Numbers into Notes: digital prototyping as close reading of Ada Lovelace's 'Note A'

David De Roure
david.deroure@oerc.ox.ac.uk
University of Oxford, United Kingdom

Pip Willcox
pip.willcox@bodleian.ox.ac.uk
University of Oxford, United Kingdom

Lovelace and Babbage

Ada Lovelace is widely held to be the first computer programmer, composing the first algorithm designed for execution by a general purpose computing machine. The algorithm was published in the "notes by the translator", appended to her translation of Menebrea's 1842 French account of Charles Babbage's 1840 seminar on his proposed steam-powered computer, the Analytical Engine, at the University of Turin (Lovelace, 1842).

This third-remove contribution appearing in small print after the main article belies both the closeness of her friendship with Babbage and how extraordinary her vision was of what such a general purpose computing machine could achieve. The phrase often quoted in the literature of computers and music offers another insight into her imaginative response to the hypothetical Analytical Engine:

"Supposing, for instance, that the fundamental relations of pitched sounds in the science of harmony and of musical composition were susceptible of such expression and adaptations, the engine might compose elaborate and scientific pieces of music of any degree of complexity or extent." (Note A)

Our work described in this paper explores this observation, taking inspiration both from Lovelace's ideas and from composer Emily Howard's creative response to them. Using digital technologies, we have prototyped software and hardware to investigate Lovelace's theory of creative computing. We developed a web-based tool, Numbers into Notes, which we used as a prompt to engage the public with these ideas at live musical performances. The musical outcomes of our research are recorded as Digital Music Objects (De Roure, 2016a) which include provenance records.

Following Galey and Ruecker, we suggest that this application can be viewed as a designed digital artefact analogous to a critical work, explicating our interpretation of Lovelace's words (Galey, 2010).

Simulator

Babbage's Analytical Engine remains unconstructed, but today we can simulate the execution of programs on it digitally, based on the detailed accounts of the Engine's design provided by Babbage and Lovelace. As an experiment in hearing what Lovelace might have imagined, we coded an algorithm to run on a simulator in order to generate number sequences which are then mapped to instruments. The numbers are strictly faithful to nineteenth-century mathematics. Human intervention decides the algorithmic parameters and the mapping of the numbers to notes and instruments, to be explored based on the musical context of the time. This experiment led to the creation of the Numbers into Notes web site, making the tools available to others for investigation and composition.

Performance

Emily Howard has also responded creatively to Note A, and the life of Lovelace, in composing her *Lovelace Trilogy* (Petri-Preis, 2013). 'Ada sketches' is a short operatic work for mezzo-soprano, flute, clarinet and percussion. Howard's time as Composer in Residence at the University of Liverpool's Department of Mathematics, and her work there with Lasse Rempe-Gillen, led to this piece which has been performed in formats that encourage audience response and participation. A performance at the University of Oxford as part of celebrations to mark Lovelace's 200th birthday investigated the audience's reception of the work. Its most recent performance, at the Royal Northern College of Music, used our Numbers into Notes web application.

Digital–physical

The Numbers into Notes software invites a thought experiment: had Lovelace lived longer, and had Babbage successfully built the Analytical Engine, what might have happened in pursuit of Lovelace's musical observation? We extended this thought experiment to ask "what might Lovelace do today?" To explore this, we constructed multiple physical devices (based on the Arduino open-source electronic prototyping platform) to re-enact the algorithms designed for the Analytical Engine (De Roure, 2016b). Today Lovelace

could combine multiple machines, and the computational power would enable real-time synthesis, putting into practice the mathematical notions of consonance that were established in the eighteenth century.

Experimental humanities

This approach, which we suggest might be framed as *experimental humanities*, has attracted engagement during events and online, and has also been a successful vehicle in teaching (in the Social Humanities strand of the Digital Humanities at Oxford Summer School). Our work uses digital tools, co-designing digital and digital-physical artefacts, to explore and re-imagine prospective and theoretical technologies of Lovelace's day. Through this we provoke new responses and discoveries relating to music practice and performance, and to the philosophy and history of technology. The practice of this *experimental humanities* approach enables critical reflection and re-interpretation: we suggest that the digital artefacts we have produced are each interpretations drawing on the life and writing of Lovelace, and the value of this practice lies in the new insights and works they inspire.

This paper recounts these experiments that play at once into generative design and into alternative histories of algorithms and mechanisms. Through making, through prototyping and co-design, we close-read the thought processes Lovelace and Babbage recorded. We point to paths in the development of computing and programming that were not taken, and extend beyond what was practicable in the nineteenth century. Our work also touches on creativity, as anticipated by Lovelace and recast in the "Lovelace questions" (Boden, 1990), and manifest today in the fields of computational creativity and creative computing.

Acknowledgements

This work is supported by: *Fusing Semantic and Audio Technologies for Intelligent Music Production and Consumption*, funded by the UK Engineering and Physical Sciences Research Council (EPSRC) under grant number EP/L019981/1, a collaboration between Queen Mary University of London, University of Nottingham and University of Oxford; *Transforming Musicology*, funded by the UK Arts and Humanities Research Council under grant AH/L006820/1 in the Digital Transformations programme, in collaboration with Goldsmiths University of London.

Bibliography

Lovelace, A.A. (Trans.) (1842) Sketch of the analytical engine invented by Charles Babbage, with notes by the translator. In Scientific Memoirs, Selected from the Transactions of Foreign Academies of Science and Learned Societies, Vol. 3, 1843, pp. 666-731, volume 3. Richard and John E. Taylor, Red Lion Street, Fleet Street, London. Translation of 'Notions sur la machine analytique de M. Charles Babbage' by Luigi Federico Menabrea, in Bibliothèque universelle de Genève. Nouvelle série 41, pp. 352–76.

De Roure, D., Klyne, G., Page, K. R., Pybus, J., Weigl, D. M., Wilcoxson, M., and Willcox, P. (2016a) Plans and performances: Parallels in the production of science and music. In Proceedings of the 2016 IEEE 12th International Conference on e-Science, IEEE, pp. 185–192: 10.1109/eScience.2016.7870899

De Roure, D. and Willcox, P. (2016b) Numbers in places: creative interventions in musical space & time. In Proceedings of the 18th International Conference on Human-Computer Interaction with Mobile Devices and Services Adjunct - Mobile- HCI '16 (2016), Association for Computing Machinery (ACM), pp. 1059–1063: 10.1145/2957265.2964199

Galey, A., Ruecker, S. (2010). How a prototype argues. Literary and Linguistic Computing, (25) 4, pp. 405-24: 10.1093/llc/fqq021

Petri-Preis, A. (2013) Emily Howard's Lovelace Trilogy: a musical homage to a mathematical pioneer. Tempo 67 (265) 28–36: 10.1017/S0040298213000442

Boden. M. A. (1990). The Creative Mind: Myths and Mechanisms. Weidenfield and Nicholson, London.