Chapter 10

Conclusions & Further Work

Overview

This chapter restates the hypothesis and then presents results which support it in the form of a series of major conclusions. The scope of the findings is discussed. Future projects based on this work are outlined and the chapter finishes with a final summary of the significance of the project.

10.1 Review of Hypothesis

The purpose of the user interface trials was to test the following hypothesis:

> **The real-time control of computer-based musical systems can be enhanced by the provision of non-analytical performance modes in the user interface.**

Section 5.4 outlined a series of factors that would characterise 'Performance Mode'. They included the following criteria:

- No fixed ordering to the human-computer dialogue.
- The human takes control of the situation. The computer is reactive.
- There is no discrete set of options, but rather continuous controls.
- The control mechanism is a physical and multiparametric device which must be learnt by the user.
- Further practice develops the user's control intimacy and thus increased competence of operation.
- The human operator, once familiar with the system, is free to perform other cognitive activities whilst operating the system.

Chapter 6 further defined what the above mentioned 'multiparametric' system should involve:

- Continuous control of many parameters in real time
- More than one conscious body control (or limb) is used
- Parameters are coupled together
- User's energy is required

From this specification a multiparametric interface was designed and implemented. Two more interfaces were designed for comparison. The sliders interface had the first two of the above 'multiparametric' characteristics, but not the last two. The mouse interface had none. These interfaces were tested over 3 sessions by 16 subjects and then over a further 10 sessions by 3 subjects. The results of these tests were summarised in the previous chapters.

10.2 Major conclusions

The following seven conclusions have been drawn from the test results and the user comments:

1. Real-time interactive control *can* be enhanced by the multiparametric interface
2. The multiparametric interface was shown to permit performance mode
3. Mappings which are *not* one-to-one are more engaging for users
4. The “Ten-minute rule” about learning interfaces is *not* always appropriate
5. Complex tasks may need *complex* interfaces
6. The 'mouse interface' is good for simple tests and for little practice time
7. Some people prefer to think in terms of separate parameters

The following seven sections correspond to these conclusions. They use the 'Major findings' of the tests (section 9.2) and 'Summary of comments from taped interviews' (section 9.3) to justify each point of conclusion and to aid in discussing its implications.

10.2.1 Real-time interactive control can be enhanced by the multiparametric interface

The following two results are perhaps the most significant of the entire thesis:

- For tests where more than one parameter changes simultaneously the multiparametric interface gives the best overall results.
- The multiparametric interface nearly always allows improvement over time (independent of test complexity).

Taken together they show that the multiparametric interface is the only interface of the three that consistently permits improvement by the user, and that for the harder tests it is the only one which allows good results. These findings are best expressed graphically and can be seen in Figures 9.2 to 9.4.

Clearly real-time control can be enhanced by the multiparametric interface.

The multiparametric interface is the only one of the three interfaces tested which permits performance mode. This is explained in the next section.

10.2.2 The multiparametric interface was shown to permit performance mode

Providing that it can be shown that only the multiparametric interface permitted performance mode, then the hypothesis is true. Each of the criteria for performance mode is reviewed for the three interfaces in the following table.

Criterion	**Mouse**	**Sliders**	**Multiparametric**
Computer is reactive	Yes	Yes	Yes
Continuous controls	Yes	Yes	Yes
Physical & Multiparametric control device to be learnt by the user	Yes	Yes	Yes
Further practice develops the user's control intimacy and thus increased competence	Rarely	Sometimes	Yes, nearly always
Human operator is free to perform other cognitive activities while operating the system	Sometimes	Rarely	Yes

Table 3: Performance Mode criteria for three interfaces

The bottom two rows of this table show the distinguishing features of the multiparametric interface. Let us review each one in turn.

1) Further practice develops the user's control intimacy and thus increased competence.

This was shown to be true by the result quoted in the previous section:

- The multiparametric interface nearly always allows improvement over time (independent of test complexity).

2) The human operator is free to perform other cognitive activities while operating the system.

The following common characteristic drawn from the users' comments indicates strongly that this interface relied more on motor co-ordination than on cerebral thought:

- Users often reported that they felt "out of control" with the multiparametric interface, but this was not always a negative comment - rather more a statement that they had achieved a task but couldn't analyse how they had done it. This seems to be linked to the comment that this interface put the least mental load on the subjects. They were free to concentrate on completing the task, or on other things, rather than consciously controlling the interface.

Another set of comments were noted which highlighted the special performance-enhancing nature of this interface:

- Various people reported that the multiparametric interface felt like a musical instrument rather than a tool or computer program. It was described as "flowing", giving "more freedom" and having a greater dimensionality.

Therefore it is clear that the multiparametric interface exhibits all the characteristics which were stated as being necessary for performance mode. The mouse and sliders interfaces exhibit some of them - and are certainly not worthless - but only the multiparametric is shown to support performance mode.

Thus the hypothesis that the "real-time control of computer-based musical systems can be enhanced by the provision of non-analytical performance modes in the user interface" is supported (within the limits of the work done on this thesis - see section 9.1.5).

10.2.3 Mappings that are *not* one-to-one are more engaging for users

The following three comments summarised from the users indicate that there was something about the multiparametric interface which allowed spatial thinking that was entertaining and engaging.

- The multiparametric interface allowed people to think spatially, or to mentally rehearse sounds as shapes.
- The majority of users felt that the multiparametric interface had the most long-term potential. Several people commented that they would quite like to continue to use it outside the context of the tests!
- Several users reported that the multiparametric interface was *fun*.

In contrast the sliders interface often elicited the opposite response:

- The majority of people found the sliders interface confusing, frustrating or at odds with their way of thinking. This was often focused on the requirement to break down the sound into separate parameters.

Since both the sliders and multiparametric interfaces allowed the user to have continuous control over all four sound parameters, we can conclude that the above differences can be accounted for by the parameter *mapping*. In other words:

Mapping strategies that are *not* one-to-one can be more engaging to users than one-to-one mappings, leading to a relative improvement in performance over time.

10.2.4 The "Ten-minute rule" about learning interfaces is not always appropriate

Ted Nelson's "Ten-Minute Rule" is often quoted by user interface designers to indicated that interfaces must be simple to understand and easy to use. It states that:

> *"Any system which cannot be well taught to a laymen in ten minutes, by a tutor in the presence of a responding setup, is too complicated. "*
>
> [Nelson, 1987]

It was noted in Chapter 2 that nearly every musical instrument and vehicle in existence would fail this test. The results show that for complex tests the multiparametric interface scores very well, but for the simpler tests it does *not* give the best results initially. A comparison of Figures 9.2 and 9.4 shows that for many mid-complexity tests the mouse initially has higher scores, but it is overtaken by the multiparametric interface after 5 or 6 sessions. This corresponds to (5 or 6 x 5 minutes per session =) 25 or 30 minutes. It would be interesting to see what happened over several hundreds of hours' practice, such as the player of an acoustic instrument might put in to achieve grades of instrumental achievement.

The result already quoted in section 10.2.2 stated:

- The multiparametric interface nearly always allows improvement over time (independent of test complexity).

This demonstrates that a short time limit on the learning of this interface would be to entirely limit its potential.

At first glance, then, it would appear that we have shown the following:

The ten-minute rule is not always applicable - particularly to real-time systems involving the physical manipulation of many parameters.

However, in fairness to Ted Nelson, we should discuss the second part of the "Ten Minute" quote that is not always cited:

> *"This may sound far too stringent; I think not. Rich and powerful systems may be given front ends which are nonetheless ridiculously clear; this is a design problem of the foremost importance".*
>
> [ibid]

Perhaps he is saying that the basic instructions to operate a system should take no longer than ten minutes to digest. In this respect the multiparametric interface took about three minutes to describe and demonstrate. Maybe Nelson assumes that people do indeed have to practice to improve their performance, but instructions shouldn't be unnecessarily complicated. Whatever his intentions, the average musical instrument *cannot* be taught to a layman in ten minutes, so the rule is still rather suspect.

10.2.5 Complex tasks may need complex interfaces

The following result is really rather bizarre:

- The performance of the multiparametric interface nearly always *increases* with test complexity.

It is almost counter-intuitive to conclude that results could get better for harder tasks, but that it clearly what is shown in Figure 9.4. This feature is only demonstrated consistently for the multiparametric interface. Various comments from the users indicated that this was indeed what was happening. It is worth being reminded that only one of the sound tests out of the nine (test no. 9) was actually created on the multiparametric interface, the others being constructed mostly as number streams, or mathematical progressions of parameters. This shows that the interface allows people to cope with tests of arbitrary complexity, not just with gestures that were input by an identical gestural interface.

Perhaps we should ask what we mean by a 'difficult' or 'complex' test? Maybe we call them 'hard' because they **are** hard on traditional interfaces. However most users were able to use the multi-dimensional nature of the multiparametric interface to formulate spatial and motor strategies for navigating the complex data-space. They therefore found it easier to cope with the more highly dimensional sounds. In contrast the 'simple' sounds, made up of a step change in one parameter, are very difficult to achieve on the multiparametric interface. This is because the network of interconnected mappings makes it difficult (at least in the early stages of contact with the interface) to isolate a single change in one parameter without affecting any of the others.

This is reminiscent of the work done by Jacob et al where the authors note that:

> *"Current input device taxonomies and other frameworks typically emphasise the mechanical structure of input devices. We suggest that selecting an appropriate input device for an interactive task requires looking beyond the physical structure of devices to the deeper perceptual structure of the task, the device, and the interrelationship between the perceptual structure of the task and the control properties of the device".* [Jacob, 1994]

They describe simultaneous tasks as being *integral* (perceived as one by the user) or *separable* (perceived as independent). Their experiment shows that interfaces which couple together integral tasks perform better than those which keep them separate. This could perhaps provide a reason why the 'complex' tasks are carried out best on the multiparametric interface (which clearly couples several parameters together).

> *Our research hypothesis is that performance improves when the perceptual structure of the task matches the control structure of the device".* [ibid.]

This is confirmed by the user comments that the multiparametric interface allowed them to think in shapes or gestures. In other words the pitch/timbre/volume space is perceived as being *integral* and thus needs an interface to match.

If a general conclusion can be drawn from this result it is this:

Interfaces should be designed to suit the user's perception of the dimensionality of the data-set that is to be controlled.

10.2.6 The 'mouse interface' is good for simple tests and for little practice time

The effectiveness of the mouse interface can be summarised by this result from the tests:

- For most people the mouse interface gives the best results for the simplest tests, and the multiparametric the worst with these tests.

and this statement from the user comments:

- The mouse is the easiest interface to use at first, but is clearly limited to controlling one parameter at a time.

Sections 10.2.1 through to 10.2.5 have encapsulated a series of very positive conclusions about the multiparametric interface. The drawback is that it is the worst interface for the simplest tests (at least initially). It is here that the mouse interface scores best. In other words:

If people only tried the simple tasks for a *short time* they would conclude that the mouse interface was clearly the best.

Many tasks are indeed simple and do not require any significant depth of user learning. The emphasis on easy-to-use systems is quite relevant for public systems such as cash-point and parking ticket machines. In these cases the user only has occasional and 'shallow' contact. Interface styles such as menus act as a reminder to the user about what (limited) options are available. Where a more regular and more involved level of contact is required, such as with office machines, industrial control systems and musical processing devices, the commonly accepted interface styles may be lacking.

It needs to be stressed that there are a number of concessions made with the mouse interface used in these tests that give it an advantage over more traditional mouse interfaces. There are no menus. The on-screen sliders are set up into their starting positions automatically. Real-time operation is allowed. There is no off-line programming of numbers or lists. The sliders on the screen can be directly manipulated with the mouse Even with all these advantages the multiparametric interface wins with increasing practice time and test complexity.

10.2.7 Some people prefer to think in terms of separate parameters

There seems to be a small group of people who prefer to work in *analytical* mode rather than the holistic, performance mode. One of the user comment summaries stated:

- A small proportion of people (about one quarter) favour the sliders interface.

Could it be that certain people are highly analytical and do better on an interface which reflects the breaking down of the task into individually manipulable components? Could the following, highly speculative, argument be true?

> Most people who are employed to design user interfaces are highly analytical. They read the HCI literature which is highly analytical. They produce interfaces which suit highly analytical people. They represent only a small proportion of the population. Their interfaces are used by the population at large, the majority of which think in a very different way.

It is not within the scope of this work to try to prove or disprove that argument, but it could possibly account for the analytical nature of common computer interfaces.

10.3 Scope of findings

The hypothesis summarised in section 10.1 could be expanded as follows:

> The performance of musical instruments is an area which highlights many of the differences between two cognitive models ('Analytic'/'Holistic'; see Chapter 4). Computer-based musical instruments have often been designed using the analytical model consisting of parameter lists, icons and linear connections. This model needs to be expanded to incorporate experimental and multiparametric direct manipulation techniques in order for future computer instruments to be fully interactive and of long-term use to musicians.

The hypothesis and thus the conclusions of section 10.2 are focused on the real-time control of computer musical instruments. However, it is the author's strong belief that the conclusions may be much more widely applicable to the world of the Human Computer Interface in general. In particular it is quite possible that Performance Mode may be a valid mode of operation in other fields of real-time control that involve computers and associated machinery.

In other words, the hypothesis could be expanded even further, to the following:

> Most computer interfaces are designed within a linear, iconic and analytical model and therefore constantly demand cognitive interpretation by the user. Much more attention needs to be given to explorative and holistic designs (based around multiparametric control with non one-to-one mappings) if we are to maximise the human potential of the human-computer interface.

It is not claimed that the results of this work somehow 'prove' the above hypothesis. It is far too wide a claim to be tested. However, the results clearly indicate one area where the application of such a holistic design *has* improved the potential of the interface. It is therefore open to speculation how many other areas are potentially affected by these results.

Let us therefore consider some areas that might benefit from an investigation into interfaces that exhibit 'performance mode'.

10.3.1 Musical synthesis & editing

New instruments should have multiparametric and non one-to-one mapping control if they are to engage musicians to develop a high level of control intimacy.

I suggest that there are many electronic music functions, such as phase-vocoding, time-stretching, and granular synthesis (that are typically controlled by text files) and standard synthesis algorithms that could be manipulated in real-time using a multiparametric interface. Rovan et al explain it like this:

> *Additive synthesis, for instance, has the power to virtually synthesise any sound, but is limited by the difficulty encountered in simultaneously controlling hundreds of time-varying control parameters; it is not immediately*

> *obvious how the outputs of a gestural controller should be mapped to the frequencies, amplitudes and phases of sinusoidal partials.* [Rovan, 1997]

One of my MSc students [Woodward, 1999] has completed a project to control a time-stretching algorithm in real-time. A MIDI keyboard is used to control the pitch, while various controller wheels are used to adjust the parameters to the algorithm. The resultant effect is of a versatile performance instrument which allows the player to sculpt and hold/stretch sound as it is played.

10.3.2 Studio Mixing

A typical mixing desk consists of many sliders and dials, and is rather like the 'sliders' interface on a grand scale. Whilst it would be strange to suggest that such a time-honoured interface would be replaced, it could perhaps be enhanced. The Mixing-Desk style, as it stands, is an excellent way of having individual control of many parameters and of distributing these parameter controls in space.

Imagine a new mode of operation where a multiparametric interface (perhaps using a pair of data-gloves as a control device) is used to control many of the mixing attributes simultaneously. It may be possible to have hand gestures which continuously control hundreds of mixing desk parameters in real-time. An example of this might be that the closing of one hand controls the High-EQ (low-pass filters) on sound channels 2-20, whilst the position of one hand in relation to the other determines the relative volume of all the strings and the brass. Thus whole sections of instruments can be mixed and moulded with hand gestures, independent of their layout on the main desk.

This way of working is much closer to the task of ‘conducting’, which is also a time-honoured way of controlling the balance between groups of instrumentalists.

10.3.3 Real-time industrial and vehicle control

It was stated in Chapter 2 that there have been many instances of 'over-automation', where human system operators rely too much on 'auto-pilots' or plant management systems and thus cannot regain a satisfactory degree of control when something goes wrong. The standard response to this in the literature seems to involve making a better automatic system so that less things can go wrong. This is a laudable goal, but there are two issues of equal importance which do not seem to be discussed:

1) Should we be making systems that cannot actually be controlled by humans? I am deeply worried by the fact that aircraft are deemed so complex that they cannot actually fly unless several computers intervene between the pilot and the physical controls.

2) Rather than making better automatic systems, should we be investing some time and money into making better, richer human control interfaces which keep the human operators actively involved and engaged in the task at hand?

This warrants a major investigation which is clearly outside the scope of this project, but the results given above may form a starting point for such an inquiry.

10.3.4 Artistic packages

It is proposed that performance modes may be equally beneficial to visually-based artistic packages. Wherever there is a complex parameter set that warrants exploration by the user, then a multiparametric interface may improve the performance. Too often the artistic process is sequentialised and broken up into individual commands *because of the structure of the interface*. Another of my MSc students has started a practical study of how explorative interfaces might be used for the creation of complex images [Merrison, 1999].

10.4 Final Summary

The hypothesis:

> **The real-time control of computer-based musical systems can be enhanced by the provision of non-analytical performance modes in the user interface.**

has been supported by the work described in this thesis.

The experimental work into the comparison of three different interfaces (mouse, sliders and multiparametric) has revealed the following seven major conclusions:

1. Real-time interactive control *can* be enhanced by the multiparametric interface
2. The multiparametric interface was shown to permit performance mode
3. Mappings that are *not* one-to-one are more engaging for users

4. The “Ten-minute rule” about learning interfaces is *not* always appropriate
5. Complex tasks may need *complex* interfaces
6. The 'mouse interface' is good for simple tests and for little practice time
7. Some people prefer to think in terms of separate parameters

Many of these original findings are in the process of publication or have been disseminated already. IRCAM approached us to discuss the work, and their endorsement of the importance of the experimental results and ideas about *mappings* led them to invite us to submit a chapter to the book *Trends in Gestural Control of Music*. This has marked the start of a series of collaborative projects with IRCAM in the areas of gestural control of musical synthesis and multimedia algorithms. A number of grant applications have been obtained and several are pending at the time of writing.

This thesis offers software designers some radical ideas on the design of real-time interactive systems and particularly those intended for musical applications.

It is clear that time is needed to learn an interface, and that some interfaces may require a longer practice time in order to achieve good results. This is perhaps hardly surprising if we consider the amount of time needed to learn to drive a car or play a musical instrument. If it took several months or years to master a computer interface it would typically be rejected as non-viable. In many cases there is an assumption that a user interface should only take a few minutes to master. This would rule out every musical instrument and vehicle driving system that had ever been invented.

So therefore perhaps our preconceptions about computer interfaces are wrong. Possibly for some tasks we should *not* expect an ‘easy’ interface which takes minimal learning. For many real-time interactive interfaces we need control over many parameters in a continuous fashion, with a complex mapping of input controls to internal system parameters.

Maybe we need a substantial amount of time to learn a complex control interface in order to give us confident real-time control over complex systems.