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LAMI: A gesturally controlled three-dimensional stage Leap (Motion-based) Audio Mixing Interface

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ABSTRACT

Interface designers are increasingly exploring alternative approaches to user input/control. LAMI is a Leap (Motion-based) AMI which takes user's hand gestures and maps these to a three-dimensional stage displayed on a computer monitor. Audio channels are visualised as spheres whose Y coordinate is spectral centroid and X and Z coordinates are controlled by hand position and represent pan and level respectively. Auxiliary send levels are controlled via wrist rotation and vertical hand position and visually represented as dial-like arcs. Channel EQ curve is controlled by manipulating a lathed column visualisation. Design of LAMI followed an iterative design cycle with candidate interfaces rapidly prototyped, evaluated and refined. LAMI was evaluated against Logic Pro X in a defined audio mixing task.

1 Introduction

The Audio Mixing Interface (AMI) enables the user to combine and manipulate multiple audio channels to form a "mix". The layout of the AMI has remained largely unchanged for the past 50 years with the majority of AMIs presenting channels to the user as repeated vertical strips of controls that feature faders, knobs and buttons to manipulate and blend the constituent audio channels. This implementation-centric design is termed the channel strip paradigm (CSP).

Recently, researchers have questioned whether the CSP really meets the needs of the user. Ratcliffe states that the position of the channel on the interface can be misleading with regard to pan position [1]. For instance, a track panned hard right may actually be placed furthest left on the interface. This arguably places undue cognitive load on the user [2] and offers the user no direct, easy way of visually ascertaining the stereo image of a mix. Similarly, if we consider the equalisation (EQ) for a single channel on an analogue CSP, a user has to map multiple visual EQ knob positions to determine applied spectral manipulation. On digital mixing desks, Digital Audio Workstation software and audio plugins there are often equalisation (EQ) curve visualisations for individual channels which address this issue. However, whilst there are an emerging number of EQ software tools that allow two channels' EQ curves to be viewed simultaneously [3] there don't exist any solutions that allow the user to easily get a visual overview of the EQ applied to all channels simultaneously.

One might think that the user can obtain sufficient information regarding the relative levels of the channels by scrutinising the fader positions, however, this is not the case if the audio played through each channel has not been recorded at, or normalised to, the same level as other channels.

Additionally Ratcliffe argues that there exists a dissonance between a channel's fader position and apparent depth, with fader positions closest to the user sounding further away [1].

In addition to the shortcomings of the visual feedback provided by the CSP, the authors believe alternative input devices to faders, knobs and buttons should be considered. The XY-pad is well established having been made popular by Korg in their Kaoss Pad and associated products [4]. Joysticks have appeared for some time on a number of mixing desks but are normally only used in surround sound panning [5]. Touchscreen interfaces are becoming more common in audio applications. For example, iPad interfaces are provided to supplement AMIs e.g. Midas M32 [6]. More recently gestural controllers are appearing in commercial music production tools e.g. Roland D-Beam for synthesis expression [7] and Fairlight 3DAW for 3D audio mixing [8]. This research will explore the use of the Leap Motion controller which tracks hand and finger gestures in an AMI [9].

The aim of this project is to reconsider this established AMI and take advantage of recent controller technology. This paper outlines the design and evaluation of a graphically enhanced, gesturally controlled AMI called LAMI: Leap (Motion-based) AMI.

2 Background

2.1 Brief history of the Audio Mixing Interface

The origin of the CSP can be traced back to the ergonomic frustrations that engineers faced while using interfaces borrowed from the broadcasting industry to create mixes in the 1950s. These broadcast consoles featured three inch knobs for controlling level which meant that it was impossible to manipulate multiple knobs simultaneously by hand. The advent of slide-wires (i.e. linear faders) meant the channels could be placed closer together enabling the user to "play the faders like you played a piano" [10]. Most commercial AMIs still adopt the CSP despite many having digital and software architectures which remove the dependence of AMI control placement on the layout of the underlying physical electronic components.

2.2 The Stage Paradigm

The introduction to this paper has highlighted the poor visual feedback provided by the CSP interface. In an attempt to overcome these shortcomings researchers have proposed alternative designs based on psychoacoustic principles that correlate with sound localisation in humans [10]. These proposed AMIs conform to the metaphorical stage paradigm.

The basic concept behind this paradigm is that each audio channel is graphically represented on a stage by an icon/node. The position of each icon/node on the stage represents its level and pan. In contrast to the CSP, the stage paradigm adopts a 'depth mixing' approach for channel level [11] with the icons/nodes closest to the user having the highest level. This approach to level mirrors what happens when a fixed level sound source moves towards the listener in the real world. Although very few commercial embodiments of this paradigm exist [13, 14] it has been suggested as a possible alternative to the CSP in the academic literature given its psychoacoustic associations.

The three-dimensional stage paradigm proposed by Gibson [15] was the first attempt to present an alternative to the CSP and features a virtual cuboid stage with individual audio channels represented as coloured spheres. The horizontal plane position of each sphere is related to the level and pan setting of the associated track. Gibson appears to use audio channel frequency for vertical sphere position.

The stage paradigm represents a significant improvement over the CSP in enabling the user to visualise the absolute and relative spatial distribution of audio channels. Unfortunately these visualisations can become cluttered in real-world scenarios. Gelineck remarks that because mix engineers are usually working on many channels of audio, the stage paradigm quickly becomes cluttered and potentially difficult to use [12]. This is because channels with similar pan positions and level will overlap each other on the display.

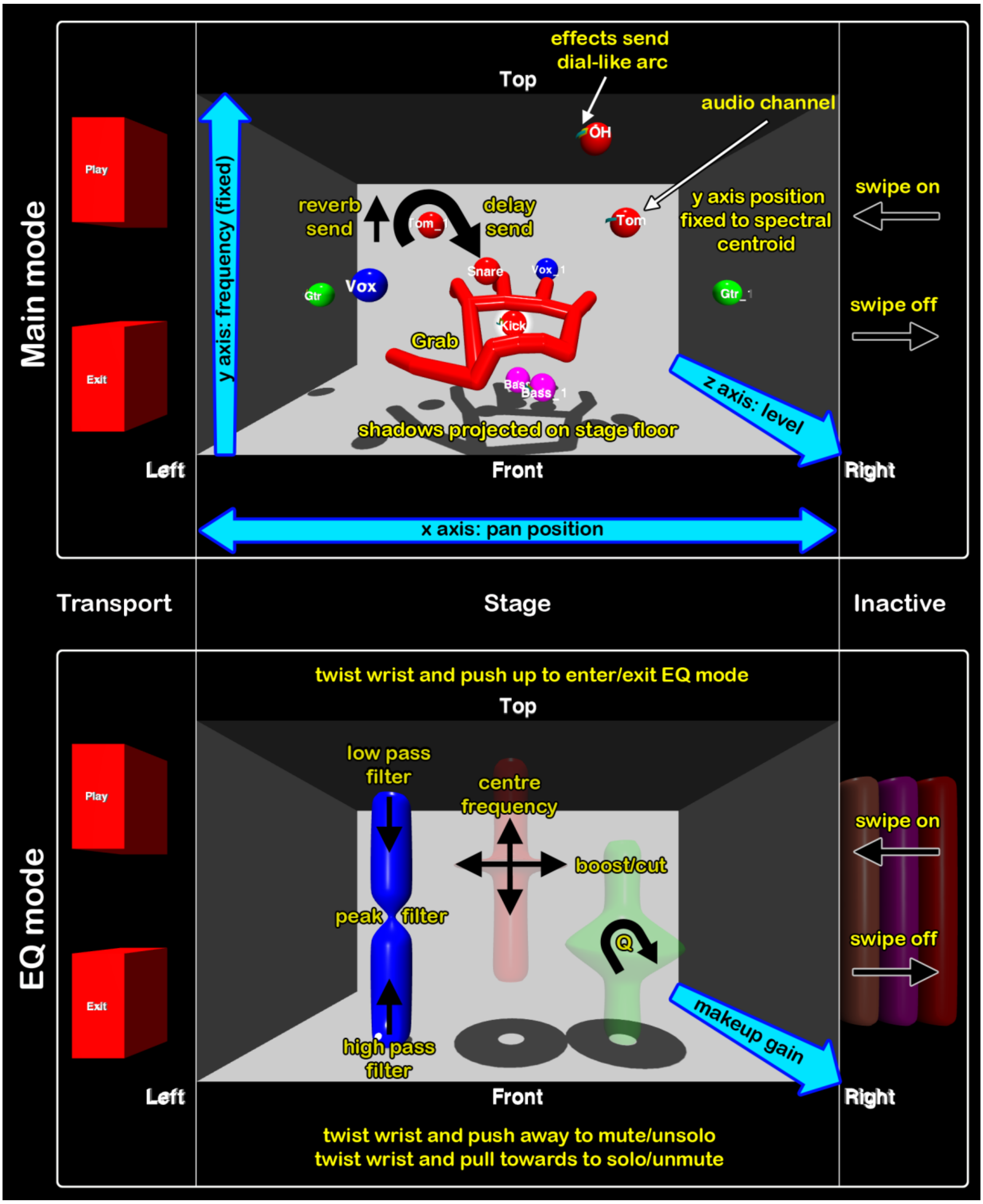

Figure 1: Annotated LAMI visual interfaces. Gestures are indicated by the black arrows and control annotations are yellow. LAMI's stage parameter space is shown with the blue arrows with black annotations.

2.3 Gestural control of mix interface

Several studies have considered the use of gestures as a method of controlling the mix interface. Lech & Kostek [16, 17], Ratcliffe [1] and Gelineck [18] have all developed gesturally controlled interfaces that conform to the stage paradigm.

In Lech and Kostek's study the GUI is projected onto a screen with a webcam used to detect the user's gestures using image processing techniques. Their system interprets this data sending MIDI messages to a DAW. This implementation involved the user learning a gesture library based on semantically derived static and dynamic gestures. The system can operate both with and without visual support. The visual version uses circles to represent audio channels with circle size indicating level, horizontal position representing pan and vertical position representing EQ gain. These parameters can be directly manipulated via gestures. Additional numerical parameter values for each audio channel are displayed next to its circular representation with a pop-up slider for manipulation. They conclude that mixes produced using gestures "are not worse regarding aesthetic value" than ones obtained by traditional use of DAW software [16]. Whilst this implementation is the first to use gestures for control of a wide range of mix controls, only three parameters can be directly manipulated. The remainder are overlaid as numbers and this clutters the interface. This paper aims to explore whether a strong visualisation can negate the need for numeric parameter display. Furthermore Lech and Kostek's semantic gesture library appears to be complicated for the user to learn and use.

Ratcliffe's implementation is visually similar to Gibson's proposed interface featuring channels represented as three-dimensional coloured spheres and uses the Leap Motion controller and MAX/MSP to interpret gestures and control channel parameters in Ableton. The GUI is rendered in 3D by Jitter. Ratcliffe's implementation uses horizontal hand position to control channel pan and hand depth position (in the z axis) to control channel level with all of the spheres' vertical positions being fixed and aligned. Ratcliffe experienced difficulty in implementing track selection via the Leap Motion and chose to use a TouchOSC layout on a separate mobile/tablet to select tracks. This research aims to develop a better, Leap Motion only solution for audio channel selection. Furthermore Ratcliffe's interface is limited to direct manipulation of two parameters only, this work will seek to extend this.

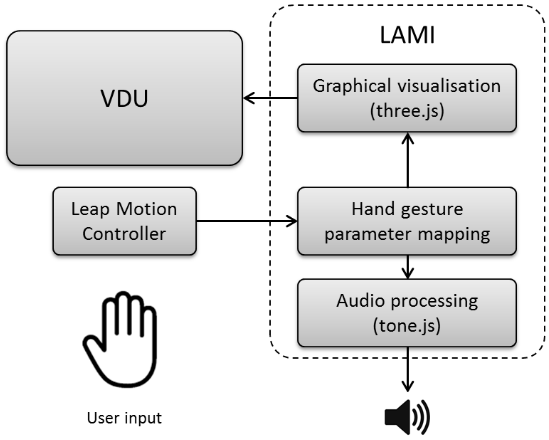

Figure 2: Flow diagram of LAMI.

3 LAMI

LAMI is an extension of the interface developed by Ratcliffe [1] which was limited to pan and level. LAMI extends this to cover EQ, auxiliary sends and muting/soloing and additionally provides an interface for audio channel frequency content visualisation and manipulation.

3.1 Implementation

LAMI was implemented in HTML5/JavaScript and uses several open-source JavaScript libraries. Three.js [19] is used to render the GUI, tone.js [20] is used to abstract control of the Web Audio API and the leap.js [21] library is used to capture and interpret the user's hand gestures, movements and position. A flow diagram that outlines LAMI's architecture is shown in Figure 2.

3.2 Design Process

A user-centred, iterative rapid development cycle was adopted with the first and second authors providing periodic expert user evaluation and design improvement ideas and the third author acting as developer. The authors met once to twice per week over a three month period to develop the current prototype of LAMI. This approach allowed ideas to be rapidly prototyped and evaluated in terms of their suitability for each of the interaction, visualisation and audio processing mappings considered.

3.3 Design heuristics

Several design considerations (heuristics) emerged during the design process:

- Visual representations of track settings were favoured over numerical displays. This was motivated by the desire to visually represent multiple track features simultaneously, thus enabling the user to compare mix position and audio manipulation applied to multiple channels at a glance.
- A wide range of gestures were explored and intuitive gestures were favoured, with single handed gestures appearing most suitable.
- The authors observed that they were more susceptible to detecting mismatches between hand gestures and the visual display than between the hand gestures and the auditory feedback i.e. when the visual display did not correspond to the users action, user experience (UX) was compromised. This seems counterintuitive for the task of mixing audio which is essentially a critical listening task and is at odds with views expressed by "eyes closed" mixing proponents. However, when the visuals displayed matched the hand movements of the user, UX was enhanced and analogous to sculpting or shaping the mix elements.
- Smoothing the data values received from the LeapMotion controller improved UX and made the interface feel aesthetically smoother. This was because the smoothing meant that the user could make broad and coarse changes to track settings with fast hand movements and fine changes with slower hand movements, as one would when operating a dial or slider on a physical AMI.

3.4 Overview

LAMI has two modes: main and EQ. The annotations on Figure 1 explain the available gestures and show the visual feedback provided by LAMI and Figure 3 shows LAMI in use. LAMI's stage interface is cuboid in shape with a large push button provided to the left of the stage to control audio playback. Audio channels are represented as coloured spheres which can be swiped on to the stage from an 'inactive' region to the right of the interface. Spheres can be moved back to the inactive region by performing a swipe-right gesture. These gestures can be performed for all spheres simultaneously with an open palmed gesture or performed on a selected sphere.

Individual spheres can be selected via a grab gesture (i.e. going from open palm to closed fist) with the corresponding sphere element highlighted to indicate its active state. Once a track is selected via a grab gesture, the user can perform three types of operation.

Spheres can be freely moved in the stage's X and Z axes to change the track's pan position and perceived level accordingly. Spheres cannot be moved in the Y axis because the Y position represents spectral centroid. This approach is loosely based on the psychoacoustics of pitch-height perception [22] and helps to declutter the visual interface [1, 12]. Additionally it assists the user in channel identification [23]. Consequently the Y axis is available to be used to control the selected track's auxiliary 1 send level. Visual feedback of this parameter is provided by a dial-like arc around the track's sphere. The selected track's auxiliary 2 send level is controlled via a wrist rotate gesture with the same visual feedback method. In the current implementation auxiliary 1 is connected to a reverb effect and auxiliary 2 is connected to a delay.

Consequently it is possible to control the pan, level and two auxiliary send levels simultaneously in main mode. From a creative mixing perspective this was felt to be desirable.

Tracks can be muted/unsoloed by the user performing a clockwise wrist rotation and push away sequence of gestures and conversely soloed/unmuted by performing a clockwise wrist rotation and pull towards sequence. Mute/solo/unmute/unsolo can be performed on all channels simultaneously by performing the same gesture sequences without selecting a sphere.

The user can enter 'EQ Mode' by performing a clockwise wrist rotation and upwards gesture sequence on a selected sphere.

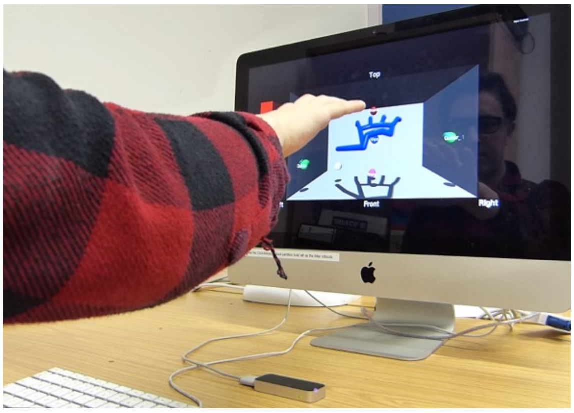

Figure 3: LAMI in use.

In 'EQ mode' the spheres used to represent the channels are replaced by lathed horizontally aligned columns. The lathed shape of each track's column represents the EQ curve applied and provides the user with visual feedback of these settings. All other audio channels' EQ visualisations can be seen whilst in this mode with the non-active channels being transparent. Three EQ bands are provided to modify each channel; LPF, peaking and HPF. Users are able to select the appropriate band for modification via a closed hand gesture. A closed hand with palm facing downwards selects the LPF band. A closed hand with the palm facing towards the lathed column selects the peaking band and a closed hand beneath the column with the palm facing upwards selects the HPF band. Opening the hand activates the respective EQ band for modification. In LPF mode, moving the palm upwards or downwards along the Y axis increase or decreases the cut-off frequency respectively. Similarly, in HPF mode, moving the palm upwards along the Y axis increases the cut-off frequency and moving downwards decreases the cut-off frequency. Three open handed gestures are used to control the peaking EQ band. Moving the open hand in the Y axis sets the centre frequency; a wrist rotation sets the Q and movement of the hand along the X axis relative to the lathed column sets the gain/attenuation. At all times, in EQ mode, moving towards the user increases the EQ make up gain.

Consequently it is possible to control up to four EQ parameters simultaneously in EQ mode. From a creative sound-sculpting perspective this was felt to be desirable.

4 Evaluation

An initial evaluation of LAMI was conducted with eight subjects who had at least one year's experience of mixing audio. Each subject undertook an individual training session before being asked to freely explore the candidate interface with a mix session that contained ten tracks of audio. The subjects then completed a NASA-TLX questionnaire [24] which has been used in a variety of contexts to assess workflow [25]. The choice of using a subjective, free exploration evaluation of LAMI was influenced by previous work by Gelineck et al. [12]. Unfortunately asking our subjects to freely explore the interface had the unanticipated consequence of the subjects not spending much time using LAMI. Many of the subjects complained of suffering from 'Gorilla Arm' [26] during the session which appeared to be another factor in the reduced engagement with LAMI. This limited use of LAMI was disappointing as we did not feel the subjects engaged sufficiently to provide a meaningful evaluation. Furthermore, the lack of a benchmark interface meant the NASA-TLX scores generated proved difficult to evaluate as they could not be compared against scores for a traditional CSP AMI.

In light of the concerns regarding the efficacy of this initial evaluation, a second, more structured evaluation was conducted. This involved a defined audio mixing task with the same ten track audio session used in the first evaluation. To provide a benchmark the subjects mixed this session with

LAMI and Apple's Logic Pro X. Eleven different test subjects who were undergraduate Music Technology students, studio technicians and lecturers were selected to take part in this evaluation. Roughly half of the subjects mixed the audio session with LAMI first and half with Logic Pro X first. The subjects awaiting testing were allowed to sit in on the evaluation sessions.

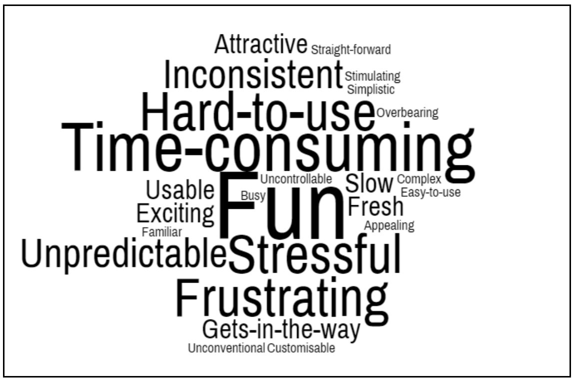

Figure 4: LAMI Word-cloud.

Figure 5: Logic Word-cloud.

Prior to mixing the tracks with LAMI, the subjects undertook a training session. A training session was not required for mixing the tracks with Logic Pro X because all test subjects considered were competent users of this Digital Audio Workstation (DAW). To provide a realistic comparison of the two interfaces the subjects were restricted to using a HPF, LPF and one band of peaking parametric EQ when using Logic Pro X. Furthermore the reverb and delay parameters were pre-set to replicate the effects used in LAMI with subjects only being allowed to change the auxiliary send levels.

Once the subjects had completed the mixing task with both interfaces they were asked to the select five keywords that best described each interface from the Microsoft Desirability Toolkit [27]. Following Neilsen [28], the range of keywords was reduced from 150 to 55 to simplify the process of selecting keywords for the test subjects.

Following the usability evaluation, the mixes created by the test subjects were bounced down to individual stereo interleaved .WAV files (22 mix files in total). These were then processed using Adobe Audition's match volume tool to standardise loudness to -23 LUFS. Each file was named randomly and all 22 files passed on to three experts who all have significant experience in evaluating mixes. The experts were asked to grade the mixes using a scale of 0 to 10 (with 0 being a very bad mix and 10 being a very good mix).

5 Discussion of Results

The adoption of a focused task was particularly successful. The subjects spent a much greater amount of time interacting with all aspects of LAMI's interface because the inclusion of a task provided the subjects with a purpose for using the interface. Interestingly there were hardly any complaints about suffering from 'Gorilla Arm'. Allowing subjects waiting to be tested in to the room facilitated a supportive and friendly environment. In comparison to the first test, subjects were much more talkative while using LAMI, verbally sharing their successes and failures with the subjects awaiting testing. The authors are of the opinion that the peer support (and peer pressure) provided by such an environment meant the subjects felt more at ease.

5.1 Word-clouds

The word-clouds generated by keywords selected for LAMI and Logic Pro X (shown in Figures 4 and 5 respectively) clearly indicate the test subjects' preference for Logic Pro X over LAMI for the mix task considered. LAMI's keywords are largely negative and Logic Pro X's keywords are largely positive. Given the subjects' experience of using Logic Pro X for such tasks, this is unsurprising and the predominance of *familiar, predictable* and *trustworthy* in Figure 5 supports this. Evaluating a new interface against an established interface that the subjects are familiar with is always going to be problematic. It would be interesting to repeat the evaluation with subjects that have no experience of using AMIs to see whether this produces different keyword selections. Alternatively a longitudinal study with experienced CSP users may result in a different evaluation.

During testing the authors observed the subjects struggled to zero the effects send level 2. This was an unfortunate artefact of the smoothing algorithm which ideally would have been removed before evaluation. Additionally the creative possibilities afforded by being able to control multiple mix parameters simultaneously was not well received. Many of the subjects commented that for mixing audio they preferred to edit parameters individually. Inadvertently altering other parameters in this process was a hindrance to them instead of an asset. These observations may explain the predominance of keywords *inconsistent, hard-to-use, unpredictable* and *frustrating* in Figure 4. The subjects were all associated with technical sound engineering courses and this may be a reflection of their approach to mixing. It would be interesting to see if different results were provided by audio practitioners with more artistic goals.

When the subjects were first shown LAMI a number commented that they weren't expecting to use an interface that was so radically different to the traditional CSP. Interestingly, despite the wide range of negative keywords, *fun* was selected by 7 of the subjects for LAMI. Additionally the authors noticed that the subjects were often seen smiling when using LAMI but had a serious expression when using Logic Pro X. This prompted the authors to further consider the Logic Pro X visual interface. The authors formed the view that the Logic Pro X visual interface is a work-oriented, technically detailed and functional whereas LAMI presents a new visual representation that is engaging and simplified.

5.2 Expert evaluation of mixes

Figure 6 presents the average mix scores of the three experts for LAMI and Logic Pro X with 95% confidence intervals plotted as error bars. The results show that overall the expert mix assessors preferred the mixes produced using the benchmark interface.

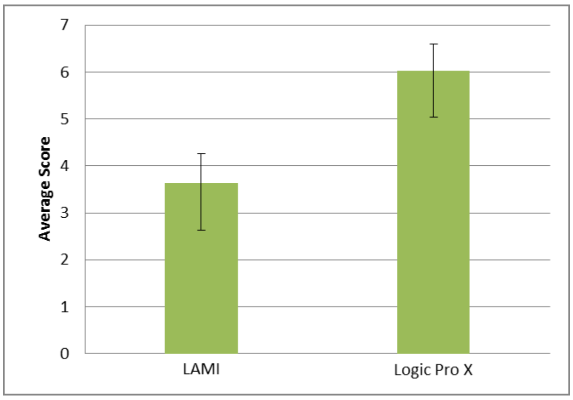

Figure 6: Average mix scores for both AMIs evaluated.

Despite the overall consensus that the Logic Pro X mixes were better than the LAMI mixes, differences did exist between the expert scores. For three of the subjects' mixes Expert 1 rated their LAMI mix the same as their Logic Pro X mix. Expert 2 gave two of the subjects' LAMI mixes a higher score and for three subjects the LAMI mix the same score as the Logic Pro X mix. On only one occasion did Expert 3 rate a subject's LAMI mix equal to their Logic Pro X (with no LAMI mix rated better).

Whilst this approach provides an indication of mix quality, which is a multi-variate problem, more revealing results may be elicited by conducting an A-B listening test with expert engineers directly comparing subject mixes for the two interfaces. This would enable the experts to explore sonic differences between the mixes and help indicate the ways in which LAMIs interface affected the outcome.

Whilst the assessed quality of mixes produced by LAMI is lower than the Logic Pro X, it is important to note that the tests subjects were new to LAMI whereas they are experienced in Logic Pro X and also that there was an implementation issue regarding the auxiliary send 2. A couple of subjects mentioned that if it had been their first time using Logic they would have struggled with it because it is such a complicated interface. We chose test subjects with mixing experience because LAMI is ultimately intended to target professional/semi-professional/experienced amateur mix engineers but these results again suggests that we should consider using inexperienced users to achieve a fair comparison with an established professional interface.

6 Conclusions

This paper presented a description and evaluation of LAMI; a gesturally controlled three-dimensional stage Leap (Motion-based) AMI that extends the interface developed by Ratcliffe [1].

Despite significant design effort in choosing and refining gestures for LAMI unfortunately the testing frustratingly revealed a remaining issue with zeroing auxiliary send 2 which was based on a wrist rotation control.

The adoption of a focussed mix task and peer supported environment facilitated the subjective evaluation of LAMI against a benchmark interface.

The results of the evaluation suggest that the multi-mapping of parameter controls to hand movements opposed this set of test subjects desire to control parameters individually. Despite this, seven out of eleven test subjects deemed LAMI *fun* to use and were receptive to alternative AMI paradigms. Expert assessors judged the mixes produced by LAMI to be inferior to the mixes produced by Logic Pro X.

Evaluating new interfaces for knowledgeable, intermittent users (or indeed frequent, expert users) against existing AMIs with which they are familiar is challenging. Ideally a longitudinal study would be undertaken where the test subjects use the new interface over an extended period of time in their everyday mixing. However getting such longer term engagement from test subjects is problematic. Arguably a fairer comparison between LAMI and Logic Pro X would involve using inexperienced test subjects.

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