoid. By changing the pulse time of the voltage applied to the solenoids we obtain very precise control over the dynamic of the pipes. Responsiveness is excellent and speed astonishing.

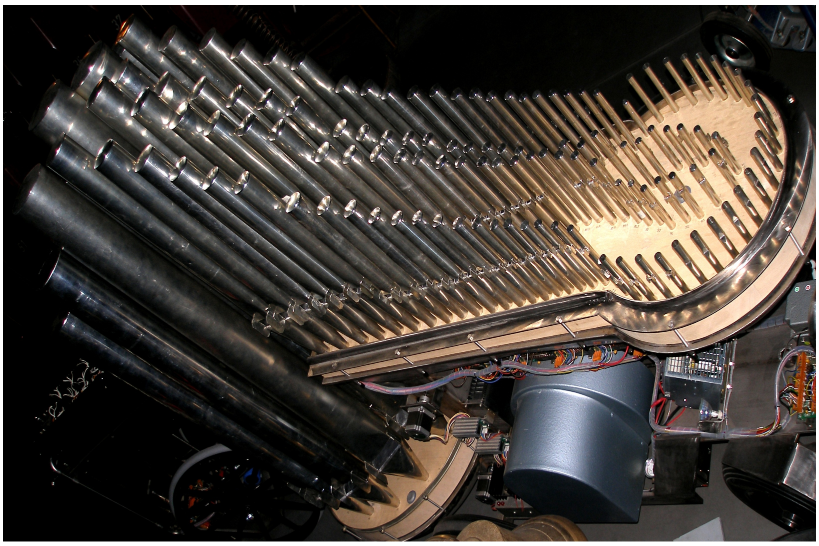
Although <Puff> cannot produce sustained notes, it is capable of producing a steady flatterzunge on each note. Here is a detail of the air pumps, driving solenoids and speaking pipes:

This robot also comes equipped with build-in gesture sensing, using microwave radar detectors working in the 24GHz range.

A wooden cromorno register, using newly made pipes, lead us to the design and construction of the <Krum> robot:

The pipes, covering a range of five octaves, use brass reeds mounted on wooden shallots. The resonators are full length and have intonation caps on their extremities. The wind in this module can be controlled using the motor-controller – inherently slow because of the inertia of the propeller – or by a large regulating valve using a bidirectional solenoid that is placed on the wind inlet of the compressor. Nominal wind pressure is 7.5 mBar. The result, with the pipes arranged in three rows, turned out to be extremely compact and transportable. The wind modulation scheme was ultimately not very successful because the pipes do not keep their tuning very well under variable wind pressure conditions. The tuning system of reed pipes in general leaves much to be desired and we are convinced there is place for serious technological improvement here.

In 1997 we succeeded in getting a research project accepted to design and build a completely new module: a quartertone organ with a compass of six octaves using metal pipework and closed pipes. The <Qt> organ robot was built in collaboration with Ghuislain Potvlieghe and Johannes Taelman. The pipes are made of a lead-free tin alloy, containing 5% of antimony as well as copper. This makes them quite a bit harder than traditional organ pipe work. The material was chosen keeping in mind that the instrument was going to be transported often, and thus exposed to shocks and vibrations. For the same reason, the pipe feet were all made purely cylindrical, protruding deep into the thick upper plate of the wind chest. In this design we applied velocity sensitivity to each individual note for the first time. Note aftertouch was also implemented, but not yet in an optimal way, as we learned later on.



With its 145 pipes, <Qt> could barely become a light instrument. Although it weighs over 270 kg, it is easily transportable using its own sturdy and flexible wheelbase. The wind chest was split into two section to achieve compactness and to limit building height. The two tremulant rotating valves in the wind supply channels are driven by stepper motors. Wind pressure for <Qt> is 14mBar and can be modulated.

Our most recent organ automaton, finished in 2010, was <Bomi>. The purpose here was to explore the extremes of what can be obtained in expression control using otherwise traditional pipework. Through the systematic use of conical valves driven by solenoids in the wind chest, we not only could implement attack control, but also individual note aftertouch and modulation for each pipe. A very flexible and responsive tremulant valve, again realized using a conical valve, can be used not only as a tremulant but also as a very fast-responding wind pressure modulation device.

The wind pressure at which this automaton works was deliberately set very low (4.5 mBar, or 45mm water column using traditional organ units). Hence the sound is also rather soft and gentle. The musical possibilities easily surpass anything possible in any traditional organ design we know of and this module has in fact been used on many occasions for performances of ancient music, where it can easily cope with the most musically sensitive recorder or flute parts.

Although our main concern in instrument building is the extension of expressive possibilities in musical automata, a need strongly felt in the field of contemporary music, we believe strongly that the perspectives of application of technologies developed here are extremely relevant even when it comes to the valorisation and preservation of dead historical organs for which complete reconstruction is not an option. Almost all churches have or used to have a pipe organ. Not all of these instruments, by far, have characteristics that can legitimate their preservation, let alone their restoration. And even if they have the required characteristics, it may not be a very rational or economically wise decision to invest considerable funds in restoration. The use of the instruments can in no way be guaranteed since the future of churches as churches is far from evident.

For those churches that serve a function as a monument and do attract visitors, it is a realistic option to reconstruct the essential parts of the organ – register by register – using the technologies described here, such that the original sound of the instrument can be heard whenever required. We stress the fact that automating such instruments is fully reversible on one hand and on the other it does not render normal manual playing impossible.

Further references:

All construction drawings, electronic circuitry, welding plans, scalings, micro-controller firmware, essential parts lists and a construction diary for each individual robot in the M&M robot orchestra are available on our website at:

http://www.logosfoundation.org/instrum_gwr/manual.html

A detailed paper on the design and construction of the <Bomi> robot can be downloaded as a PDF from:

http://www.logosfoundation.org/instrum_gwr/Bomi_paper.pdf

An (ongoing) report on technologies for achieving expression control in automated instruments in general is available at:

http://www.logosfoundation.org/g_texts/expression-control.html. This paper was presented at the NIME conference in New York in 2007 as a keynote paper.