EVOLVING SONIC ENVIRONMENT

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Abstract. The project consists of two embodiments: a society of sonic devices distributed in a room and a mechanism for recording and reviewing the history of the population. It was hoped that the collective behaviours of the devices would be affected by the way that the room was occupied (by people or other mobile objects) and, as such, the room would develop a "perception" of its occupancy. One might say that the society of devices together functioned as a "people sensor", though there were no "people sensing" functions built into the individual devices.

1. The project as built

Drawing on the work of Gordon Pask, Donald Hebb and Andrew Adamatzky, the project is an architectural experiment to investigate how one might construct an interactive environment that builds up an internal representation of its occupants through a network of autonomous but communicative sensors. The "society" of sonic devices function like simple neurons, though using acoustic rather than electrical coupling. They both respond to and create high frequency sound, cascade during high activity, alter their thresholds during periods of low activity and become apparently "bored" by repetitive inputs. The units are constructed chiefly from analogue components and therefore are not "programmed" in the conventional sense to exhibit particular properties. In order for us, as external observers, to get a glimpse into the changing states of the room (and in order to "observe" the room's "observation") we have two possible points of entry.

The most straightforward method is to enter the room and listen to the units "talking" with each other through high frequencies. However, entering the room affects the communication paths of the devices and therefore alters the internal state of the room, particularly sonically. The high frequency sound employed creates varying maxima and minima throughout the room; people obstruct communication paths and interrupt the "conversations" being carried out between devices.

An alternative method of experiencing the changing states of the room analogises the process of EEG recordings of the brain: audio from the population, shifted down 10 octaves in real time to comfortable human hearing range, is provided in a second corresponding room. This includes visualisations of the sound as well as a visualisation of movement as sensed by a camera that is positioned in the other room. It provides a different observation of the room which will alter depending on how the room is occupied, how frequently, by how many people and in which locations people tended to remain.

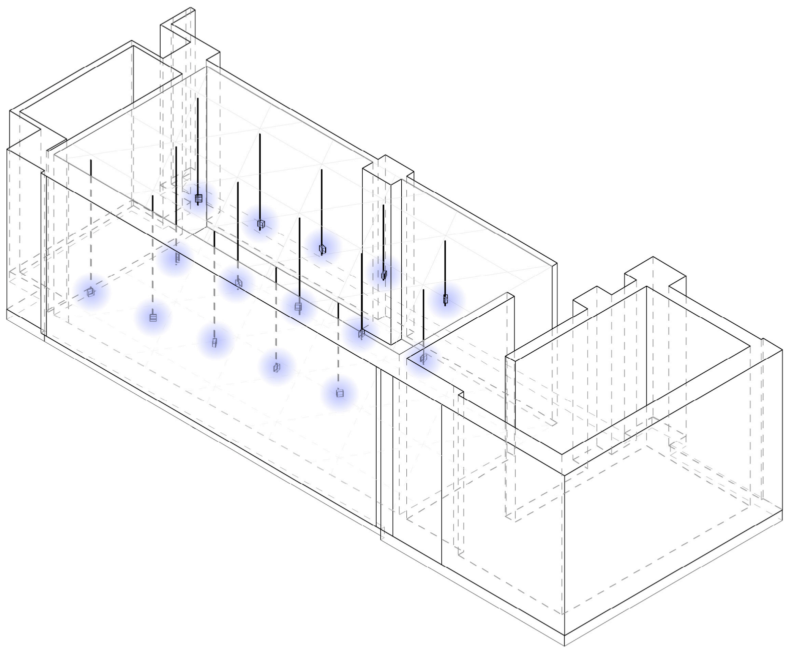

Figure 1. Axonometric drawing of room

The units were distributed in the room in a regular triangle grid on plan, with a separation of 1.3m between units. They were suspended from the ceiling (height 3.6m) at a height of 0.8m in one corner and rising regularly to 2.0m in the opposite corner.

3. Individual units

Each individual has a small microphone within a horn like metal housing, tuned by the depth of the microphone from the opening of this housing. This forms a quarter wave resonant cavity to help match the microphone to the pitch of other individuals in the group.

There are four processing blocks that follow the acquisition of room sounds from the microphone;

1. *Amplification and filtering*: this is achieved using a 2 op-amp high Q band pass filter with high gain. The resulting signal directly drives the tone decoder block.

2. *Tone decoding*: a circuit consisting of I and Q phase detectors driven by a voltage controlled oscillator running at approximately 16KHz to drive an output transistor into saturation when the pass band signal is detected.

3. *Neuron*: an integrate-and-fire type of neuron having both excitory and inhibitory inputs (we are only using the excitory inputs in this setup). This was realized as a form of relaxation oscillator having excitory connections to the output of the tone decoder, as well as to a fixed current source and finally to a JFET transistor having its gate connected to a short aerial. The purpose of the fixed current source being to allow the neuron to fire spontaneously at low rate in the absence of an input signal (stimulus), the signal from the JFET was used to allow changes in the electrostatic field gradient near the individual to contribute to the excitation of the neuron. The tone decoder was connected as an excitory input so that signals heard from other members of the group would tend to increase group activity (it may also increase the order of the society, but analysis of this is pending). The summing element of the neuron is a capacitor, slowly becoming charged by these excitory inputs until a threshold is reached when the neuron fires, dumping almost all of the capacitors charge in a short period. This signal was used to drive the output stage. The neuron also incorporates a second very high value capacitor with very low leakage current, connected such that it controls the neurons firing threshold. This capacitor becomes charged with increased activity in the neuron such that further firings of the neuron become easier. This is responsible for long term (Hebbian) learning in the neuron. The charge on this element may also diminish over time. Many repetitive firings may overcharge this part of the circuit so that the neuron may become effectively bored if over stimulated.

4. *Output Stage* - here the output of the neuron is used to frequency modulate a continuous 16KHz square wave oscillator. The signal is then smoothed to remove excess harmonic content and amplified for output into a transducer measuring 50-65mm in diameter. Due to the high frequency employed, the wavelength of the sound is comparable to the diameter of the speaker, thus the sound gains a very directional, beam like quality.

Figure 2. Units suspended in the occupied room

4. Reasons for design approach

As the vast majority of components used were analogue in nature, due to manufacturing variations, each individual was imparted with a natural variation in component values allowing the possible individual differences to emerge. Also, the possibility exists that unexpected sensory channels may develop. For instance it was noted that a magnet held near a neuron circuit would occasionally stall the firing process; this was not deliberately designed into the system, but is an idiosyncrasy of the circuitry.

The departure from purely digital design allows the possibility of a more "organic" processing structure to emerge, one that has vagaries and allows less intention on the part of the designer to creep into the exact function of the devices.

5. Method

The room was monitored by video camera. A frame of video was taken when the room was unoccupied and compared to frames as the experiment progressed. The degree of occupancy was computed as the sum of absolute differences of pixel luminosities between live frames and the reference frame. The sound from the room was sampled from a single microphone placed in a corner of the room at a rate of 48KHz. The audio was then converted to the frequency domain via fast Fourier transform in real time and these data logged, together with the corresponding occupancy data for offline analysis.

6. Results

Due to camera noise a threshold of occupancy was derived so that data could be sorted clearly into occupied and non-occupied classes, this threshold being the mean occupancy (12.9021). All data with occupancy values above this threshold were classed as occupied, and all those below as unoccupied. Figure 3 is a time series showing level of occupancy over the data analysed. The room was occupied approximately 35% of the time.

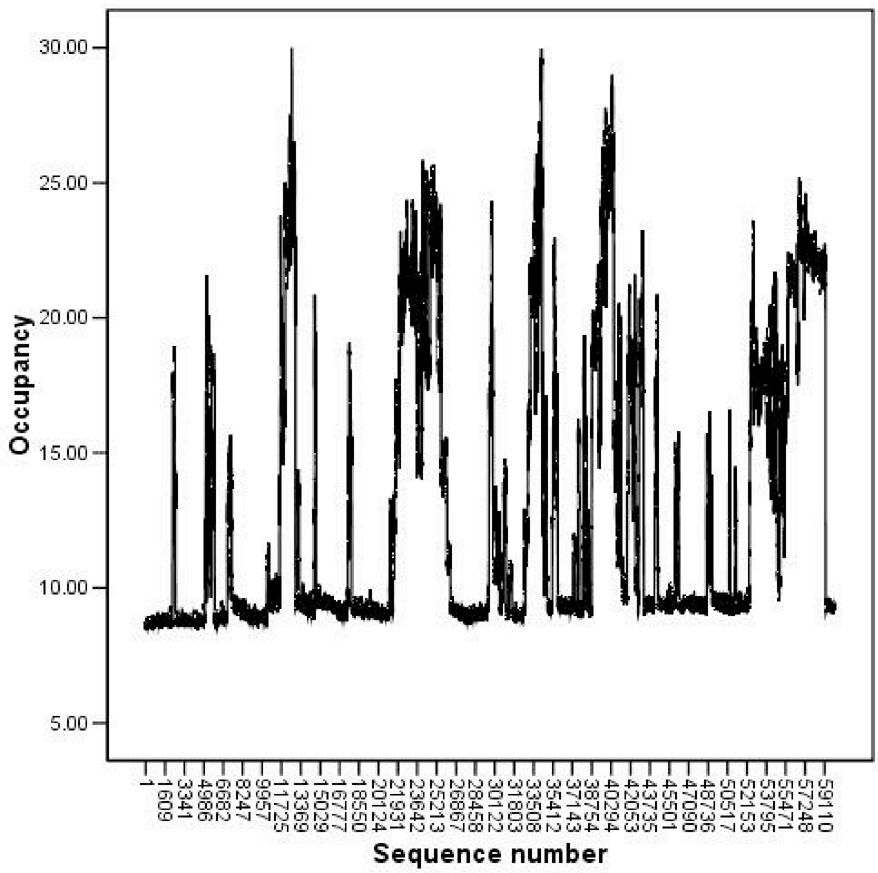

Figure 3. Graph of room occupancy

Figure 4 shows the variance of each frequency bin for both occupied and unoccupied states, the difference between these curves is also plotted. It appears a good deal of variance occurs in the major peak when the room is occupied, while a smaller peak displays a drop in variance when the room is occupied.

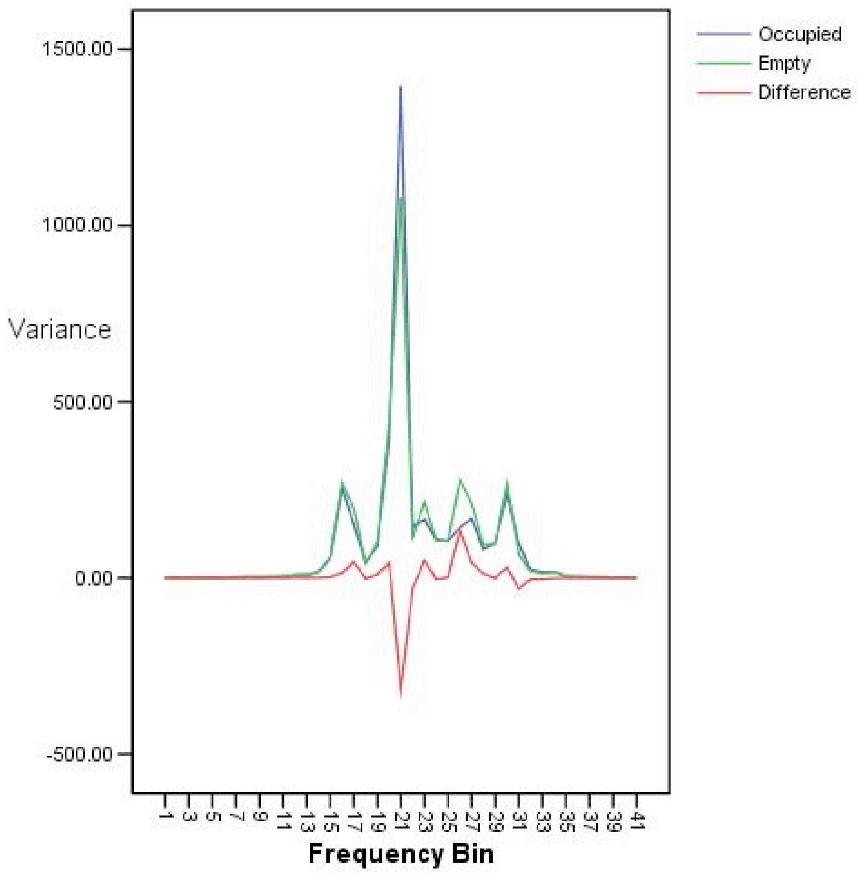

Figure 4. Variance across frequency for occupied (N=20726) and unoccupied (N=39274) cases

7. Conclusion

There is a good deal of change in variance of frequency between occupied and unoccupied states. This suggest that there are changes in neural activities resulting from communications loops between individuals being obscured or created by the presence of people in the room. When there are no people in the room, patterns of data spontaneously develop and appear to resonate; the presence of people modify and sometimes destroy these patterns. On exiting the room, the system slowly reverts to this behaviour. The exact pattern of behaviour in these unoccupied states is never exactly the same however. This suggests that some long term adaptation occurs. It can indeed be said that the behaviour of these acoustically-coupled neurons does change meaningfully with occupancy, even though no specific people-sensing devices were combined in the design. It is hoped that further testing may show that this behaviour may be used to classify further the level and type of occupancy. There also appear to be four main peaks of this activity. Given that there were 15 functioning devices in the room, this suggests that some flocking behaviour has occurred in these wavebands, a spontaneous self organisation of behaviour.

Acknowledgements

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References

Adamatzky A.: 2004, Collision-based computing in Belousov-Zhabotinsky medium, *Chaos, Solitons & Fractals 21*, 1259-1264.

Hebb, D. O. : 1949, *The organization of behavior: A neuropsychological theory*. New York: Wiley.

Pask, G: 1961, *An Approach to Cybernetics*, Harper & Brothers, USA