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□ Electronic Sheet Music
Product Description
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PROBLEM: Musicians have never adequately overcome the problems of working with written music: page turning usually requires unnatural breaks in performance or a dedicated page-turning detailee; using written music outdoors is subject to the wind; marching band members employ unturnable music of inadequate size; and the non-professional accompanist must endure with the key signature (pitch) the music is written in rather than a key tailored to her particular playing situation. Musicians performing outdoors have been seen using clothespins to secure their music to protect against the wind, considerably compounding the page turning problem.

SOLUTION: A proposed device, hereby given the working name ESM (Electronic Sheet Music), is a device slightly larger than an 8 1/2" by 11" pad of paper, and resembling a 1990's era "pen-top" computer, a computing device possessing only a screen without a keyboard. The ESM will appear to the user as written music, standing vertically and displaying the notes on its screen graphically. The ESM, using a variety of mechanisms, will be able to follow the player and know when to "turn the pages" (display a new screen containing the next page's notes) when the player approaches the bottom of the display, leaving the user free of annoying distractions and able to concentrate on making music.

More Detail

The ESM will appear to the user as dedicated hardware which can hold hundreds of pages of sheet music, all instantly recallable and instantly transposable. Internally it will contain a full-fledged computer, with CPU, RAM, solid-state disk, serial port, and large high-contrast liquid crystal display. In use, the ESM can graphically reconstruct the note events stored internally, and display them at a moment's notice. Because the music is stored as note events rather than a giant bit-mapped graphics file, it saves considerable memory and is "self-aware"; that is, it knows that nature of the graphic symbols being presented to the user, and therefore knows whether to advance to the next page or return to a previous Coda. Storing the music as note events also has the advantage of making transposition an easy task; this function alone is a much-sought-after tool amongst professional and amateur accompanists.

The ESM will also possess electronic hardware and software that enables it to "know" when to display a new page. This can be accomplished in one of two ways:

- 1) Special directional microphones embedded within the unit's frame can listen to the player's music, recognize the

pitch, and be able to track where on the displayed page the musician is currently playing. This will be the preferred mode which will appear in the majority of advertisements

2) For instruments which produce many notes at once or are not directly in front of the ESM, (such as a piano or guitar), a tethered three-position foot pedal can be detached from the ESM's frame and placed on the floor for foot-based actuation. Because this solution does not have the same high-tech appeal as the audio tracking ability outlined in 1) above, this feature should be advertised but not loudly heralded. □

More technical details about the page-turning mechanisms appear later in this document.

A four-tiered product line is envisioned, aimed at a wide variety of professional and amateur musicians. The ESM can become an indispensable necessity for the musician, much as the music stand and the modern chromatic tuner are necessities today.

Product Requirements and Technical Approaches

- The ESM must be as reliable as sheet music - readable in all ambient light levels, and no risk of surprisingly going "dead" in the middle of a concert.

A high-contrast, reflective, vertically-oriented LCD display will be employed. These can make the most of ambient light without resorting to producing their own backlight at the expense of battery life.

The unit will employ the latest in low-power 3.3v computer technology originally designed for the laptop market. A design goal is to have the ESM last hundreds of hours on a pair of ordinary batteries. A "Fuel Gage" function will graphically and reliably depict how much battery life, measured in hours, remains.

The unit will know when to display a new page.

Audio Tracking Method: Two highly-directional microphones will be placed in the frame of the ESM, pointing so that their listening paths converge a few feet in front of the unit, roughly where the user will likely appear. The two signals will be fed into an electronic comparator, which will accept only the in-phase signals common to both microphones, and reject all other sounds. This is an effective way to eliminate unwanted background noise, such as other players in the symphony. The signal is then fed to a circuit (firmware) similar to that which appears in a chromatic autotuner, which can identify the pitch of the incoming sound (what note is being played).

The note is then sent to the note display program, which is assigned the task of tracking the user's place on the page. With a knowledge of the notes being presented and a log of the notes being played and timestamps of when they were played, the software can continually estimate where the user is. Newly played notes automatically invoke a re-calculation and re-positioning as described above. The tracking software need not be completely accurate; dead-reckoning will compensate for missing individual notes. As long as the page turn occurs within +/- one measure, many missed notes can safely be tolerated. (This would be a good application of fuzzy logic and neural networks - tracking human music is a very non-rigid and fuzzy activity.)

Foot Pedal Method: Another page-turning method is the foot pedal, which is placed on the floor and operated by the user: in "Manual" mode, applying pressure to the left side of the pedal turns the page back, applying pressure to the right side turns the page forward. In Automatic mode pressing either side of the pedal automatically turns the page forward or back depending on the music presented and where you are in the song; the ESM is aware of the music's structure (such as repeat signs) and can branch intelligently.

Metronome Method is a third, blind way of page turning which is ideal for the beginning music student. Pressing the 'Start' button automatically starts a clicking sound and a vertical scrolling bar to help the student keep pace. In this scenario, the ESM dictates the pace and position of the player, not the other way around. When the scroll bar gets to the bottom of the page, the next correct page is displayed.

- The user can capture and store any available sheet music.

Each unit comes with a plug-in hand-held strip scanner with image-reconstruction software and OCR-MIDI translation software. The procedure for capturing sheet music is to simply scan in the music using vertical "swipes" and have the software do the work of aligning the two halves (strips) and turning the graphic notes into note events. There already exist commercial, off-the-shelf software packages that perform these two functions separately.

Alternatively, the Professional Version (described later) supports two additional ways of capturing note events: playing them on an external MIDI keyboard, or "writing" them on the display's surface using a stylus.

- No booting up; turn it on and it's there.

Even though there's a complex computer inside, this should be completely hidden from the user. All that should ever be seen is the ESM's user interface display. This requires ROMable firmware, a static CPU implementation and a small amount of on-board EEPROM to insure that 1) the ESM program never exits, and 2) the computer should never need to reboot, even after extended battery removal (or if it does, the user will never see the usual bootup messages on the screen).

- A minimal function set insures that the device is easy to learn and use.

All interaction with the unit will occur with membrane pushbuttons embedded in the vertical sides of the display's frame. The buttons and their legends are listed below, followed by their definitions:

- Left Arrow (used for backward page turning or to go to last repeat sign; also used for making selections in different modes)
- Right Arrow (used for forward page turning; also for making selections in different modes)
- "Top of Song" goes back to the beginning.
- "Follow My Playing", where the unit starts listening to the notes and tracks the user's progress through the song and displays new pages automatically.
- "Show Me Titles" brings up an alphabetized title list, which the arrows can scroll through and select.
- "Coda On\Off" selects between on-demand page turning or page turning in accordance to the process of the sheet music.
- "Lead sheet only" suppresses all but the melody, lyrics and chords of the selected song; handy for guitar players and accompanists.
- "Change Key": this button pops up a menu of potential key signatures; the arrows are used to scroll through the list and select the desired key. The last item on the list, "Original", restores the display to the native key.
- END/Enter - Stop listening, or stop metronome mode (saves considerable battery power) / Accept current screen menu choices.
- "On/Off" - Self explanatory. There will be NO automatic timeout mechanism.

Envisioned Product Line

Ideal for the beginner, the price-conscious, and/or the piano or guitar player (two instruments where the "Follow My Playing" mode would be ineffective). This unit has an inexpensive, 3-position footswitch stored in its frame, which is detachable during use and is connected via a wire.

Standard

The standard unit performs the audio tracking method described earlier. The inclusion of this feature is the only distinction between the Standard and the Low-End unit.⁵

The standard unit is the unit that will appear in the majority of advertisements.

Marching Band

A smaller device resembling the horizontal 5" x 7" form factor currently in use by marching bands. Audio tracking for this device should be much simpler; just listen to the loudest sound and AND it with vibrations detected by the mounting bracket.

Professional

This is a highly advanced version, to be released after a few years, allowing for the markets and expectations to develop and for the extra R&D to be performed. The Professional version boasts of an additional pen-based interface, where music composition, notation, and event manipulation can occur using an electronic stylus. It also has a built-in MIDI interface, so that it can capture notes played on an external keyboard (or other MIDI device), and/or play back notes entered or manipulated via the stylus.

While the initial appeal to the professional composer will be as a blank sheet music pad on which note scribbling can occur (a pen-based word processor for music), the pro version could also have an autotuner screen/ function; while in this mode the whole screen turns into an analog scale and when a note is played it graphically depicts what note was heard and how close it was to the proper pitch.

The Professional version is geared for those who compose or arrange for a living, and who need a tool that closely emulates the natural interface of a pen and pad while retaining the power of today's computerized sequencing and notation software packages that run on PCs.

Pie-in-Sky

The super-duper advanced version will probably take a decade to develop. It will be flexible enough to be rolled up like sheet music and carried to the next gig. It will be an accompanist; tracking the user's playing and controlling other MIDI devices to the pace of the soloist (a much more difficult task than simply figuring out where the user is on the current page). It will also have a Sound Blaster (tm) or equivalent sound board built-in as an alternative to controlling external MIDI devices; making for more portable

accompaniment operation. It will also be able to listen to ambient music and turn them into note events (a digital signal processing challenge!!!).

Envisioned Markets

Students who ride to school in a BMW
Accompanists that need to transpose a lot.
College students
Professional composers

Technical Challenges

- A new kind of LCD display will be necessary. No backlighting; very high contrast vertically-oriented display with no grey scale and slow response time. (The original Mac laptop displays are the kind I'm looking for. The active matrix one-transistor-per-pixel type.)
- Investigate fuzzy logic/neural networks as the easiest method of audio tracking.
- Must be low-cost, light-weight, low-power. Must run hundreds of hours on AA batteries.
- Overall, the product must be as reliable as sheet music.
- Ideally should cost under \$100, but current research places it closer to the \$800 range (assuming favorable licensing agreements with other companies - see "Corporate Strategy" below).

Advertising Ideas

Full page ads in music magazines would be ideal. Need pictures of outdoor musicians with sheet music flying away.

The professional market will probably be the last to flock to these; therefore this market should be pursued last (2-3 years after the initial offering; besides it'll take that long just to implement all the high-end features.

It's like air conditioning or voice mail or microwave ovens: once you use them you'll never go back to life without them.

Corporate Strategy

A one-year research phase began on July 12, 1994. During this time many categories will be investigated to assemble a strong case for embarking on this journey:

- Marketing focus groups and user surveys will be consulted,

- a business plan will be written up and scrutinized (the Caltech Management Association scrutinizes entrepreneurial business plans in public on a regular basis -- let's take advantage of that!),

- Patent and literature searches will be conducted, and a patent applied for if the specific problem of page turning for written music is not uncovered,

- A technical design will be finalized,

- Uncertainties in the approach will be investigated and defined, and an approach outlined, and

- Case studies of other high-tech start-up firms will be gathered so realistic corporate performance goals can be set and other hard-earned lessons can be learned. (Logitech comes to mind as an example company, but they might be so thinly spread that their profits may not look appealing enough. We'll have to see.)

If the projected market and the technological approaches still appear sound after this one year incubation period, venture capitalists will be approached for initial funding. We will be seeking financiers who understand the utility in the invention and can commit their resources and energy over the long run (a 5-year period typically) rather than some investment group which expects a unrealistically high return in an unrealistically short time frame.

Continuing with technical development: Several of the software pieces we need to integrate into the ESM already exist in Windows form; re-creating all of this capability from scratch is both difficult and wasteful. We need to make arrangements with companies that make scanner software, music OCR software, and sequencing/music notation packages to enable us to either:

- Have access to their source code so we can modify it;

- Work with them to tailor their code to our specific needs in exchange for the promise of increased sales

- Buy them out (insert evil laugh here).

It is estimated that two years will be required for R&D, corporate negotiations, system integration, hardware design, and fabrication arrangements. Things will be easier if they employ Windows' DLL and OLE 2.0 links, or will run faster if their software is DOS only.

Manufacturing, packaging and board layout will probably all be subcontracted to firms that specialize in it to insure product remains state-of-the-art, to reduce lead times, and to keep our initial staff small. At the end of that period 2 product will be

introduced simultaneously: the low-end and the standard product (both described above).

If PDAs become a widespread device (it will happen when the world sees a "killer app" -- perhaps this is it??), we can phase the product to the new hardware platform and eventually become a software application company. (Obviously the PDA to which we migrate will need a built-in microphone of suitable quality, and DSP algorithms of sufficient complexity must be developed for this shift to occur.)

The business will have an Internet feed, and have a Mosaic home page. We can also charge other businesses for the service of creating and maintaining their home pages on the world wide web. (A side business in case the music one fails. Plus, I can sell my photographs and Xaphoons (people can download a sound sample!)

Other Last-minute Ideas

- The ESM can be placed on a music stand or employ it's own built-in stand, similar to that of a picture frame.

- When it hears the first few notes from the top, it should have a flag to go to the beginning directly. Alternatively, uttering the word "Home" ideally should do the same thing.

***** END OF TECHNICAL SUMMARY *****