

UNIVERSITY OF SOUTHAMPTON
Faculty of Engineering and Applied Science

A group design project summary report submitted for the award of
Master of Engineering

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GDP 7
Electronic Timpani

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April 26, 2002

Introduction

The timpani is a large orchestral instrument that lends weight and substance to music. The timpani must be large to produce these low frequencies, but its size renders it awkward, expensive and difficult to transport. A training instrument could be used to learn the skills of timpani playing, without requiring access to a set of classical timpani. This projects designs and prototypes an 'electronic timpani' to meet this need.

The system uses a rigid aluminium honeycomb-structured plate supported on sensors to receive the force of the hit.

The signal from piezoelectric transducers is passed through conditioning electronics into a PIC Microcontroller. This then groups the sensors readings into 'frames' which and them transmitted to a PC via a RS-232 serial link.

A custom piece of software is then used to convert these readings into output sound waves. The software has the following primary stages;

- Scanning of serial port stream and extract of strike and damping information
- Generation of waveforms for each strike
- Playback of waveforms that accounts for changing conditions (like damping)
- Combination of channels
- Writting to the sound card

During the course of the project a series of timpani recordings was collected. This then formed the basis from which to generate the sound algorithms. It is likely that any future projects will wish to improve and expand this collection of recordings.

Objectives

There are several different inputs that the electronic timpani system should respond to. These inputs were prioritised, in consultation with our sponsor and supervisors.

1. Strike strength
2. Pitch pedal position
3. Radial strike position
4. Damping
5. Glissando
6. Timpani type
7. Mallet type

For a useful training instrument at least the first four of the inputs must be included. The project will therefore attempt to design and implement a prototype that can respond to the first four, and create a reasonable timpani sound in real-time.

Resources

The team had the following resources:

- **Budget**

The project budget of £700 was provided by the Faculty of Engineering.

- **Laboratory Space**

Unfortunately both the department (ECS) and the Faculty of Engineering were unable to provide laboratory space. The unprompted generosity of the ISIS research group, in their provision of laboratory space, contributed significantly to this project.

- **Communication**

Most formal discussion was performed using a threaded email-list. This became especially important during the period in which our supervisor was abroad. In the early stages a dedicated website proved useful for sharing research and links.

- **University Timpani**

Some of the university timpani were used during the course of the project in order to obtain recordings. The first, in early December, was used for initial recordings in the Turner Sims concert hall. The second, for two days later in December, were used for more formal recording in the ISVR anechoic chamber. For this latter recording session, an insurance policy was taken out to cover the timpani for accidental damage, and the help of the University Security staff was requested in order to transport the timpani from the Music Department to the ISVR.

- **Timpani Player Availability**

At various occasions the project sponsor, John Abenstern, was able to provide essential insight and comment about timpani playing.

Constraints

- **Team Reduction**

Although the team initially had six members, the majority of the project was performed by four. Two members chose to leave the course after the team had been allocated. Adam Johnston, studying Mechanical Engineering, chose to graduate at the end of Part III and Peter Wood studying Electronic Engineering assumed a sabbatical post on the Students Union Council in November 2001. Additional team members with programming experience would have reduced the workload on the software developers and allowed other avenues of research, such as the data-driven modelling, to be explored more completely.

- **Orchestra**

Initially the team hoped that a close working relationship with the University Orchestra would develop, this did not develop, in part due to members leaving the team.

- **Timpani Availability** The availability of the University Timpani was limited because they are in constant use by the Music Department. The team was granted access to them on two occasions.

Approaching the task

The project was divided into several related, but distinct sections. This allowed team members to focus on those areas particularly suited to their skills.

Stephen Emsen: Selection and initial programming of PIC Handling a serial port using POSIX functions Generation of code for interpreting and processing the input to differentiate damping and strike information

Christopher Heal: Research into the acoustic behaviour of the timpani Creation of the database from the recordings of the timpani Development of Matlab prototype code for sound generation Project secretary

Richard Sunderland: Design of the software architecture Sound API interfacing Implementation of data storage and access functions Coordination and integration of all software components

Robin Willis: Construction of drum pad and sensor assemblies Design and construction of the electronic circuit board Development of programming of the PIC Project coordination

Important Results

The electronic timpani is fully playable, with unnoticeable latency, using the five input dimensions below:

1. Strike strength
2. Pitch pedal position
3. Radial strike position
4. Damping
5. Glissando

Initial costing and system performance indicate that this project may well evolve into a useful and potentially commercially viable training instrument.

Conclusions

This project has successfully taken an initial idea through to a working prototype. The project provides a stable and well-designed development platform that will be a firm foundation for future work in this area.

The group managed its changing resources effectively, allocating and re-allocating job roles as the need arose. Care was taken to ensure that each team member's skills and enthusiasm were used to the benefit of the project.

Although strain gauges may provide a clean hardware solution to the detection of damping, there are several promising techniques that may render them unnecessary. These include digital filtering and direct input transformation using machine learning.

The current prototype responds to inputs with no audible latency. Although detailed testing has not been performed, initial qualitative analysis indicates that the system, as it stands, would meet appropriate latency specifications.

Currently thread scheduling of the program is effective, but does not handle resource competition well enough. Further research into scheduling, especially the real-time variants, should yield a solution to this problem.

Recommendations

Although this project has laid a very solid foundation there is plenty of scope for further development. This section outlines some of the ways the project could continue.

1. *Multiple Timpani*

Inclusion of further timpani (i.e. more input pads) should not be difficult.

2. *Further Sensor Development*

The system could be made more accurate if a set of strain gauges, or similar.

3. *Machine Learning Based Hit/Damping Detection*

It may be possible to improve hit/damping detection algorithms using some form of machine learning (such as Support Vector Classification, Neural or NeuroFuzzy Network).

4. *Tuning Pedal*

Future versions would require a mechanism to more accurately simulate the action of a real timpani pedal.

5. *Communication Method*

A faster communication standard such as USB or FireWire would allow further flexibility in the sensor sample rate.

6. *Drum plate*

Careful attention should be given to the selection of materials to minimise the sound of strikes on the pad, and mimic the bounce of a real skin.

7. *Signal Noise Reductions*

This could be reduced if higher precision components were used with a printed circuit board. Careful signal routing will further reduce noise.

8. *Digital Filter Based Input Processing*

Digital filtering may provide an effective and robust method of separating strike and damping information.

9. *Improve Sound Generation*

There are several techniques that may allow a more faithful recreation of a timpani's output. These include neural networks and support vector machine regression.

10. *Improved Dataspace*

It may be necessary to collect a better dataspace, including more sizes and types of instrument.

11. *User Interface*

A display of the hardware could allow selection of timpani type, size and mallet type, as well as giving basic diagnostic information.

12. *Marketing*

It is hoped that this project may eventually evolve into a marketable product. To date however, there has been no research into its potential.

13. *Alternative Applications*

The current hardware and software architecture have been designed with flexibility in mind, the system could easily simulate alternative instruments.