2 (The) speaking of characters, musically speaking

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> If you've ever sat in a forest or a garden and sensed the plants breathing, you'll appreciate how the exhibit heightens and celebrates this sensation.
> (LaTempa 2007)

> The computerized sounds were spacey and sometimes menacing, sounding at times like Chafe was trying to tame an evil subterranean beast.
> (Ying 2011)

The pair of reviews above caught the moods and temperaments of a custom-designed computer music synthesis algorithm, Animal. The works described capitalise on Animal's great expressive range and use it to give voice to musical characters. The former refers to an interactive music installation, *Tomato Quintet* (2007), and the latter to *Phasor* (2011) for contrabass and computer. This chapter will discuss how Animal's moods and temperaments arise from its dynamics and dynamical response in performance. It will also situate these pieces between poles of new and traditional media and compare how Animal has been adapted to each. 'New media' will be used here as a label for data-driven art and digitally produced works in the millennial period.

The musical characters achieved in these two pieces are different faces of a single, identifiable instrument. In the following, we will examine their dichotomous personalities. In the installation piece, updates from environmental sensors near vats of tomatoes are mapped to Animal's parameters so we can listen to the tomatoes ripening. For *Phasor*, signals from a sensor bow are used to 'play' the algorithm. Different strategies for performance and different roles for their audiences distinguish the two works, but manipulation of the Animal system is a central element in the construction of both. *Tomato Quintet* is performed by its tomatoes and by its audience, inviting interactive participation, which builds understanding through 'hands-on' manipulation, whereas the audiences of *Phasor* are observers and require that the soloist do the manipulations, coaxing the system and exploring its qualities.

Tomato Quintet is an exhibit that foregrounds with a singular focus the ripening process of tomatoes. Gas sensors monitor this process and computers translate the gas levels into sound and graphs. My collaborator, Greg Niemeyer, calls it a 'new media still life' since very little seems to change, at least when taken on the time scale of the gallery goers. The sensors pick up the ten-day increase and then decrease of carbon dioxide and ethylene as fresh-picked green tomatoes redden and die. Viewers can interact by blowing on the sensors and prodding the system into real-time reaction. However, the exhibited process is so slow that it is essentially imperceptible until the listener/viewer lets go of the 'now'. The extreme mismatch between the process speed and human perception contrasts with a much faster-paced work, *Oxygen Flute* (2002), in which the life-giving exchange of carbon dioxide and oxygen between plants and humans is made perceptible. That work gives sound to respiration and photosynthesis in real time and makes the human element a central object (Chafe 2005, 220).

Tomato Quintet II is a second version in which the initial form of the exhibit, which was largely about observation from outside and 'slowing down', is transformed into one enjoining participants to observe themselves from the inside (like *Oxygen Flute*). The human element is objectified by enclosing both the tomatoes and the participants in a five-armed tent in which tomatoes are set to ripen. As they ripen – or if visitors breathe on them – the tomatoes trigger CO_2-sensitive sensors that cause salsa music to play and coloured lights to flash. The installation's visitors dance to 'ripening melodies' from Animal's gas-level sonifications and to rhythmic music synchronized with disco lights. The new version was featured in the San Jose Zero1 Biennial 'Build Your Own World' and again in the Beijing National Art Museum of China (NAMOC) Triennial 'Translife: Media Art China 2011', where it was shown in the context of a broad discussion around new media.

If 'Translife' poses numerous tough, even uncomfortable, questions, its biggest challenge is perhaps to the notion of art itself. Fan Di'an, director of NAMOC, acknowledges that some see the show as an effort to popularise science and technology rather than as an art exhibition, but he disagrees with this view. 'I think New Media as art is not really understood by the public', he said. 'This is scientific art and it is also artistic science'. Zhang Zikang, the curator, went further. 'Art is at a crossroads', he said. It has exhausted its possibilities and needs to expand. 'Representational art is past', he added. 'Even the most avant-garde art is past. New media art is real-time art – it is not signifying something. The media itself is the content' (Melvin 2011).

Tomato Quintet's 'delicious reddish spheres' and *Phasor*'s 'evil subterranean beast' are characters that get their voices from Animal; it is the medium through which they speak. Cast in the 'post-human' milieu of Zhang's 'Translife' Exhibition, Animal as medium is manifested as the work's content. On the other hand, by shifting the definition to a contrasting pole (one describing a more 'human' and less 'post-human' context) the primary content manifests itself as empathy with these beings. The tomatoes (wired up and ‘singing’ for *Tomato Quintet*) and the evoked beast (a metaphorical invention of one reviewer hearing *Phasor*) are musical characters, foregrounded explicitly in the one case and implicitly in the other. Without humans in the loop, either as observers or as observed, such empathy cannot exist. At the end of this chapter, we will turn to another work in which the ‘human’ over ‘post-human’ dialectic will completely dissolve. *Tomato Music* (2008; derived from *Tomato Quintet*) fits ideally into Zhang’s ‘media is the content’ proposition. It is a data-driven concert work, bereft of agonistic character. At the conclusion of this chapter, I will examine the lack of ‘musically speaking’ characters in *Tomato Music* and ask: in the absence of characters (virtuosic or otherwise) can expression exist?

Expression comes into the game when a musical voice communicates a musical ‘something’. This could be a melodic construction or gestural figure. It is a moment in which sound contacts our feelings. The communication takes place through a transmitting character, for example, a flautist (our agonist) plays a melody, which the composer has deftly assigned to her/him at a particular moment in a composition. Or perhaps the flautist works in an improvisational context in which one time and one time only s/he plays the most expressive accumulation of notes and articulations to bring the performance to a climax or conversely to quietly close it. These are hypothetical illustrations, but they symbolise expressive possibility in music. Overt communication of such emotional messaging has even been tied to evidence of physiological changes in the listener such as the ‘frisson response’ (Huron 2006, 282–83). Descending as far as we wish, dissecting performance to the most micro-time scale, expression might be found in a moment of felt emotion covertly evoked by one part of one note that is brilliantly changed, perhaps the most modest modification of the flautist’s comportment, but musically thrilling in ways difficult to put into words. No list of these expressive ‘somethings’, or even a list of the ‘types of somethings’, could ever be complete.

Easy ‘instrument-ness’

The physical components responsible for carrying musical ideas are of interest in studying Animal’s application in the two works. A subdivision into instrument and performer helps us approach the works’ systems and is in accord with a ubiquitous paradigm that bisects computer music systems since its earliest days: the instrument is what sounds when manipulated by a performer and the performer is responsible for communicating ideas (Mathews and Miller 1969, 35–6). By virtue of its digital signal-processing (DSP) properties Animal acquires ‘instrument-ness’ of a particular kind. The performers are tomatoes, gallery goers or a musician. The corresponding ideas are biological process, inquisitive manipulation or those with musical import.

The DSP of Animal can be categorised as a physical modelling abstraction and as such it has an antecedent in a project integrating physical

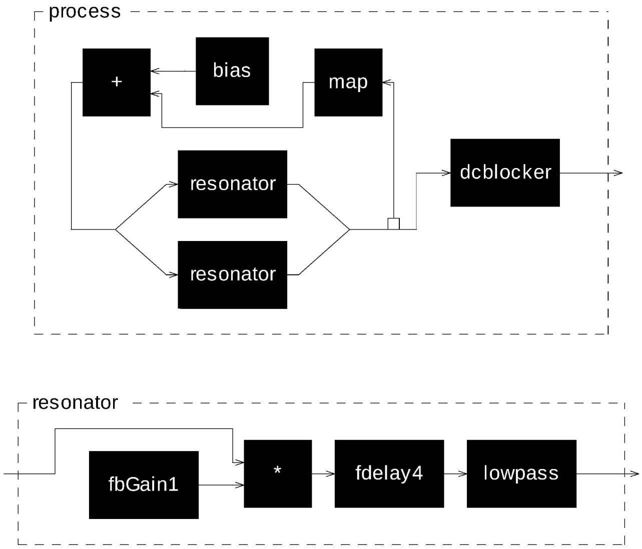

Figure 2.1 The Animal algorithm is comprised of two parallel resonators with the logistic map in their feedback path.

model families – Perry Cook's 'meta-physical' model (Cook 1992, 275) – and another in a musical work, which recombines physical model components in physically impossible ways (Burns 2003). DSP designs are open to inclusion of mathematical 'parts' from other domains. In Animal's case, the logistic equation has been borrowed from population biology (May 1976, 460). Figure 2.1 shows the entire DSP algorithm for Animal.

Algorithms using additive, subtractive or modulation-based synthesis (wave shaping and frequency modulation) can be factored into multiple instrument identities. For example, a given synthesis technique can be used for both percussion and woodwind simulation. A unique and specific 'synth instrument' using one of these general-purpose techniques represents a particular algorithm and set of algorithm parameter tunings endowed with an instrument identity. The Animal algorithm is not derived from a general-purpose technique, nor does it extend to more than a single identity. Its identity is intrinsic to its physical model technique.

To take this a bit further for the sake of clarity, frequency modulation (FM) can be used in many algorithms (or 'patches'). The timbre possibilities have produced a magnificent range of synthetic instruments across many families (from brass, winds, percussion and vocals to new identities). Tuning or 'voicing' a particular FM algorithm to match an identity is an art in its own right requiring experimentation, specialised knowledge, intuition and even some amount of luck. These ingredients are described in a primer written by Chowning (the inventor of FM) and Bristow (1986, 140–59) who produced banks of successful voicings for the Yamaha DX-7 FM keyboard.

It is often a twofold quest to create both a coarse identity (some kind of distinguishable instrument) and then a more sharply defined variant. Voicing real pianos is analogous to this final aspect. Piano technicians will adjust the felts and touch to achieve a capability for rendering subtle shades of expression. Luthiers make similar adjustments to stringed instruments. As a cellist, I recently had the experience of comparing a couple dozen cellos in a two-hour sitting; all were priced in the same mid-level. They were well-made, excellent sounding instruments, and the experience impressed upon me the fine-grained differences underlying the unique personality that each possessed. Their differences resided in their respective timbres or in their responsiveness to my playing, affecting the ease with which I could evoke a full palette of expressive tonal qualities. Overall, an identifiable personality seems to be a complex mix of static qualities and dynamic responses. The latter aspect, which is exposed by parameter deflections in performance, is what makes Animal come alive.

Physical ingredients

Animal is a nonlinear difference equation solved in real time to produce a stream of audio samples. Computational studies of this kind (but not in real time) were extended to musical instrument acoustics in the early 1980s in the work of McIntyre, Schumacher and Woodhouse (1983) who showed that sustained oscillations of the edge-tone instruments (flutes), reed instruments and bowed strings were the result of negative feedback systems. The production of musical tones (and a variety of other sounds) was accomplished by setting up a model system of equations and iterating it one audio sample at a time. Like Animal, these models consist of a resonator (analogous to an air column or string) coupled with a nonlinear excitation mechanism (the mouthpiece or bow) through which the system can be driven by an external force (the player). The output of the nonlinear element feeds back to its input after passing through the resonator. During the same period that physical models of this kind were being studied for their resemblances to real-world instruments, two congruent projects emerged, which intersect in the genesis of Animal.

The Karplus–Strong physical model synthesis technique was developed for its inherent guitar-like sound and its computational efficiency (Karplus and Strong 1983, 43–44). Like the models proposed by McIntyre, Schumacher and Woodhouse (1983), the plucked string algorithm has a resonator component, but it uses a more efficient computational method (lumped-circuit waveguide rather than convolution). Only simple plucks or strikes are possible, transient excitations, which are created from the initial condition of the waveguide. The basic synth instrument, which was originally intended for game sound effects, was adapted for high-quality musical use by adding several features including precise pitch tuning, a method for achieving a variety of pluck types (Jaffe and Smith 1983, 59–67) and guitar body modelling (Smith 1997, 264–267). Extending the model to include the effect of guitar feedback through a guitar amp provides a self-oscillating capability (Sullivan 1990, 32–34). Animal's double resonators employ waveguides with precise tuning. The self-oscillation method is used rather than an external driving force.

The other domain studied concurrently was the existence of chaotic systems made of iterated nonlinear difference equations. Earlier work had subsequently discovered chaotic behaviour in systems of ordinary differential equations, which have no explicit temporal dimension and require three or more dimensions in the system of differential equations to exhibit chaos. Numerical solutions of such dynamical systems by computer evolved into a field in their own right (Lorenz 1963, 137). Simpler iterated difference equations were subsequently found that can also exhibit chaos. One of the first examples was the logistic map from biology (May 1976, 460), a nonlinear feedback system that iterates generation by generation. Its single state variable models a population in which the magnitude of each subsequent generation depends on the previous magnitude. Depending on the value of the equation's tuning parameter, the state will either remain constant (at a fixed point), vary periodically (in a limit cycle) or behave unpredictably (exhibiting chaos). Generating a sequence of states in a computer program tuned for chaos demonstrates the butterfly effect, wherein if the initial state is slightly different it will yield sequences that diverge further and further from one another. Animal inherits these dynamics through its inclusion of the logistic map as its nonlinear excitation component.

Chaotic dynamics can involve a 'basin of attraction' with the right parameter tunings of the map equation. States that lie outside the basin will gravitate towards states within it as the map is iterated. Once a sequence is trapped, subsequent behaviour will oscillate inside the basin but never exactly periodically. Using such a system to produce a stream of audio samples creates a timbre 'basin of attraction' and a quasi-periodic waveform pattern. A fixed-media piece, *Vanishing Point* (1989), used the same dynamics to create oscillatory rhythmic patterns by iterating the system much more slowly, once for each note, and triggering percussion samples. Rhythmic 'basins of attraction' were created that had qualities of predictability (because of the bounded oscillation), variety (because states never exactly repeated themselves) and transient behaviour (because the system could be 'kicked' outside the basin momentarily and then gravitate back in).

Animal's parallel resonators are delay-line and low-pass filter units with delay times whose periods created frequencies in the pitch range. First-order Butterworth low-pass filters are used in series with the delays to attenuate higher harmonics. The logistic map is applied to the sum of the resonator outputs, and its output is fed back to their inputs. A DC-blocking filter is applied to the entire circuit's output. A tiny DC source biases the system to kick-start it and to avoid the computing of subnormal numbers (i.e. very small values near zero resulting from numerical rounding errors). The algorithm is 'self-excited' as in Sullivan's guitar feedback rather than excited via the MWS-style external energy source. The use of dual resonators in feedback through a potentially chaotic system produces acoustical behaviours including mode quenching and beating that produces amplitude modulation (AM). This results in dual sidebands, period doubling, multimodal regimes and various distortions. The parameters available are the gain of resonators, the length of resonators, filter cut-offs and *r*, the logistic map's tuning parameter shown in the following equation: $x_{(n+1)} = rx_{(n)} (1 - x_{(n)})$. The algorithm does not intentionally mimic any particular physical instrument though at times it has a clarinet-like or brassy tone, depending on parameter values. It produces a palette of sounds whose time-varying transitions are rich in the timbre features of familiar instruments.

From 'instrument-ness' to refining character through 'timbre moves'

What does it mean to say that creating character is up to the performer? First, it requires that the identity of the instrument type be stable. Alternatively, if it is unstable, then the choice of identity is made by the performer. Either way, the choice of instrumental source is bound and controlled by the performer. A melodic figure with a persistent 'croaky' timbre at its most lethargic, and a sharp crisp, rippling, piercing quality when awakened would constitute a recognisable character. As a thought experiment, we shall call this one Animal 'A' and imagine an Animal 'B' with a contrasting sets of characteristics. Animal 'B' might simply be a stutterer that tries to hit pitches and only sporadically succeeds. Both 'A' and 'B' are recognisable instances of Animal and are constructed from the set of sonic 'moves' afforded by Animal's identity. Consequently, they share an identity but differ in character. As musical voices, they are separable and could play contrasting roles. Or these characters could hold forth in tandem: the resulting duo could start badly and end happily, etc. – all of this would depend on the musical ideas being constructed.

Can there be musical expression without character? In simplest terms, no, because we suppose that expression is the planting of ideas from one consciousness into another. We also need to remember that, as listeners, we relentlessly try to identify the source communicating to us. We will even infer or construct a plausible source model in the absence of a recognisable source. Ascribing character is the essence of this tendency. We conjure the performer whether the provenance of the music is human or mechanical. A robot is a valid character, as are the 'actors' in the recorded sound of a tropical rain forest. Once we accept a rain forest as music that is 'communicating to us', the music's source entities are immediately endowed with what can be called 'character'. If that fails, does the music fail? Can the rainforest itself be communicating? Yes, music sometimes fails, and yes we can hear music in many ways and things.

Figures 2.2–2.7 illustrate 'timbre moves' that are available to the performer constructing a character with Animal. As a lab experiment, all but one of its seven parameters are held at their medium value. The independent parameter is varied in a linear ramp from a low to a high value. Many acoustical features present themselves in these isolated contexts illustrated below: envelopes shaping amplitude; spectral evolution; pitches supported by harmonic and subharmonic series; possibly multiple series at the same time; effects similar to overblowing, sul ponticello, sul tasto, and 'creaky voice' and nonharmonic sideband modulation and distortion.

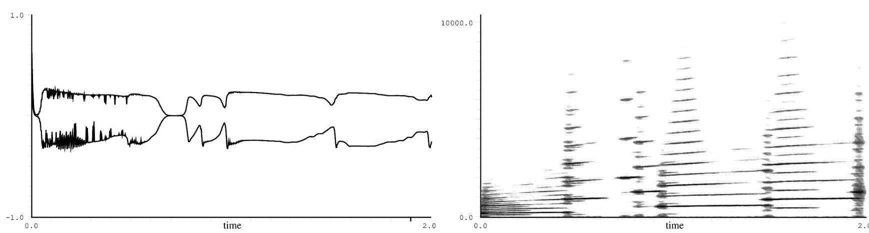

Figure 2.2 Amplitude and spectrogram display of two seconds of sound from ramping up ratios of resonator delay lengths from 1.04 to 8.0. One resonator delay length is held constant while the other's length is shortened. Varying ratios create a variety of pitches similar to overblowing or sul ponticello effects.

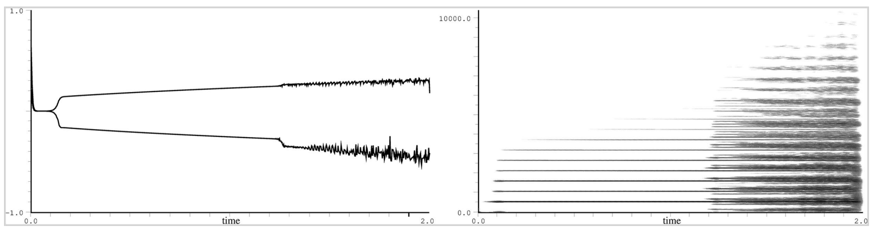

Figure 2.3 Amplitude and spectrogram display of two seconds of sound from ramping up feedback gain to both resonators from 0.0 to 1.0. Animal is self-excited by the slight DC bias injection, which is constantly present. The algorithm will not speak with a feedback gain of 0.0. Increasing feedback gain energizes the system and tonal quality traverses from muted to brilliant, eventually hitting modes that are gravelly and forceful.

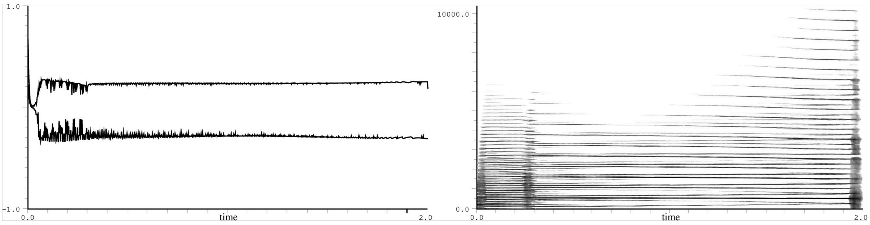

Figure 2.4 Amplitude and spectrogram display of two seconds of sound from changing the balance between resonators. With resonators holding non-coincidental tunings of delay length and/or lowpass frequency, effects can be derived from altering their relative contribution. The figure shows three pitch regimes obtained, including subharmonics.

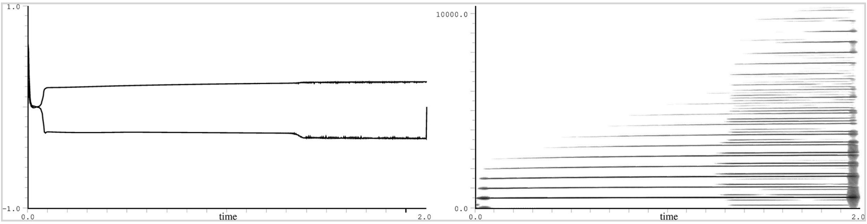

Figure 2.5 Amplitude and spectrogram display of two seconds of sound from ramping up the low band pass frequency from 550 to 9000 Hz. Akin to increasing feedback gain, but without the gravelly sound in Figure 2.3, the higher low band pass cut-off frequency towards the end of the sound creates a brightness effect.

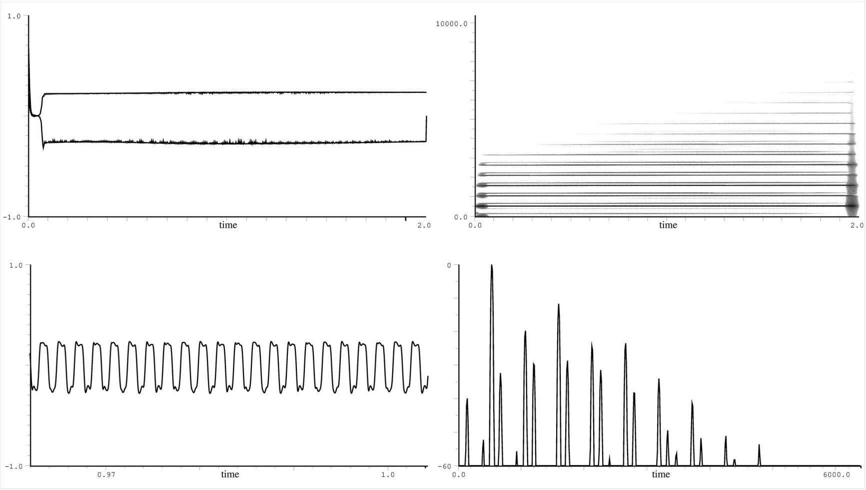

Figure 2.6 Amplitude and spectrogram display of two seconds of sound from ramping up ratios of resonator low band pass frequencies from 1.003 to 4.0. Almost undetectable in the sonogram, but visible in a zoomed spectral slice, the ratio of resonator low band pass frequencies create a quality shift by traversing a region with sidebands. The overall percept is strongly pitched. An inflection in tone is caused by sidebands growing and diminishing in strength.

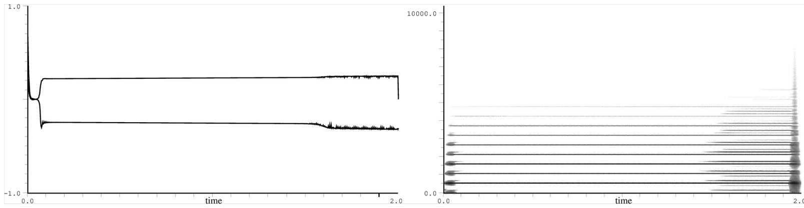

Figure 2.7 Amplitude and spectrogram display of two seconds of sound from ramping up the parameter *r* of the logistic map. Increasing *r* grows the second (octave lower) subharmonic as seen in the end of the figure.

What animal is and is not

To summarise, Animal is a synthesis technique manifesting a single instrument identity. Its performer can construct personalities of different character, which are fit to the intended musical role. Using its possible 'timbre moves', the performer is free to construct characters that are as convincing as the music itself.

The application of this technique in *Tomato Quintet* stretches the notion of character to its limit. Transference is the goal. Listeners ascribe to the tomatoes a sonic character that they infer from the music. The music contrasts slow time scale material (the tomatoes) with much faster time scales (corresponding to human activities). Animal provides a voice for both. The ambient 'tomato character' consists of pitched material driven by slowly changing signals from carbon dioxide sensors tracking the ripening of the fruit (other ambient layers use other algorithms that produce sounds of wind and transient, percussive sounds reminiscent of hail on a roof). Faster figurations create the human-related musical characters, which are energised by the motion of accelerometers when visitors touch the sensor systems.

Phasor employs a chorus of Animals to achieve a pitched texture performed directly by bowing gestures. The bassist uses the cello model of the K-Bow, which tracks several factors that contribute to the sounds a string instrument will produce, using a three-axis accelerometer, grip strength sensor, tilt sensor and hair tension sensor. The system also tracks the bow's position from the bridge or across the violin. The K-Bow provides gesture signals to the accompanying sound-generating computer via Bluetooth.[1] The character evoked is one of intricate pitch structures whose modulations are interspersed with abrupt rhythmic surprises and textural intrusions.

Animal, as used in these pieces, does not conform to rigid scales or categories of familiar tonal qualities (the backbone of more traditional music). The surprises it creates in pitch and timbre are a part of its identity. It is capable of large shifts and small in-between shades as control values are traversed. Its two resonators with their separate gains and filters make it difficult to tune precisely or predictably, because it tends to jump between states and create parasitic tones. In 'On the Oscillations of Musical Instruments', McIntyre et al. (1983) conclude with a description of the acoustical qualities of model systems that resemble Animal. They refer to 'playing' numerical solutions via computer programs started with different parameter values.

> A little experience with this soon reminds one of a well-known property of non-linear phenomena, namely their non-uniqueness. Several different regimes may be possible for the same final set of parameter values. One soon learns how to encourage a given type of oscillation during the initial transient, a matter in which musicians develop superlative skill. One is also reminded of the rich variety of periodic and aperiodic behaviour, which may be exhibited by even the simplest nonlinear oscillators (see Appendix A Relation to the Theory of Iterated Maps). The question of which behaviours are physically realistic for musical-acoustical purposes, and which result from too unrealistic a choice of model characteristics, has yet to be studied systematically, although instructive examples regarding stable versus unstable behaviour were encountered in foregoing sections.[2]
>
> (McIntyre et al. 1983, 1339)

Tomato music

The *Tomato Quintet* installation spawned the concert piece *Tomato Music* that was composed from data collected during the first exhibition. The two compositions are worth examining in light of Zhang's comments on new media noted above: 'New media art is real-time art' and 'When we talk about time, it is multiple times now.'

Tomato Music is purely sonified data. Gas-level recordings from one ten-day run of *Tomato Quintet* are compressed into ten minutes of music. The gas-level readings are mapped to parameters playing fifteen synthesised slide-flute-like instruments (the parameters are air pressure, tube length, portamento and embouchure). *Tomato Music* is primarily a process work – much like Alvin Lucier's *I Am Sitting in a Room* – in which a fixed procedure is applied to a given input. The algorithmic machinery in *Tomato Music* elicits a rigidly occurring interruption of texture every forty-nine seconds by updating its data-to-instrument mapping to a new scheme. Though not interactive (it is a fixed-media piece) and not 'real time' (because its data is compressed in time), *Tomato Music* does create its own time scape. Works that engage a process as a primary component and make time malleable are species of new media. *Tomato Music* engenders music devoid of character (in the sense described above) landing musically closer to Zhang's 'The media itself is the content'.

The instrument in *Tomato Music* is a physical model, not Animal but one that began with attempts to simulate the pipes of the ancient Greek hydraulis or water organ.[3] The model produces tones, which can be shrill and austere but also can emit rumbling subharmonics or quiet 'hissing' sounds, qualities reminiscent of György Ligeti's organ works, *Volumina* and *Harmonies*. As opposed to a music of discrete pitches (which was probably what the hydraulis mechanism played) the ‘medium’ of *Tomato Music* is a data set of smooth changes that occur during ripening. As a final nod to the polemics around new media, we can also say that the ripening of tomatoes is the content. The long ten-day arc is inscribed with shorter-spanned curves from daily temperature and light variation. These curves violate the fixed-pitch structure of the hydraulis simulation. Making them speak meant replacing the hydraulis with a bank of slide flutes capable of continuous pitch. This type of modification is something only possible in software and adheres to a commonplace practice in which physics can be violated on a whim. To finalise the transformation from simulation to new musical instrument, the organ with its polyphonic manual controlling an ensemble of pipes, was replaced with a software design unconstrained by physics. In our inhabited world, could we ever attempt or achieve an ensemble of slide flutes synchronised this tightly? Or do media of this kind take us into a realm, which, from our immediate vantage point in time, we should call ‘new’? In an honorific for Roger Reynolds’s seventieth birthday, I wrote:

> …the set of norms and institutions is plastic too, a result of so many individuals’ gifts back to culture. Music produces virtuosi in continuous streams. The sequences of teachers and students who become teachers form braided, merging and diverging schools, worldwide. Master musicians cross tens of generations when charting, for example, the gharana of sarod or tabla on the Indian subcontinent. Such histories emerge from deep time and are continuously evolving. Passed on from the teacher is both craft and a way of communicating meaning. Added by each individual is new meaning to be folded into the musical style. The folding-in is at the crux of virtuosity.
>
> (Chafe 2004)

The question left hanging in the air at this point relates to musical expression: without characters (virtuosic or otherwise) does expression exist? For many listeners experiencing *Tomato Music*, it seems that it does. In this case, expression is not a product of direct human manipulation. The ideas to be expressed in *Tomato Music* probably exist only at the outermost layer, as an element of design. What a character is and what it speaks, musically speaking, must be things conjured entirely in the minds of the receivers.

Notes

1 The K-bow was produced between 2007 and 2014 by Keith McMillen Instruments, Berkeley, California. For more information, see www.electronista.com/articles/08/11/07/mcmillen.string.interfaces/.

2 The article’s Appendix A expands on a ‘Relation to the Theory of Iterated Maps’ and is recommended for further reading.

3 'Ctesibius of Alexandrea, who lived about B.C 200, took the idea of his organ from the Syrinx or Pandean pipes, a musical instrument of the highest antiquity among the Greeks. His object being to employ a row of pipes of great size and capable of emitting the most powerful as well as the softest sounds, he contrived the means of adapting keys with levers (agkoniskoi), and with perforated sliders (pomata) to open and shut the mouths of the pipes (glossokoma), a supply of wind being obtained, without intermission, by bellows, in which the pressure of water performed the same part which is fulfilled in the modern organ by a weight.' (Smith 1874, 422–423).