Aesthetic Forms of Expression as Information Delivery Units

by
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"...emotion is the moment when steel meets flint and a spark is struck forth, for emotion is the chief source of consciousness. There is no change from darkness to light or from inertia to movement without emotion."
-Carl Gustav Jung

Abstract

This thesis presents the hypothesis that aesthetic forms of expression – such as music, painting, video – can be used for direct information delivery. In contrast to text or verbal narrative techniques, which require a conscious act of transcoding, these aesthetic forms stimulate more direct, emotional response. Such a hypothesis could open a new channel for the delivery of various types of information, providing us, in situations of information overload, with a background information channel, leaving our foreground concentrated on the more thought-demanding tasks.
To develop a viable system based on the notion of using aesthetic forms of expression for direct information delivery, we need to develop the elements from which the system would consist. This research defines the "emon", a small discrete unit of aesthetic expression, which generates an expected emotional response that can affect human behavior. The study is currently restricted to the domain of music, with candidate emons being 1-15 seconds long loops of audio that are currently assumed to be the only audio source perceived by the user. The emons are characterized as units of an independently describable value, without the necessity of connection / abstraction to / from other pattern units – i.e. if a specific emon is played we'll be able to relate to its qualities without accessing our knowledge about other emons.
In this thesis I discuss the guidelines for emons' creation, describe the categorizations process, and report the results of emons' testing performed by a group of 14 users. Given the hypothesis that the musical emons (small musical patterns) can be used to provide cues that affect behavior, a need arises in a system that can provide a further validity to the usefulness of that approach. In the "Implementation" chapter I report the ongoing development of the GuideShoes wearable system, that assists user in navigating an open space, such as streets, by sequencing emons (musical patterns) as navigational cues. I also discuss the navigation tools written for this project.

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Imagine...

You are in Tokyo. Your ability to speak Japanese equals your ability to compose a symphony. You come to a computing device that knows your location and indicate your destination. You put your GuideShoes and a pair of headphones on and go out. As you start walking down the street, music begins playing in your ears. You have no signs or language to assist you. But you are language-independent. Musical patterns (emons) provide you with information regarding the correctness of your direction – they evolve in ways which you find natural and in correspondence with the emotional states of "right", "wrong", and the gray area in between. The patterns may indicate the duration of your journey and proximity to the destination. You no longer need to remember the map or think about how to get where you were going. The only thing that is required is your ability to hear. Have you entered an unfriendly neighborhood? GuideShoes will tell you. The GuideShoes try to consider your emotional state and musical preferences, merging the invisible, inadvertent emons into a significant tangible interface utilizing background information channels.

Finding your direction is only one example of a frustrating and time-consuming task that can be addressed using emons. People who can't or won't use printed or spoken instructions – little kids, the visually impaired, users occupied with other, more urgent tasks – can be helped in new efficient ways instead of being left alone to deal with maps, ask people for directions, and understand their instructions...

"No one denies that music arouses emotions, nor do most people deny that the values of music are both qualitatively and quantitatively connected with the emotions it arouses. Yet it is not easy to say just what this connection is."

-Roger Sessions

Hypotheses

The relationship between pattern and meaning has been the object of perusal for a few generations of musicologists, cognitive scientists and other researchers concerned with the interpretation of things played, drawn, and otherwise acted. Most theories are based on sequential systems of interpretation of artistic mediums – an artistic expression is first perceived, then recognized cognitively, and then referenced or given meaning beyond its initial domain. Theorists are doubtful regarding the ability of music to deliver meaning as it lacks the precise semantics present in verbal language. According to this widespread view, music cannot convey meaning as every listener may derive very different "meanings" from the same musical piece. Even among the heteronomists, the theorists that agree on the possibility that artistic expressions are valuable beyond their aesthetic appeal, only a few believe in the possibility that artistic mediums can be used as self-contained information containers using their emotional capacity. A proof of this being possible could possibly reduce the now required cognitive step in the recognition of an incoming information stream.

In similarity to the studies conducted by Konrad Lorenz et al [21] that proved the possibility of information imprinting on animal behavior, nowadays a lot of research is being conducted on how imprinting a specific combination of emotions on information can enhance that information's appeal for humans [1]. By studying the existing mappings of aesthetic forms onto behavior models in the brain as well as imprinting our own, we can possibly achieve higher efficiency of information and make better use of users' emotional abilities. To use these mappings we need to know what the individual components of an emotion are. The whole – an aesthetic expression – should be dissected into affective (i.e. emotionally charged) units.

In GuideShoes, the implementation project discussed in the second half of this thesis, I describe our work on incorporating such units into a wearable device, providing users with information regarding their travel. The system provides users with emotional cues by employing a system of aesthetic information fragments, called *emons*.

The emon approach is based on the following hypotheses:

1. Aesthetic forms can be used as direct information delivery mediums.

We hypothesize that a person's senses can be enhanced with the emon approach. This thesis focuses on the musical segment of that approach and use of musical patterns as the building blocks. Music is convenient because its high level of abstraction allows us to test the principles of emons' construction and find whether certain candidate emons get a consistent response/ratings in a series of tests. The candidate emons with consistent rating would then be considered as true emons to be used by the users, who, upon hearing these emons, would then be able to use their judgment on music & emotion to recognize their meaning. Musical emons are also appropriate because of music's ability to communicate emotion in an immediate and efficient way.

2. Aesthetic information can be isolated into small autonomous elements (emons).

According to the traditional approach, aesthetic expression consists of a continuous stream of elements. We hypothesize that by dividing the stream into discrete emo-informational elements it will be possible to open a new channel of information delivery, and achieve a more efficient perception process without increasing the learning curve.

To provide an initial testing for this hypothesis I have created a library of candidate emons, developed a database & an evaluation test to show the efficiency & stability of emons' ratings (what were the ratings given to the emons, and how stable these ratings were). An evaluation tool that allows easy visualization of the results of the testing has also been developed. I'm also currently working on providing further testing of this hypothesis using the GuideShoes, a passive I/O device for real-time emotionally charged information content – emons. The idea is that GuideShoes will help the wearer to navigate through open space (such as streets), making navigation personalized and less cumbersome by maximizing information input, by incorporating emotional disposition and reaction, and by combining artistic and informative communication.

3. Emons can be recombined to produce predictable emotional/informative responses.

The exploration of this hypothesis – defining the laws of 'emons' combinatorics' – is a part of future emon research beyond the scope of this thesis. It would be naïve to regard emotion as a mere sequence of positive/negative states; and indeed, this work does not have that goal. I do hypothesize however that the emotional power provoked by aesthetic means can be utilized in order to achieve a more efficient means of information delivery – granted the laws of emons' combinatorics have been defined. An initial examination of this hypothesis will be provided using the GuideShoes system. I also work on a tool that will serve as a front end to the emons' database and will provide an easier framework for the research of combination-related functions. More projects are in works to provide the necessary validity for that hypothesis.

Background

The emon approach is based on a number of concepts proposed by scholars of various fields. Here is an overview of a few of the ideas that inspired me to come up with an attempt of the theoretical approach and the practical application of emons. These ideas addressed in this chapter are relevant to emons' action, meaning, parameters' definition, and composition process.

Semiotics / Cognitive Science / AI

Starting with Locke, western thought has been concerned with the study of signs. Charles Peirce, one of the founders of semiotics, held the view that "a sign can never have a definite meaning, for the meaning must be continuously qualified". He proceeded to define a sign as "something which stands to somebody for something". He categorized existing signs into three main types: "(1) an icon, which resembles its referent (such as a road sign for falling rocks); (2) an index, which is associated with its referent (as smoke is a sign of fire); and (3) a symbol, which is related to its referent only by convention (as with words or traffic signals)".

How do we perceive the idea behind a sign – be it a visual or a musical one? How does a sign brings certain concepts into our mind? Even that according to Peirce a sign can never have a definite meaning, it can be assigned one – by the environment and the action taken. How do we learn an aesthetic concept, what makes us relate to it as such?

Marvin Minsky in his "Society of Mind" proposes a theory of how the brain learns/memorizes a concept. To explain this process, he introduces the concept of *paranomes*: "The idea is that, typically, what people call a "concept' is represented in the brain in several different ways. However, these will usually be cross-connected so that the rest of the mind can switch easily from one representation to another. The trick is that although each representation-method has its own type of data-structure, many of the "terminals" of their frames (or whatever else they might use) are activated by the same "pronome" signals" [4].

His idea that "many of our higher level conceptual-frames are really parallel arrays of analogous frames, each active in a different realm" seemed truly interesting to me, because of its possible application to the domain of music. However, in order to look at what are the top- and low- level thought streams, and what are the limits of the representation stages, I would like to slightly modify his concept and propose that actually we don't have parallel arrays, but one array that is able of being inflated when needed and activated in different ways by using various I/O mechanisms.

Let's suppose (doing a mix between Minsky's theory of frames and Schank's story-frames approach) that professor Minsky is playing piano. We can describe it as "Marvin plays piano". There's the physical realm with which he is concerned (pressing keys in the appropriate order), higher level cognition realm (transferring symbols from paper through the visual system into muscular movements), and a variety of psychological realms – one "creates" music, serving as the "translator of the enjoyment" for his listeners.

If we look at this example in a slightly deeper way we see that all of these processes happen at the same time. Does it mean that they have to happen using different mechanisms? I guess it is not necessary. Let's look at the learning process of a musical piece:
What do we seem to be learning first? The notes. Here the first problem becomes visible. Good teachers always say, "never learn notes without understanding what the final result will sound like". If the layers of agencies involved in the learning process would be acting separately, the sequence of which agency gets developed first wouldn't matter as long as all of them would be equally developed at the end. As we know, this doesn't work this way. That's why I would like to suggest that we develop our skill for a specific piece by developing one common stream of knowledge (which happens to occur at different levels of psycho-physiological being) and train all of our I/Os simultaneously because otherwise it will become problematic later to train them independently without hurting the balance of the "already trained" ones by overtraining.

Music is the art of analogies and metaphors. All we can say about the outputs of the process of performing a piece (except for the simplest qualities like "this music is loud" which is actually fuzzy as well) is metaphorical. What do we mean when we say "this performer redefined how we perceive this piece..."? How is that even a little kid can easily define where the melody is while listening to a 50-men orchestra? What are the limits of our filters' capacity?

We haven't yet developed clear understandings of the mechanisms behind art creation and comprehension. That can be one of the reasons we consider art to be something more "artistic" and complicated than, say, walking, when in fact it may just have fewer (and weaker) superisonomes ([4], pp.294) for controlling levels' connections. Trying to define the smallest possible elements of emotional/aesthetic intention, or *emons*, that can serve as triggers for emotionally-charged representations, is the topic of the research discussed in this thesis.

Howard Gardner suggests that we each have multiple intelligences [5]. He describes intelligence as "a set of problem-solving skills, enabling the individual to resolve genuine problems or difficulties that he or she encounters and, when appropriate, to create an effective product; it also entails the potential for finding or creating problems, thereby laying the groundwork for the acquisition of new knowledge." Gardner theorizes that each of these intelligences is relatively independent of the others, with its own timetable for development, peak growth, and a sensitive period. Each operates from a different part of the brain. Utilizing the links between different intelligences, e.g. Spatial and Musical ones, by the emon approach could possibly help people to make better use of their abilities by using one intelligence (Musical) to help in other's (Spatial) tasks.

Information Theory

According to anthropologist Clifford Geertz, all meaning is "context-defined and context-determined"[23]. Without a clearly defined context (action frame), the quest for precise musical meaning may be naive. Meanings, intrinsic and extrinsic, abound; meanings of all kinds, moreover, are revealed in and through the social setting. In the last 30 years (with the invention of electronic music) and especially with the new mechanisms of exchange and distribution (the Net), we can see the rapid development of media that affect music in characteristic ways. Beginning with the invention of the recording it became increasingly hard to define the clear action frame and/or social setting for an aesthetic experience. Every room became a recital hall and to deliver a message using aesthetic forms of expression we have to learn how to react to the rapidly changing setting around us.

Abraham Moles in his *Information Theory and Esthetic Perception* [20] brings together the information theory and musical perception. He talks about the concept of "sonic message", with dimensions dependent on the particular composition. He approaches the components of musical creation as "atomistic", ones that can be studied independently of each other. He writes: "The esthetic procedure of isolating sonic objects is analogous to the sculptor's or decorator's isolating a marble work against a black velvet draping: This procedure directs attention to it, alone and not as one element among many in a complex framework."

According to Moles, music can be interpreted as a rule-based system, not a rigid system, but rather flexible one, in similarity to today's approach to linguistics. His approach somewhat reminds of that of the musical theorist Leonard Meyer; Moles is not a referentialist, yet he chooses to term these components as symbols. He says: "each definable temporal stage represents a symbol' analogous to a phoneme in language. The role of aesthetics is to enumerate universally valid rules, not to perpetuate the arbitrary or merely traditional." His search for a form of art where the medium itself is indistinguishable from its message brings him to talk about new instruments ought to be invented. Today, with the developments in the electronic music technology and wearable computing, we can start considering principally new ways of combining between everyday activities and creation of music.

Musicology

For musicologists, the idea of music as a container for extramusical information is not new. The discussion between heteronomists, who hold that music can and does refer to meanings outside itself, and the formalists, who maintain that the art is autonomous and "means itself" has been going on for more than 150 years.

Formalist view is problematic in regards with the presence of emotional reaction to music. Expressionist composers achieved the great emotional impact of their music in large part by appealing to the extramusical components of their listeners' perception. Wagner and others frequently associated between a specific leitmotiv and a person or an action. Hollywood, where musical "messages" had to serve as an explanation for the actions happening on the screen, has further popularized the heteronomistic view. While inappropriate and annoying at times in a form of art, message-based compositions have a great importance in the musical field of today. The extramusical connotations of music, ranging from enhancing an existing message delivered through a parallel medium (Hollywood films) to delivering a political message of its own (works of Prokofiev and many other modern composers) are the object of study for many contemporary musicologists.

Leonard Meyer acknowledged that music can and does express referential meanings as well as nonreferential ones – in other words that both heteronomists and formalists are right. The emon approach attempts to expand his view by adding that an emotional reaction / bit of information can not only be triggered by music, but also contained in the musical pattern itself – granted a defined action frame. For Meyer, in order for musical meaning and communication to coexist it has to have a cultural context. In my view, what matters more is the action context, with emons being its components. Adopting this approach allows us to bridge between the heteronomist view of music and the early 20th century attempts at creating a musical language.

Music and Language

I would like to define the initial elements of the language that emons should operate in order to serve as information containers. This language should be easy to learn, just as it is easy to remember a simple melody. In this context I find it especially interesting to talk about the parallels between language acquisition process and music. My personal experience has been that of learning to play musical "sentences" before I learned to utter verbal ones. It also works the other way around – having the perfect pitch I always perceived sounds as a certain type of words – every sound tells me its name every time I hear it. Even now the only difference for me between verbal and musical expression is based on the fact that I can express my thoughts in a much easier and sincere way by musical improvisation than by trying to squeeze them into words.

The study of the childhood language acquisition process has been one of the central topics in psycholinguistic research. Chomsky suggested that "children are born with a knowledge of the formal principles that determine the grammatical structure of all languages, and that it is this innate knowledge that explains the success and speed of language acquisition". Music represents a form of language and an early one – toddlers start reacting to music before they learn similar reactions to words. Therefore, just as linguistic constructs apply to language, these same principles can possibly be related to information transfer by musical means.

It has also been asserted that the same basic semantic categories and grammatical functions can be found in the earliest speech of children in a number of different languages operating in quite different cultures in various parts of the world. Some of the musical connotations are considered to be intra-cultural and based on tradition (e.g. use of pentatonic scale in the western music is associated with an eastern feel). At the same time even traditional musicologists admit that some of the music can hold a cross-cultural value. As Meyer puts it, "There is a great deal of evidence, some of it intercultural, which indicates that our experience of musical stimuli is not a separate special category of experience but that it is continuous with and similar to our experiences of other kinds of stimuli. Both music and life are experienced as dynamic processes of growth and decay, activity and rest tension and release…"([17], pp.260).

Heteronomists view musical expression as a base for extramusical meanings. However meanings in their descriptions are usually static concepts, or related to a certain way of engaging in a specific activity. There is an enormous amount of these fixed meanings – from Bach's musical signature in one of the fugues in the *Art of the Fugue* to Wagner's musical system of connotative symbols where a melody is frequently linked to a certain individual or a place.

This thesis is based on the interest to see how music, being a temporally-based medium can be dynamically mapped to temporally-based activities – be it navigation in a city, participation in a sport game or monitoring of the stock exchange progress. Giving the user a clear context of what the action frames are seems to help. There is a certain degree of danger of running into a peculiar experience of an individual, with one thought provoking the next – and seeing the mind wander away from the initial objective that was to be evoked by a certain musical pattern. Because of the mixed nature of music as a medium (with both intra- and extra-musical meanings), these "mistakes" can never be fully avoided. An emon that was supposed to elicit positive response can have a certain musical construct that is associated with a particularly traumatic experience. However with a large enough bank of emons and substantial number of users from various demographic groups categorizing these emons, we hope to achieve a substantially high match between the proposed and the actual actions for demographically definable groups of users.

Storytelling

According to the philosopher Susanne Langer, works of art are "presentational symbols" whose relation to their objects is purely morphological [23]. It can be argued that to interpret a work of art, one doesn't have to understand the symbols represented in that work. The possible relationship between the structure of an artwork and the symbols it uses is where the storytelling research proves relevant to this study. A storytelling theorist Vladimir Propp found that symbolic relationship to be true for tale authors, who, according to Propp, divide their narratives into a number of basic elements. According to Propp's analysis, "These elements correspond to different types of action that always occur in the same sequence."

It is somewhat ironic that we have to argue whether music has a storytelling element and an extramusical meaning. To any person who grew up in the African or far-Eastern cultures, this is a well-known fact. Playing or listening to music for its own sake is, after all, a fairly recent Western development. For thousands of years music has been an intrinsic element of religious rituals and storytelling, often playing the main role in the act. It has also been tightly associated with improvisational arts such as dance, where, once again, it defined the message content and character.

Even today in the contemporary urban African theatre we find significant elements of the old village theatre, with its emphasis on the storytelling rather than setting, and music playing a leading explanatory role in the spectacle. If we look at studies of African ritual theatres (such as Shona ritual theatre) they clearly demonstrate that African theatre is more than mere storytelling. "It is a ritual experience that seeks to recreate and, in the process, affirm desirable models of community existence. [...] Rather than rely on the written word *per se*, the African's theatrical sensibility derives its context from ritual celebration and its meaning from symbolic performance, direct audience participation and stylized artistic signals like mime, song, dance, movement, music, poetic rhythm, costume, gesture, dialogue and role-playing." [25]
Only in the last 300 years (as far as we know), with the development of what we now call the secular European performance art (opera and later musical concerts) we came upon making music for the sake of purely aesthetic enjoyment.

Affective Computing & Its Tangible Applications

The exciting new fields of research in affective and tangible computing can become an excellent home base for emons' study and experimentation, since part of the problems posed by researchers in these fields can be addressed using the emon approach.

William Buxton in his "New Taxonomy of Telematics" proposed a two-dimensional model of human-computer interaction (HCI). In his model, the interaction happens on *either* background or foreground levels, so that any medium populates one of the two cells. He is aware of the power of the background information channels and proposes "...a means of sharing the periphery, the background social ecology, by means of appropriate technological prostheses". However, his model seems not to be flexible enough to address the notion of switching between the foreground and background cells within the action frame of the same object. It is interesting to see whether the emons' approach could address the need of tangible objects to be easily transferable between those states. It would make them more adequate for use in the real world action, where switch of our attention continuously causes dynamic reassigning of attention weights in regard to the objects around us. Such objects would address the frame of action in more intelligent and modal ways, bringing us closer to the creation of natural forms of computational objects.

The question of modality is addressed by the HCI researchers. Hiroshi Ishii relates to it as one of the topics of his research in tangible interfaces. He writes, "...subconsciously, people are constantly receiving various information from the "periphery" without attending to it explicitly. If

anything unusual is noticed, it immediately comes to the center of their attention" [8]. Ishii's view in creation of a tangible user interface is to "employ physical objects, surfaces, and spaces as tangible embodiments of digital information. These include foreground interactions with graspable objects and augmented surfaces, exploiting the human senses of touch and kinesthesia" and also "background information displays which use "ambient media" -- ambient light, sound, airflow, and water movement." He seeks to "communicate digitally-mediated senses of activity and presence at the periphery of human awareness."
In this thesis I explore the notion of musical emons as basic elements of a new tangible approach – processed in the background, in parallel with other media sources, and reconfigurable to reflect the current state of the user and of the environment.

As the applications of modern computing strive towards becoming increasingly personalized, emotion starts playing a vital role in these systems. Rosalind Picard's work in the field of affective computing explores the ways of giving computers means for recognition and expression of various emotional states. Her notion that "Emotions motivate and bias behavior, they do not completely determine it"[10] underlies this research, as it allows us to see how emotionally significant tangible elements can cause motivational changes in human behavior. This in turn will allow us to design computer systems that will attain qualities of an active social setting participant. Computer will not only acknowledge the human emotion, but will aim to evoke one and trigger a behavioral change as a result. Emon approach is compliant with this vision, being a suggestive method, rather than a fixed one. It is an approach of trends, rather than of precise data, with the emotion viewed as fluid and transitional rather than solid state.

The combination of audio and wearable computing is explored by Peter Meijer in his "Auditory Image Enhancement". His vOICe system "translates arbitrary video images from a camera into sounds. This means that you can see with your ears, whenever you want to." [7]. While achieving a solution to an interesting technical challenge, it seems that mapping of the visual domain onto the auditory domain would be much more effective and easy to perceive if an emotional component played a more significant role. Meijer's approach may work well in static situations, such as in the interpretation of still pictures. However, in dynamic open-space environments, such as streets, his solution for the cognitive problem of navigation seems inefficient as it overloads the users' perception channels with vast amounts of non-filtered information and is problematic for tasks involving items of varying importance or priority.

"If you are allergic to music you may have trouble with all the stuff coming out in the next hour"
-An announcer on the GoGaGa radio.

The Anatomy of an Audio Emon

We perceive the world in a totally different way because of our ability to distinguish between audio symbols. Hearing allows us to be aware of the events in our environment that wouldn't be accessible to us, if we had to base our perception on vision alone. As nicely put by the psychologist Bruce Goldstein, "...I looked around my office, I saw my desk, a phone, some papers, [...], and my computer, stereo and CD collection among other things. However, when I closed my eyes and listened, my perceptual world changed drastically. Based on sound alone, I perceived a person in the street below my window, a dog nearby, and a car driving down the street in front of my house." [14]

So how can we make a better use of our ability to perceive this massive information stream, what constitutes an emon given the sound domain?

Music has an infinite number of properties to play with. In this chapter I'll give an overview of my decisions during the emons creation process and discuss the axes that can be populated. It has to be noted that while this thesis addresses the music domain, a similar deconstruction can possibly be performed with other forms of aesthetic expression.

Approach

In order to build an information delivery system based on aesthetic forms of expression, we have to define the elements, of which this system consists, and create a personalizable mapping system. "Colors, sounds, odors, tastes, tactile experiences, all may be "heavy" or "light" or have "volume" and dozens of other psychological similarities" (Faber Birren, defining a correspondence between color segments and emotional states) [2]. We start with an attempt to demonstrate a correspondence between certain musical solutions and emotional states. Music has a variety of interesting properties to play with – rhythm, timbre, texture, and so forth. As a complex medium, music offers us great degrees of freedom – its high degree of abstraction allows us to manipulate and adjust it in almost any imaginable way. It also presents us with the challenge of inventing a technique to reliably convey an emotional state using a unified method.

Definition

Discrete units of emotional expression, or *emons*, are aesthetic information containers, which are capable of generating an expected emotional response that can affect human behavior.

The emons are characterized as units of an independently describable value, without the necessity of connection / abstraction to / from other pattern units – i.e. if a specific emon is played we'll be able to relate to its qualities without accessing our knowledge about other emons.

Forming Expectations

In order to compose a diverse set of emons, it was important to me to think – how do we form our expectations while listening to music? Most of the Western European classical tradition (as well as other dynamic art, such as cinema) is based on the conflict-resolution structure. At the same time, we can easily find examples in the Eastern music (as well as European modern) that base their unique message not on the conflict-resolution scheme but rather on the process of music creation itself. We can say that the European tradition is more of an enjoyment "on the outside" – the role of the musician is distinctive from the role of the listener, and we are driven to continue to listen by the perspective of discovering more conflicts and resolutions. The expectation of a "happy end" – what in musical tradition is called the dissonant that comes to the consonant – is important in shaping the musical experience. To see the other ways of expectations' play, we can turn our attention to the non-western cultures. There we find music to be a much more fluid medium than what it has become in the European tradition – both classical and the mainstream modern one, such as rock.

According to Alan Ruttenberg, "...musical activity is a communications play centered on the ability of the listener to predict what will happen next. Because of limitations of human short and long term memory, music needs to be constructed in such a way as to not exceed the capabilities of the listener. Music compositions are made from a small number of elements, which are varied and combined in different ways, both sequentially and simultaneously. Because of this structure the task of the listener is reduced from literally memorizing a complete stream of music to identifying the parts and their combinations. Pleasure derived from music relates in part to the success and failure of this listening activity..." [18].

In order to look at what constitutes a musical emon, we have to look at a number of characteristics, which can roughly be divided between the "high level" ones (such as style) and "low level" ones – duration, rhythmic structure, loudness, and others. The interplay between these characteristics as well as varying the individual ones, represents a practical interest if we are to create a viable set of musical emons.

Let's look at the outline of the composition ideas I used to address some of these components:

Style

The selection of styles for emons' testing purposes was made according to the list of musical styles active in today's western listening practice (49 styles). They are listed in *Figure 12: Composition Chart.*

The wide selection of styles allows for narrower matching of subjects' listening preferences. A few points to look for include correlation between a musical style selected as a favorite and the socio-demographic group of its selectors, comparison between the ratings given to discrete emons and the rating of the styles to which these emons relate. Clarifying these points will help in defining whether the styles are directly affective of the user's choice in rating an emon composed in that style.

Many musical styles tend to have standardized melodic cadences and, consequently, time divisions (some obvious examples include the steadiness of the rhythmic structure in rap, loudness level in hard rock, or choice of instruments in baroque). Therefore, users' selection of styles can also be analyzed from the standpoint of musical components belonging to a particular style.

Duration

Emons aim at communicating a certain emotional state to be linked by the user to the activity he's pursuing. Every communication process has a beginning and an end. The duration of this process is one of the key factors in its effectiveness – the same information can be perceived in a completely different way dependent on the time span of message delivery. Trying to establish a proper temporal relationship with musical messages is even more delicate than doing the same with their verbal/textual counterparts. When creating a musical message capable of delivering concise information, the duration factor accounts for much of its success/failure.

According to the philosopher Susanne Langer, "music is time made audible" [22]. The perception of music is a continuous experience – parallel in its nature and sequential in its effect. As we expose our brain to the incoming audio signals, they are processed and evaluated according to our tastes and expectations. However, unlike the static arts, such as still painting, or photography, we don't get the full "picture" at the time that our evaluation process is going on. For example, we may be very pleased with a song in the beginning, but as it progresses we become bored or annoyed and lose our patience and focus. Our expectations play a great role. We may become annoyed if a song continues for ten minutes when it was expected to not be more than three minutes long. At the same time if the song doesn't stop there and goes on for another three hours, we may stop assigning it musical qualities and regard it as noise. The reason for this is the expectation we form regarding various musical styles. Our expectations are grounded in the style expectations, where the style itself is a composite image of various parameters of that musical piece.

When trying to use the musical domain for information delivery, a quality usually reserved for the verbal input technique, it is useful to look at the factors that affect the perception of verbal input in various cultures. One of the important factors is the length of the message. Our memory span and training plays an important role in how well a message gets perceived. This can be observed looking at the task of foreign language acquisition, especially when the language belongs to a different-than-native family. It's especially evident for cultures where the linguistic structure brings verbal conciseness to play an important role. For example In Hebrew, an absolute majority of the words don't extend beyond 2-3 syllables, which makes longer English words to be very problematic to memorize for native speakers of Hebrew (with excellent example being the word "Massachusetts"). A brain not accustomed to processing of longer verbal structures unified in a grammatically sensible way doesn't adapt easily to longer constructs. The same stands true for musical messages – someone with lots of listening/performance experience in classical 20th century music will probably have better adaptability to longer musical constructs than a person whose musical tastes are summed by "it's MTV and the knob is gone".

Texture/Density & Rhythm

While discussing the duration (length) property of a message, it is important to remember that a musical message, in contrast to a verbal one, has a powerful quality of parallelism. Multiple musical streams can be processed in parallel – either as a means to achieve a higher efficiency of the message or as a tool for wider stream of informational components. We all know that even a little kid can feel at ease listening to an orchestra and distinguishing between its various instruments, whereas it would be impossible for any of us to make the same distinction between simultaneously perceived verbal messages. Here I would like to discuss a few thoughts regarding the question of density in music and its possible application to the construction of emons:

Instrumental Density

This thesis is aimed at defining the qualities of an individual emon. At the same time, defining the rules of horizontal (sequential) and vertical (polyphonic) conjunction between emons can be partially derived from the ongoing emons' categorization process (described later in this chapter as well as in the "Results" chapter).

The question of density of musical texture has been the object of interest for many Western composers of the 20th century. Igor Stravinsky's late serial works, Witold Lutoslawski orchestral works, Krzysztof Penderecki's aleatoric compositions, and John Zorn's experiments are only a few examples of the exploration of the topic during the last 40 years. Regarding emons from a different perspective than long-established musical elements (storytelling elements as opposed to a continuous stream of composers' aesthetic expression), it is essential to give special attention to the question of an emon's density. What is the optimal density of an emon, is there a threshold after which an emon stops being a message and turns into an undecipherable noise? While impossible to answer precisely, that question can be indirectly addressed by comparing the tempi, instrumental textures, and rhythm of emons with the ratings given to these emons by the study subjects.

Affecting such parameters of audio field as volume and tempi dynamically based on user's actions can play both positive and negative roles. The benefits include yet another aspect of flexibility to the system-user interaction. A specific action can be assigned to a generally defined parameter, e.g. louder audio would signal an increasing urgency, and acceleration in tempo would be a reflection of user's pace. The question is again a threshold of such a change without affecting the qualities of the played emon as rated by its users.

Rhythm

How does rhythm affect musical character? Any general answer to that question would be culturally biased. Western tradition, with its concept of conflict-resolution, presented us with a number of presumptions. For example, sporadic changes in rhythm increase the instability/alert feeling of the listeners, as usually changes are far more controlled than in other musical cultures such as the African, where rhythm is much more linked to the emotional state experienced by the performer.

Looking at three (out of six) main components of music – melody, harmony, and rhythm, it is interesting to note that the European thought has traditionally placed melody and harmony concerns above the rhythm-related ones (e.g. the virtually rhythm-less structure of Gregorian chant with its concentration on the melody, or contemporary scores with no rhythmic structure at all). The fact is that rhythm exists in nature without melody or harmony, whereas the reverse is impossible. Rhythm permeates human experience, be it listening, performing or dancing to music, or speech communication or even the communication between cortical areas (Baird, 1996). Many modern composers refer to rhythm as the energy that drives the music. Rhythm on its own is also a great means to communicate information in an effective and timely way. Therefore, looking at the rhythm characteristics in the process of composing a viable approach to musically transferred information is essential at all the stages of emons' design process.

Emons: Bits of Intelligence?

The goal of the testing process is to define the key patterns to be the prototypes of specific intentions – "a holistic, picture-like representation of a typical or average member of the category" [3]. In order to determine the qualities of emons, both macro- and micro-level evaluations should be performed:

On the macro-level I would like to see a plausible threshold beyond which emons lose their role as information containers and start to be perceived as a random mix of sounds. In other words, check what can be the maximum spatial and temporal density of musical emons before they are perceived as a mix rather than distinctive messages.

On the micro-level, with fuzziness defined as the level of complexity of an individual emon, the level of reliability of emon recognition is to be studied in environments of both internal and external disturbance. By internal I mean situations where the necessity of urgent mental decisions weakens the ability to perceive – crossing a heavy-traffic road while trying to remember the directions you were told, for example, will occupy a substantial part of our responsiveness at that given moment). External disturbance, on other hand, stands for disturbing events initiated by a third party.

Direct evaluation of emotional information is a very challenging task. Howard Gardner's definition of intelligence is *"our singular, collective ability to act and react in an ever-changing world"* (Gardner, 1983). Using emons to enhance our ability to act and react is a way of stimulating intelligence enhancement. My longer-term hope is to show that by exposing people to musical emons, selected based on the derived statistical data gathered by analyzing the response to the questions set, it will be possible to enhance our ability to act in the modern information world.

Design & Evaluation

In order to design a valid set of emons for various life situations, I first selected an emotional model and defined criteria for emons' construction. Then I composed a set of candidate emons, defined evaluation mapping, wrote evaluation software, and started to conduct a line of tests – first on a group of subjects determining the real emons among the candidate ones and then on a different group using the selected emons for real-time navigation. A brief overview of this process follows.

Affective Categories

One of the important decisions to consider is picking the emotional model most suited for implementation of emons' goals. After looking at various approaches to studying emotion and personality, I learned about an interesting alternative model called the circumplex [15]. According to the psychologist Robert Plutchik, "the circumplex model focuses on determining how traits and emotions are structurally similar, and its underlying assumption is that a relatively seamless circular ordering, or circumplex, is an economical description of the relations among traits and emotions. The circumplex model allows a broader view of personality and of the interpersonal relationships integral to understanding just what makes a personality the way it is."

I chose to base the emon categorization on a partial implementation of this model (also called the Plutchik Model of the Emotions) [15]. The model is structured in a relatively simple (and therefore applicable) way, while being adequate in its perspective on ways of emotion synthesis from independent components. Plutchik used multi-dimensional scaling to classify emotions according to their similarities. Subjects were given pairs of emotion describing words and asked to rate their similarity. From these judgements, a map of emotions emerged. The specific categories of Plutchik's map are: [Acceptance, Aggression, Alarm, Anger, Anticipation, Curiosity, Cynicism, Delight, Despair, Disgust, Dominance, Embarrassment, Fear, Joy, Love, Misery, Optimism, Pessimism, Pride, Scorn, Shame, Sorrow, Submission, Surprise]. The partial implementation during the evaluation study (in the scope of this thesis) is limited to the primary emotions (as outlined by Plutchik), namely: Acceptance, Anger, Anticipation, Disgust, Fear, Joy, Sorrow, and Surprise. This is an initial attempt at exploring a practical application of Plutchik's vision of emotions' combinative possibilities, which may prove very helpful in dealing with discrete emotional elements such as musical emons.

Construction Principles

Meyer states: "A distinction must be drawn between the understanding of musical meaning which involves the awareness of the tendencies, resistances, tensions, and fulfilments embodied in a work and the self-conscious objectification of that meaning in the mind of the individual listener." These two notions seem to be intervened – the musical notion of tendencies can be used to deliver an objectifiable meaning to the mind of a listener thus gaining better understanding of both composition and perceiving processes.

While classifying emotion invoked by music into simply positive or negative may be an oversimplification of the actual emotional feedback, things become better as trends start to be used. Trends are fluid, they don't need to be based on a static knowledge of specific music-related parameters such as tonality. Instead, we dynamically and subconsciously adjust our understanding to the trends as they progress. The more experience we gather in doing so, the better we do, but even a person with no musical education at all can tell if a sound is getting higher or lower. That knowledge can be easily mapped to various environmental scales according to the preferences of that user or his socio-demographic group.

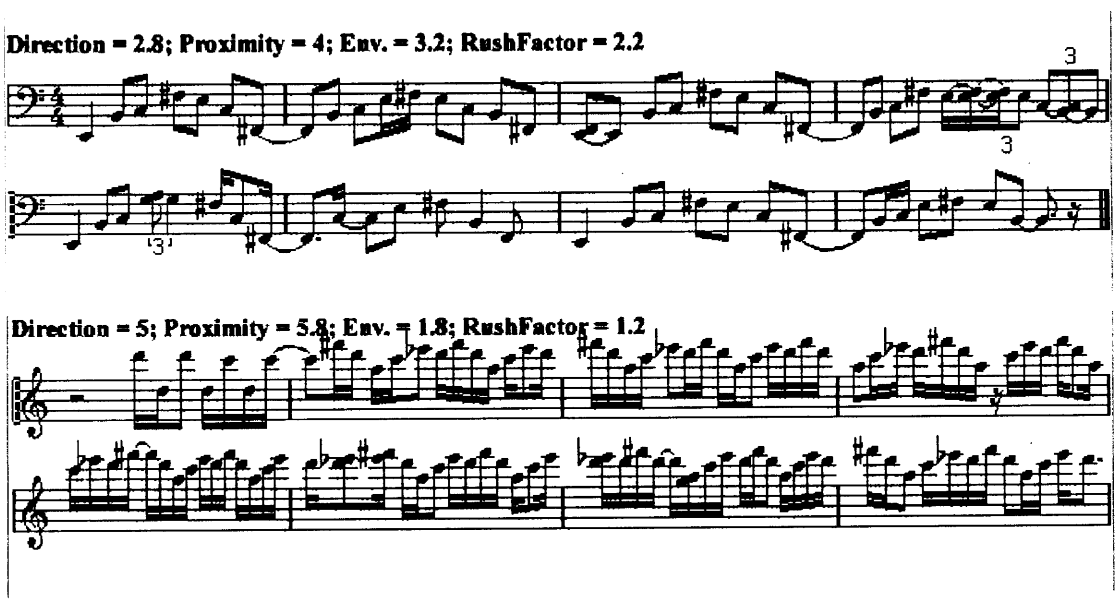
In his attempt to explain what gives rise to the natural modes of expectation, Meyer states, "...For the mind is constantly striving toward completeness and stability of shapes" (pp.87). For me that statement is a complete opposite of what emotional expectation is combined of. It's not the dissonant – consonant idea that gives us the tools to experience, and expect, but rather the expectation itself, the incompleteness of forms and their fluidity and ever-changing shape is what drives our interest (both its emotional and cognitive components). Trends in this perspective become temporal traces of the experienced emotion. When we hear music what gets our interest (or drives our emotion) is not the last chord but rather the unfolding of all the possible colors and worlds created by the composer. And just as an ideal emotion would be endless, the same stands true for an ideal musical experience (one more reason for regarding the Hollywood-style of composition merely as information containers – with themes that are written to be perceived as an identity of a specific personage or action).

Music is a wonderful tool for information transfer as it is fluid and present at any given state only at one given moment – performing the functions of a verbal language and surpassing it in its EQ. We relate to music as a matter of styles and forms, but as Meyer rightfully states "...the norms developed in the memory are not rigidly fixed but change with the addition of each new memory trace; to the extent that the norms have changed, a rehearing of a work is a new hearing, yielding new insights" (pp.90).

In order to test the emon approach, a number of libraries of candidate musical emons have been created. The emons' libraries were created free form, basing their creation on my sense of composition as well as trying to utilize the components of composition techniques from various musical styles. The candidate emons were created with no specific emotional category in mind. While composing the libraries, I thought of emons' inter-relationships in the following terms:

1. Major/minor as right/wrong. The binary notion of right/wrong is not meant to imply a binary relationship, but rather a tendency in the emotional reaction to a composed emon. In this form, the right/wrong scale can be applied to all the following pairs, however which of these gets assigned to which of the emotional scale ends is up to the actual users.
2. Loud/quiet as right/wrong.
3. Defined fast tempo vs. slow tempo.
4. Continuous sound with difference in pitch. The higher – the more positive (this one is actually appropriate for simple fuzzy relationship as well).
5. Separate pitches with specific rhythmic patterns – the more steady the pattern, the better the direction.
6. Instrumental density – the more simultaneously heard instruments, the better is the direction.
7. Sound density – same as #6, but with emphasis on the individual sounds.
8. Rhythmic and melodic repetitiveness versus [pseudo]randomness. Ostinato in the melody – improvement in the direction.

Fig. 1: Sample emon evaluations.



- Look at the *Test Questionnaire* and the *Results* chapters for the discussion of the parameters.

When composing the emons, I referred to figure 2.1 for the list of styles to be addressed and figure 2.2 as the guideline for composition of individual emons. This was done to bring some order into the compositional havoc.

Figure 2.1: Styles used in the composition process

Composition process: styles [49]

20th Century	Celtic	Heavy Metal	Opera
80's Rock	Classic Rock	Hip-Hop	Polynesian
90's Rock	Classical	House	Progressive
Acid Jazz	Country	Indian music	Punk
African	Disco	Indie Rock	R&B
Ambient	Far Eastern	Industrial	Reggae
Avant-garde	Folk	Jungle	Retro
Baroque	Funk	Latin	SKA
Be-bop	Fusion	Latin Jazz	Soul
Big Band	Gospel	Light Classic	Swing
Bluegrass	Gothic	New Age	Techno
Blues	Hard Rock	New Wave	Trance
			World music

Figure 2.2: Parameters used in the composition process

Sound: **Major / Minor / M2m / m2M**
Volume: **Loud / Quiet / L2Q / Q2L**
Tempo: **Fast / Slow / F2S / S2F**
Rhythm: **Steady / Unsteady / S2U / U2S**
Melody: **Continuous / Sporadic / C2S / S2C**
Texture: **Sparse / Normal / Dense**

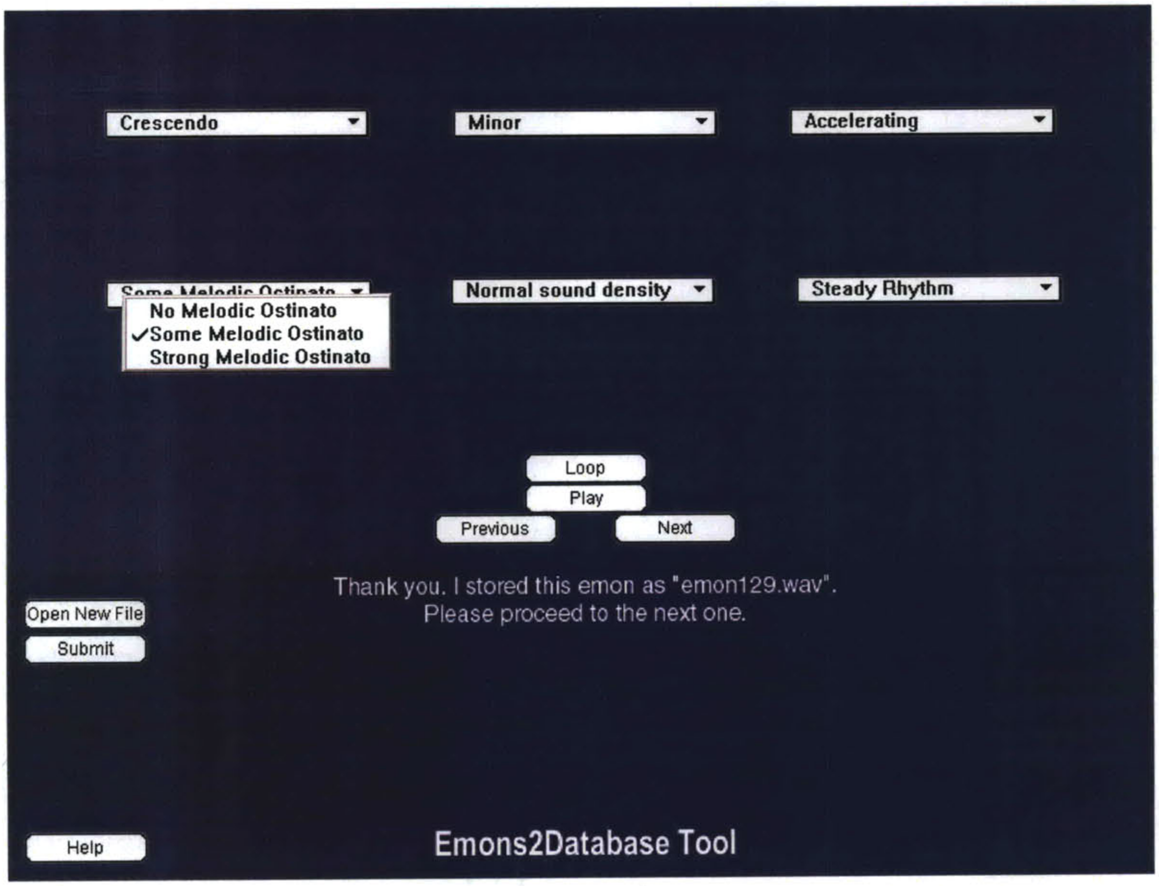
While not explicit, the guidelines in the chart in fig. 2.2 offer a set of properties to be addressed during the composition process. Emons creators can choose to address as many or as few of these as desired. Taking this chart into account helps in keeping the created emons well structured as opposed to the free composition process.

The total number of candidate emons that have been composed and put into the system is 200, each being a 1-15 second long loop (for the discussion of length, see "Duration" chapter above). After recording, the emons were saved as separate MIDI file loops, to be streamed in real time upon request.

Database Entry Tool

After the libraries were created I also wrote a tool to allow an easy categorization and further cross-checking by creators of emons in the future. The guidelines for emon categorization using the tool were the same as the ones used for the composition chart:

Figure 3: Tool for the creators of emons



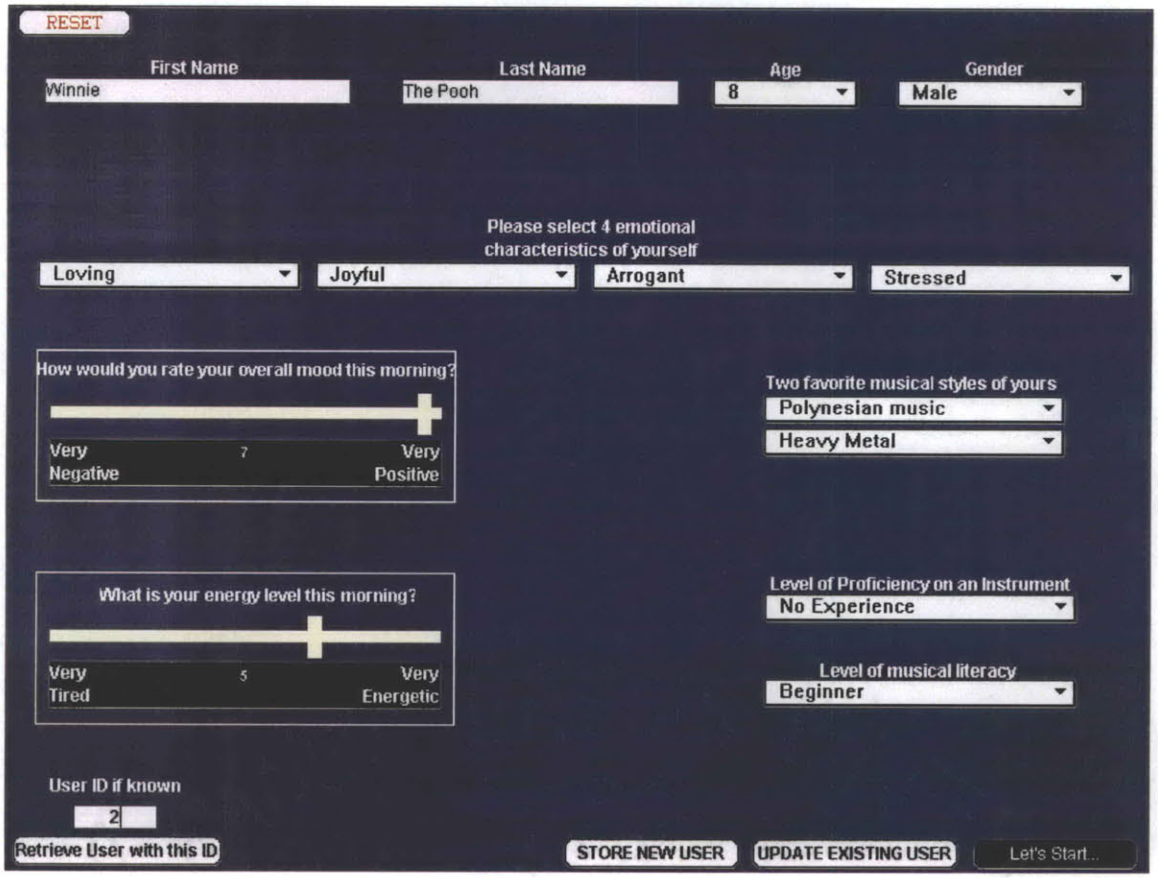
The purpose of this internal categorization is to use the data gathered from people operating the categorization tool and try to find any similarities between the popularity ratings for a specific emotional state and their compositional characteristics.

Creation of test questionnaire

The goal of the audio emons in GuideShoes system is to provide us with a navigational means as well as to enhance our awareness of the surroundings. The testing process is aimed at gathering data for future exploration of various ways of mapping emotion/music to physical spaces.

In the beginning of a test session, the subject is asked to fill a short questionnaire that asks for their age, gender, favorite musical styles, level of musical literacy, up to four emotional characteristics of themselves, current mood, and the arousal level (fig. 4).

Figure 4: User Details Tool



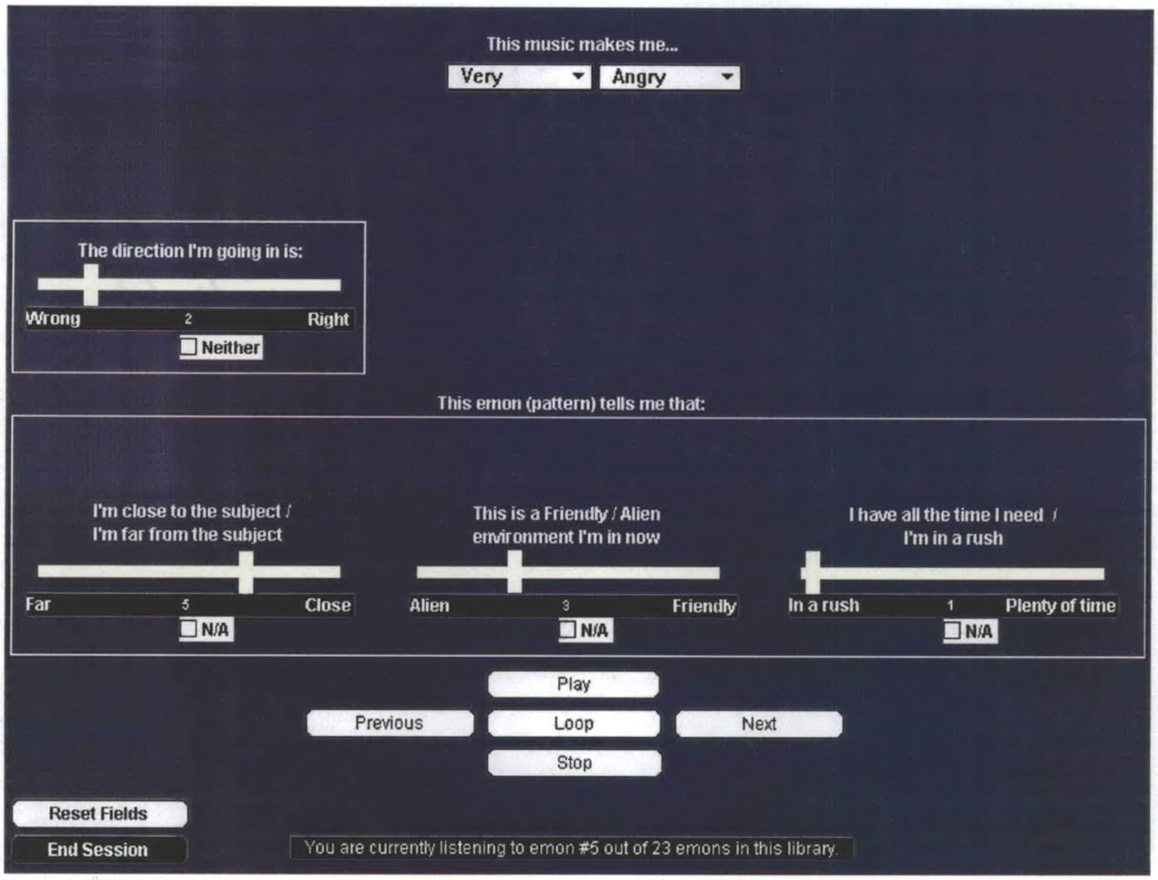
After filling in this questionnaire user proceeds to the Emons Categorization Tool (fig. 5).

There are two groups of questions to be asked regarding each candidate emon during the categorization process divided into Emotional & Social groups:

- The Emotional Group consists of two pull-down menus combining which the subject is asked to choose up the emotion that most closely reflects his emotional response regarding that sound. In addition he is asked to rate the movement on 1→7 scale with '1' being wrong direction and '7' being the correct one. The goal of this group of questions is to provide us with initial emon→emotion mapping. A valid number of subjects voting for an emon as related to a specific emotional category will provide us with the needed data on the setting in which this emon can later be used. This data will be subsequently correlated with both Social Group of questions as well as the subsequent real life testing.

- The Social Group consists of three questions, namely: "I'm close/far to/from the subject", "This is friendly/alien environment I'm in now", "I'm in the rush/I have all the time I need". Each question is represented as 1→7 scale with an option of "N/A" answer. The goal of this group of questions is to provide us with social aspects of usability of a particular emon. This group of questions also serves as a supplementary model to provide validity for the Emotional Group rating.

Figure 5: Audio Emons Categorization Tool.



Test Procedure

The emon categorization test consists of asking a group of users to provide us with representative data by filling a demographic questionnaire, and then asking them to classify emons into predefined emotional and social categories. They are also given the option of contributing their own emotional states. The subjects perform the test by sequentially listening to each of the candidate emons (presented to each subject in a different order to avoid bias) and relating them to one of the emotional categories, as well as rating the emon's environmental scales (as defined in software shown in fig. 5). After the experiment, the subjects are asked to provide their comments in free form.

Future Work remark

The test of the full GuideShoes system will be conducted with a different group of users – to avoid mistaking learned response to previously heard emons for a proper perceiving of emons. This group is asked to fill a demographic questionnaire similar to the one used by group I (they enter their age, gender, two favorite musical styles, and rate their current mood and energy level). Then they are asked to put on the GuideShoes pack and proceed wherever they feel the dynamically coming emons are guiding them to go. All the users' movements are logged using the GPS data coming from the wearable. The success/failure to effortlessly get to the marked destination point based on provided emons (and the degree of efficiency in doing so) will serve as an additional validity meter for the results derived from the first group of tests. This serves as an addition to the evaluation of similarities across the demographic data of the subjects, as described in the *Results* section below). The validity of emons→situations→users mappings is to be continuously refined during the tests of the real system / further categorization of the existing emons by people representing larger demographic diversity.

The long-term goal of this and future tests is to help in discovery of new ways in which the relation between specific music patterns and exact information can be defined – in other words, how the emotional palette of musical patterns can be classified into behavioral responses. These and following tests will help us to define the level of universality in musically delivered information and the complexity levels at which an overly large amount of emons used continuously causes a "human perception buffer overrun".

Technical Issues

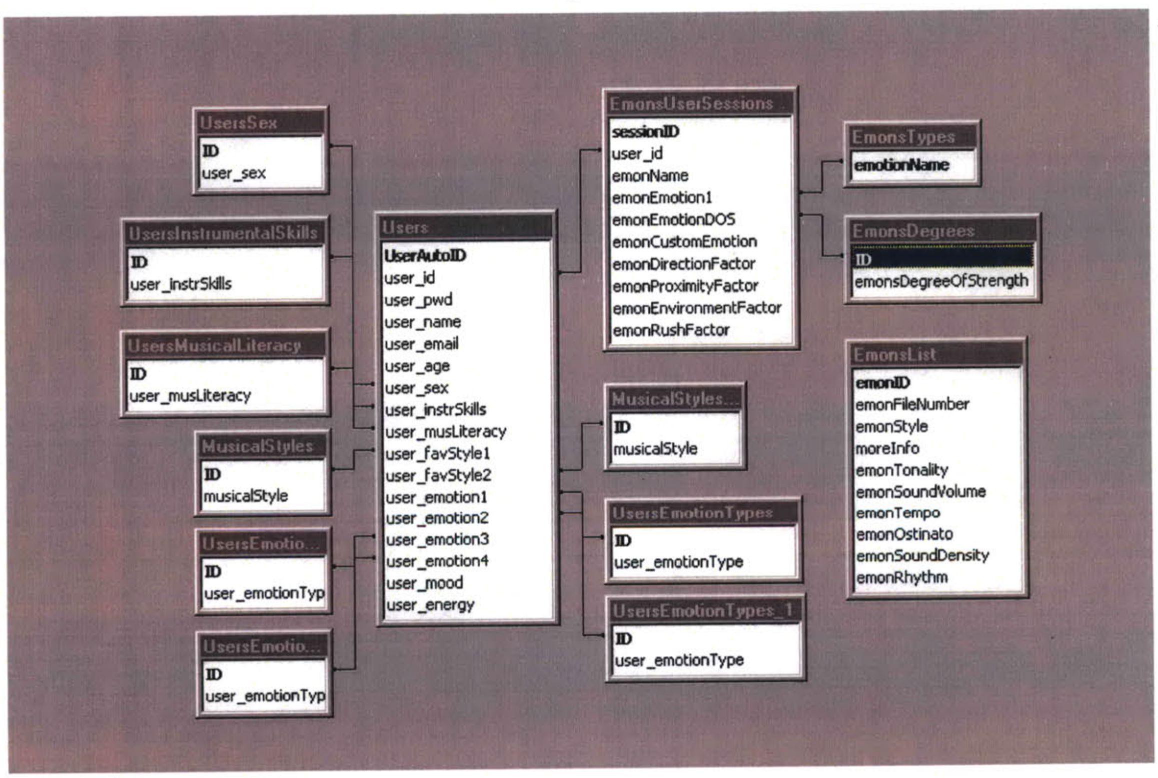
All of the emons were composed using Korg Trinity V3, Roland SoundCanvas SC-88, and NordLead synthesizers, edited in Steinberg Cubase VST/24, recorded as onto the hard disk using MOTU 2408 & DigitalAudio CardD+, and converted to WAV-formatted loops in Steinberg Wavelab. The categorization tool used by the first test group to classify the emons into various emotional/action categories, was written in Lingo, with additional Visual C++ modules for database access (with MS Access connectivity package), MIDI files playback, drawing capability, and visual effects. Multiple clients can run simultaneously via the network and the database is located on a server, hence making the testing faster and more efficient.

Database Structure

The database consists of seventeen tables, partly shown in fig. 6. The database's relationships have been defined to allow an easy search mechanism, fast retrieval queries, as well as human readability. The rules/restrictions on fields' entries have been thoroughly placed, and the database seems to be fairly bug-proof. The main tables are:

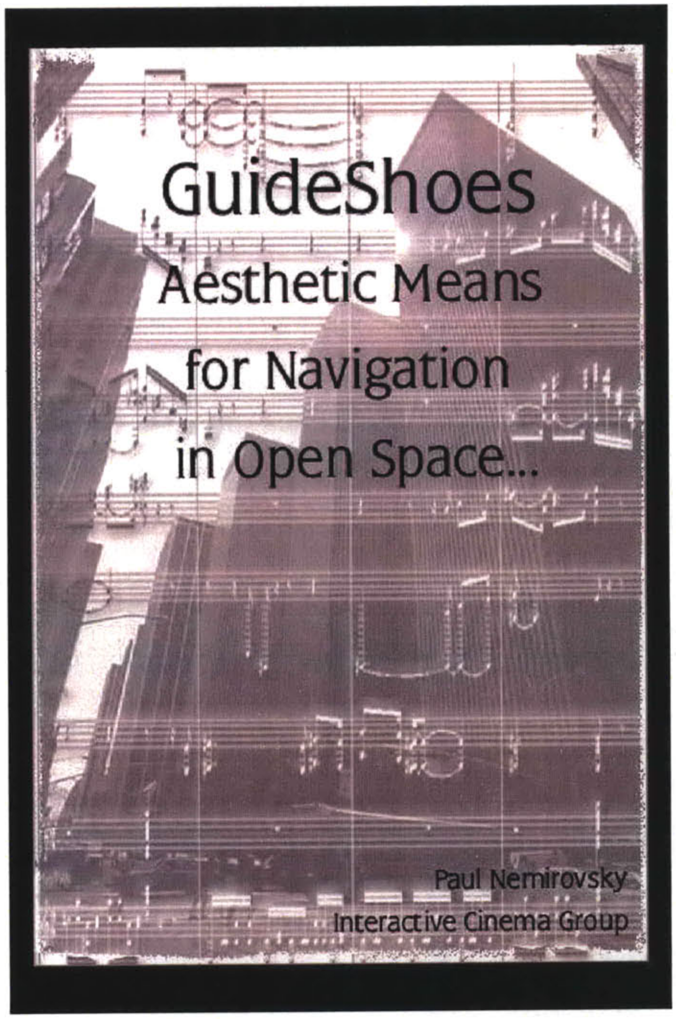
1. Users table, containing the demographic details about each user of the system.
2. Emons-related tables, containing information about emon internal categorization as well as qualifiers of its technical parameters.
3. EmotionCombies table, containing information regarding emotions' closeness (based on Plutchik's Wheel of Emotions).
4. UserSessions table, linking these and other tables' information together and providing the details of categorization sessions. This table has multiple indexes.

Figure 6: User-centered view of emons database (partial view).



GuideShoes Implementation

Figure 11: GuideShoes poster



Why GuideShoes?

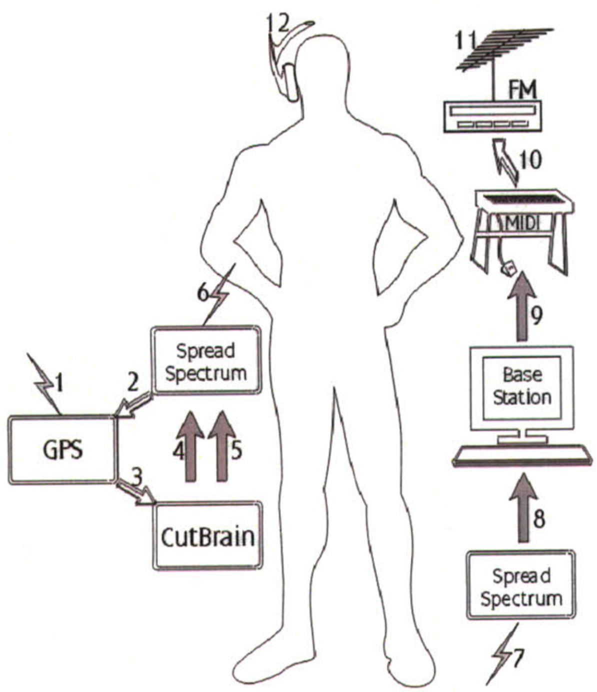
After creating a number of other systems exploring the use of emotion in news- and video- delivery, as well as a few tangible interfaces, I was looking to create a wearable device based on the emon approach, a system that would serve a real need of a specific category of people.

GuideShoes were selected to serve as the initial interface for the test of the emons' approach. Our primary goal with the GuideShoes system is to test the emon-related hypotheses by providing information using musical emons, while hoping to provide a new navigational tool. Navigational control was chosen as an example of a rather simple (and easy to enhance) task that has opportunities for exploring both binary (right/wrong) and fuzzy (better/worse) relationships. Using GuideShoes wearable interface is useful as it allows us to come up with multiple test scenarios to provide validity for the emon approach (as outlined in "Hypotheses" section).

Scenario of Interaction

A user comes to the base station, picks a destination point on the map, specifies a few profile details (such as age, gender, and favorite musical style), puts the GuideShoes on, and starts walking. Depending on the correctness of the direction, and compliance with the properties specified for the travel, the user hears different musical patterns that provide the necessary navigational cues to get to the destination, while leaving the cognitive foreground free for more creative tasks.

Figure 12: System architecture. Numbers show the flow of data.



System Overview

The GuideShoes system consists of a wearable part – a leg mounted pack equipped with a GPS, wireless spread spectrum radio, and a custom-built motherboard plus a pair of FM radio headphones – and a base station that acts as the central unit for path selection, data processing, and pattern retrieval/playback. The emons are produced by a MIDI synthesizer, and delivered to the user using an FM transmitter – at the place and time where you need them.

The placement of the wearable has been chosen based on a few factors: unobtrusive location, otherwise unused strong spot of the human body, and closeness to the body, thus allowing accurate readings for attached sensors.

System Operation

Every second, the base station sends differential corrections to the client's differential GPS, which sends the corrected user position back to the base station. These and other data exchanges are held by the spread spectrum modules on both ends. The base station processes the corrected DGPS data and, based on the correctness of the movement, retrieves and sends one of the emons from its library back to the GuideShoes, where it is played through a wireless headphone set.

Technical Development

The wearable-related part of the GuideShoes project has two main development directions:

1. Hardware & embedded software (to be installed on the GuideShoes).
2. System & high-level software for the base station.

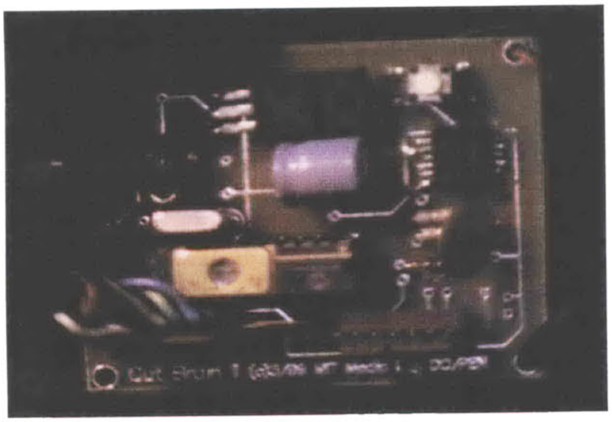
- I chose to design this prototype system as a distributed rather then fully self-contained environment, as that allows me to gather more instantaneous data (for analysis and possible playback) and also reduces the size of the wearable.

System Structure: Wearable (Hardware & Software)

The wearable client consists of:

1. A differential GPS unit – Ashtech SK-8. GPS stands for Global Positioning System, a satellite-based system used to deliver real-time position of GPS clients. The SK-8 consists of the main unit (1.57x2.44x0.47 inch, 0.7oz), and a 1" antenna. The unit picks up the satellite signal, deciphers it and passes it to the wearable's CPU (CutBrain). *The SK-8 GPS* is differential ready, a feature allowing it to provide much better precision in determining user's coordinates (precision = 2→5 meters).

2. A spread spectrum radio – FreeWave. For the needs of this prototype I'm using FreeWave RS-232 OEM Module Spread Spectrum Transceiver to handle all the communications between various components of the wearable and the base station. Spread Spectrum radio is a wireless digital modem that is capable of providing us with high speed (up to 115.2kbit/s) access on distances of up to 20 miles open space (tested up to 96 miles), with real city environment distance estimation of about 1½ miles (without additional retransmitters).



3. A custom-built CPU – CutBrain. The CutBrain board serves as the controller of interaction between the DGPS unit, the spread spectrum, and the accelerometer. It is based on the 17C43 PIC, capable of storing 4K of data, and has five general I/O pins to which various sensors can be attached. An ADXL150 accelerometer has been installed on the CutBrain to provide the data regarding the stability and strength of user's pace.

4. Pair of Sony radio headphones. Our initial design included *an on-board MIDI synthesizer* (the MiniMIDI synthesizer board that was developed a year ago at the MIT Media Lab). The board seemed attractive, as it is relatively small in size, has a wave-table synthesizer, on-board memory, and serial interface. The synth was to be connected to the wireless device (through the CutBrain), using which it (on that stage of development) would receive commands from the base station, and trigger one of the patterns stored on-board. However the quality of the audio produced by the board proved to be low enough to defy its use in the project. Taking into account the importance of high-quality audio for this project, we decided to use a radio broadcast on that stage. This solution provides us with a acceptable audio signal and complete freedom regarding the effects/patches used in the emons, but takes away the per-user easiness of customization of GuideShoes. The next version of the interface will possibly switch back to using an autonomous synthesizer module – granted the availability of a relatively cheap, small (PCMCIA or CF-size factor) module with high quality wave synthesis.

GPS and spread spectrum devices have antennas. The GPS and spread spectrum units showed interference when positioned next to each other. Therefore the GPS antenna has been positioned on the person's shoulder where it is supported by a tiny metal piece (the antenna has a built-in magnet).

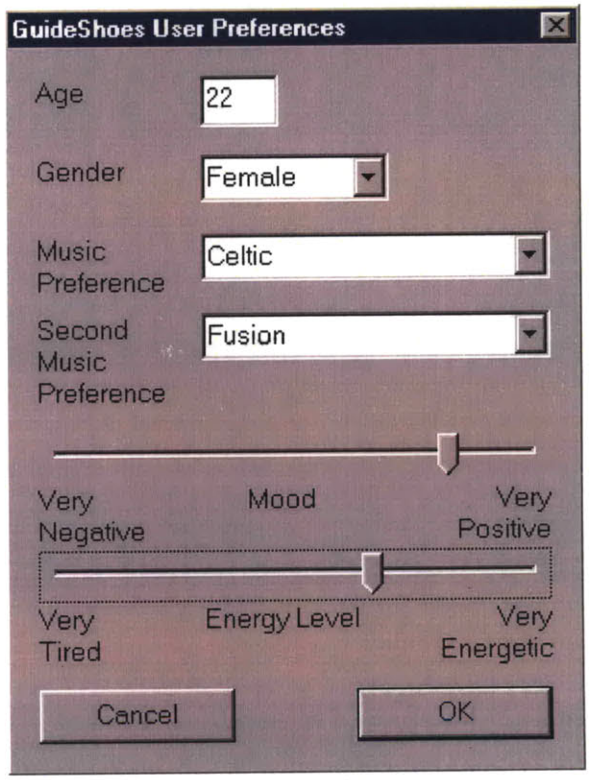
The size/weight of individual components of the wearable:

Model	Size (Inches)	Weight
CutBrain	2.5x1.75	~0.8oz
Ashtech SK-8	1.57x2.44x0.47	0.7oz
Freewave RS-232 OEM Module	2.44x5x0.66	2.29oz
Sony radio headphones		

System Structure: Base Station (Software)

The base station software consists of:

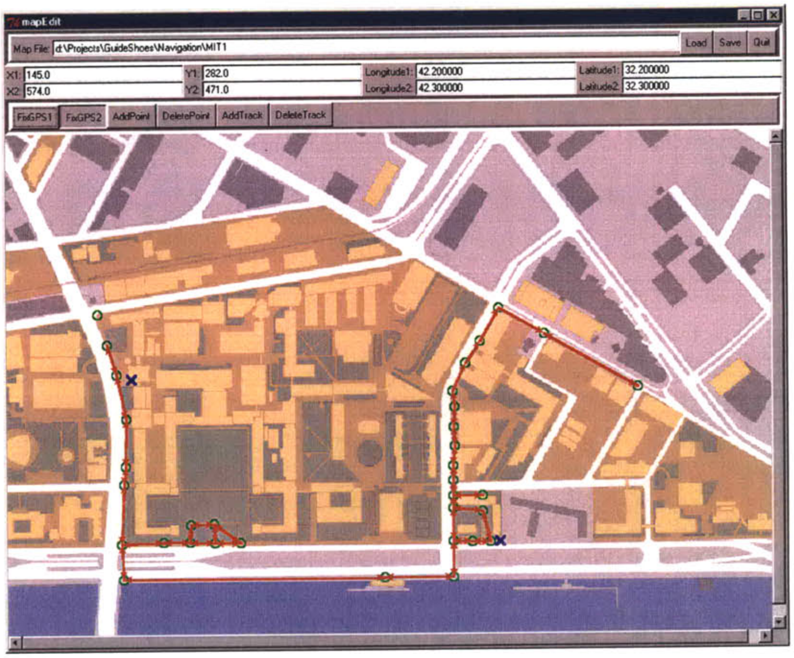
Figure 13: GuideShoes Commander Intro Screen



1. GuideShoes Commander: This program, implemented in Visual C++, presents a first time user with a short demographic questionnaire. After the questionnaire has been filled, GSCommander connects to an MSAccess database that contains the data from user tests as well as information about individual emons. It runs a search, trying to match the user to one or more users stored in the database. After it has found one, it allows the user to select the destination point of the travel. It then starts the communication exchange with the optimal path selection program.

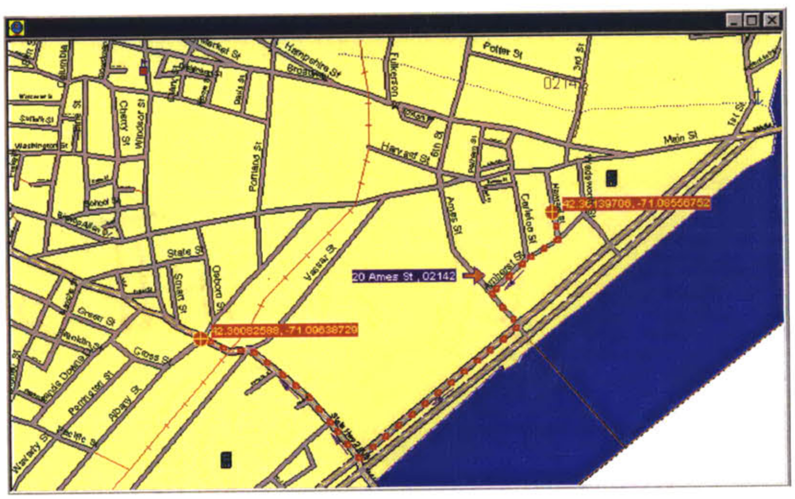
- In the next version of the software, a similarity coefficient will be defined between every new user and the users from the emon-rating group. Each emon will then be assigned a weight average by adding the similarity coefficient for the users that use the emon in certain situations (coefficient in 0→1 range). As the result, the emons that rate above the system-defined threshold will become emons of the new user.

Figure 14: MapTool



2. The path selection programs (both Klynas Engineering's Streets On Disk and a custom built MapTool implemented in Tcl/Tk were used) give us the ability to select a destination point and calculate the optimal path. Currently the path optimization algorithm is running on maps intended for automobile use, with some degree of customization. The programs also have additional features, such as displaying the real-time position of GuideShoes' user as he makes progress in his movement.

Figure 15: Klynas StreetsOnDisk

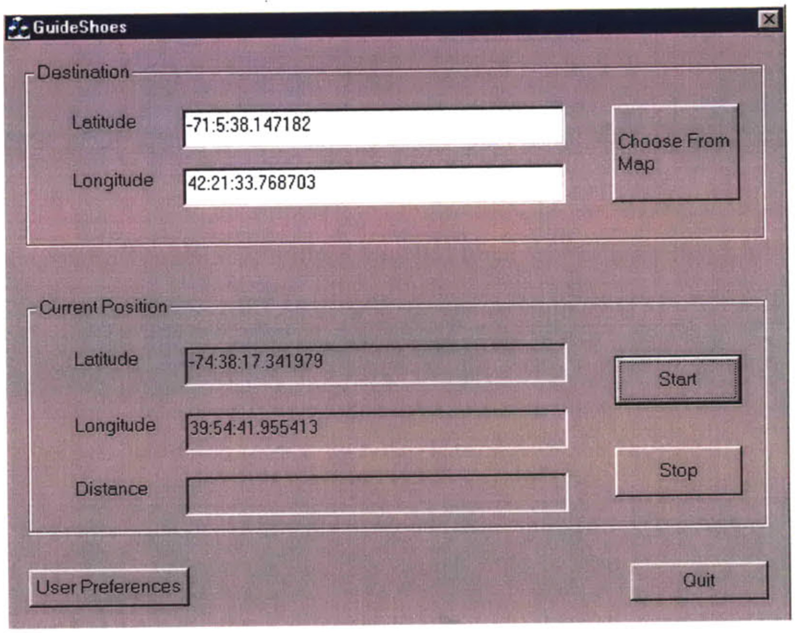


3. After the initial optimal path has been selected, GuideShoes Commander starts continuously monitoring the serial port and parses the incoming data (that consists of GPS values interspersed with accelerometer readings) to infer the location/action of the GuideShoes wearer. The GPS data is then interpreted using the GPS Toolkit (Stellar Navigation) and routed for analysis into GSCommander. If user wanders off the right path, and a correction is needed, a request is sent to the path optimization program, to provide us with a new optimal path. It then passes the data to the emon retrieval engine (written also in VC++), which, based on the correctness of the movement and other criteria (outlined in the *Design & Evaluation* section), retrieves specific emon (or set of) from the

emons' database and broadcasts it to the user. The GSCommander is able of handling multiple clients simultaneously.

4. It also controls the FreeWave base station, SBX-2 differential beacon receiver, an additional SK-8 DGPS for detection of base station location, and Veronica Kits FM transmitter to deliver the audio to the GuideShoes user.
5. The data received from the user is stored locally for future analysis. On a later stage a tool will be written to allow GuideShoes' users to retrieve temporal, spatial, and other data about their past travels.

Figure 16: GuideShoes Commander Direction Monitoring



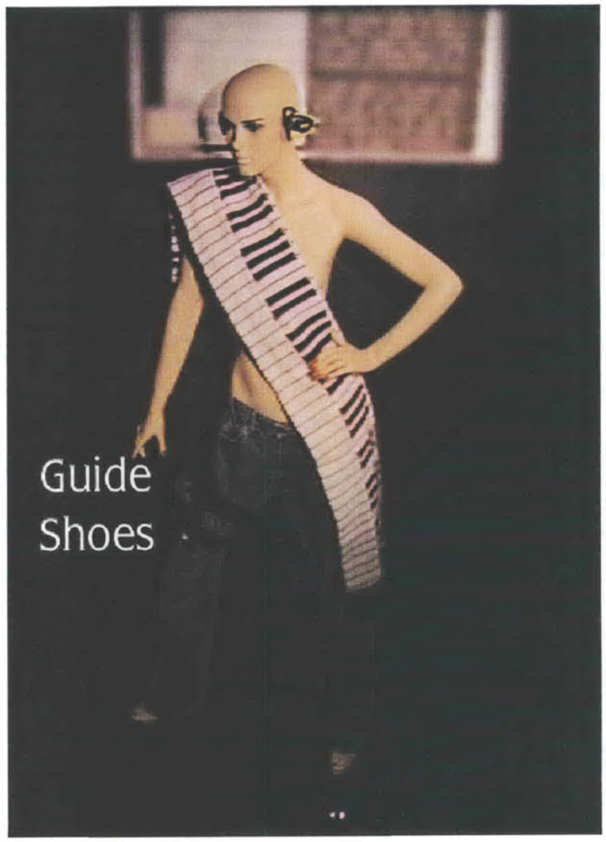
System Structure: Base Station (Hardware)

1. DGPS BR (Differential GPS Beacon Receiver) – this device provides the client GPS with the differential corrections, thus increasing GPS precision by an order of magnitude. The CSI's SBX-2 is used because of its small size and easy setup procedure. It is also cheap as it uses the corrections provided for free by the Coastal Guard.
2. FreeWave Spread Spectrum Base Station Module – this is the base station component of the FreeWave system, capable of supporting multiple clients. It is connected to the computer running GuideShoes Commander and its goal is to provide the wireless communication link to the GuideShoes client.
3. Veronica FM Transmitter – this radio unit is connected to the GuideShoes host computer. It broadcasts the emons according to the commands given by the database engine (part of the GuideShoes Commander).

- All three units have antennas installed on the top of the Media Lab.

Navigational Applications

Figure 17: GuideShoes System as a leg-mounted pack



GuideShoes is a navigational tool designed for a wide range of people that can be roughly divided into two categories: users with navigational difficulties and users for whom the emons' approach presents a plausible alternative for the otherwise cumbersome task of classical navigation.

Navigational Difficulties group

1. Kids: The problem of kids' safety (such as not getting lost while walking through a city) can not be fully solved by GuideShoes; however GuideShoes can make this problem more manageable. If a kid was exposed to the proper use of emons, GuideShoes could provide him with a fun and helpful aid for getting to the place he needs to go and can give the parents knowledge of his current location / alert them to potential direction problems.*

2. Orientation for disabled (blind & psychological orientation impairment): GuideShoes, if wisely implemented, can become an important tool for navigation for people with severe vision problems. As the work of Peter Meijer [7] aims to show, people can be conditioned to fairly complex patterns of movement expression using audio information, and the melodic structure of the emons should make them easier to relate to than to a purely algorithmically produced audio. Mapping emons to the validity of walking direction (as well as potentially to the locations of objects) can enhance their navigational abilities.

3. People with brain damage: According to the experiments conducted by Martha Farah (1989), people with certain brain damage in the area of visual perception also had visual memory deficits "directly comparable to their perceptual deficits". Therefore, it will be interesting to test whether people with spatial disabilities (such as being unable to see relative locations of

objects in a scene) can rely on GuideShoes as a complementary device to receive the same information through the alternative channel of music. **

4. Tourists: While not having the navigational difficulties similar to the three groups before, tourists have to find their way around in cities without signs in their native languages, while concentrating on the experience and not on the navigational task.

- ** As of today, DGPS precision is limited to 2 to 5 meters.*
- *** Testing with narrowly defined groups of population is beyond the scope of that thesis.*

People looking for Alternatives

There is a substantial group of people who, while not having the difficulties of the latter group, prefer not to be overwhelmed with unnecessary information. Among these are young people for whom GuideShoes represent an easy to learn alternative, and people with well-developed auditory perception, which currently goes unused in their daily navigation process.

Conclusions

The first round of tests of the emons library has been conducted in order to define the characteristics / limitations of the emons use for navigation purpose. A group of 14 users has classified the candidate musical emons using the categorization tool. The average age of the subjects was 30 and the male/female ratio was 4/3. The findings of the tests are described below. The initial prototype of the GuideShoes system has also been built. While a malfunction of a commercial hardware prevents us from running the full-scale tests of the GuideShoes, we have conducted preliminary tests (running the navigation system in non real time) that are also described below.

Current Results

Testing Process

A test evaluation tool (fig. 18.1 & 18.2) has been developed to allow easy comparison between the results received from various demographic groups of subjects and visualizing the correspondence between their emotion- and socio- related ratings. The colors and position on vertical axis show the average rating for the current candidate emon, and the number below shows that emon's standard deviation.

Figure 18.1: Aggregation of users' responses acc. to directionality factor (bars show +/– standard deviation)

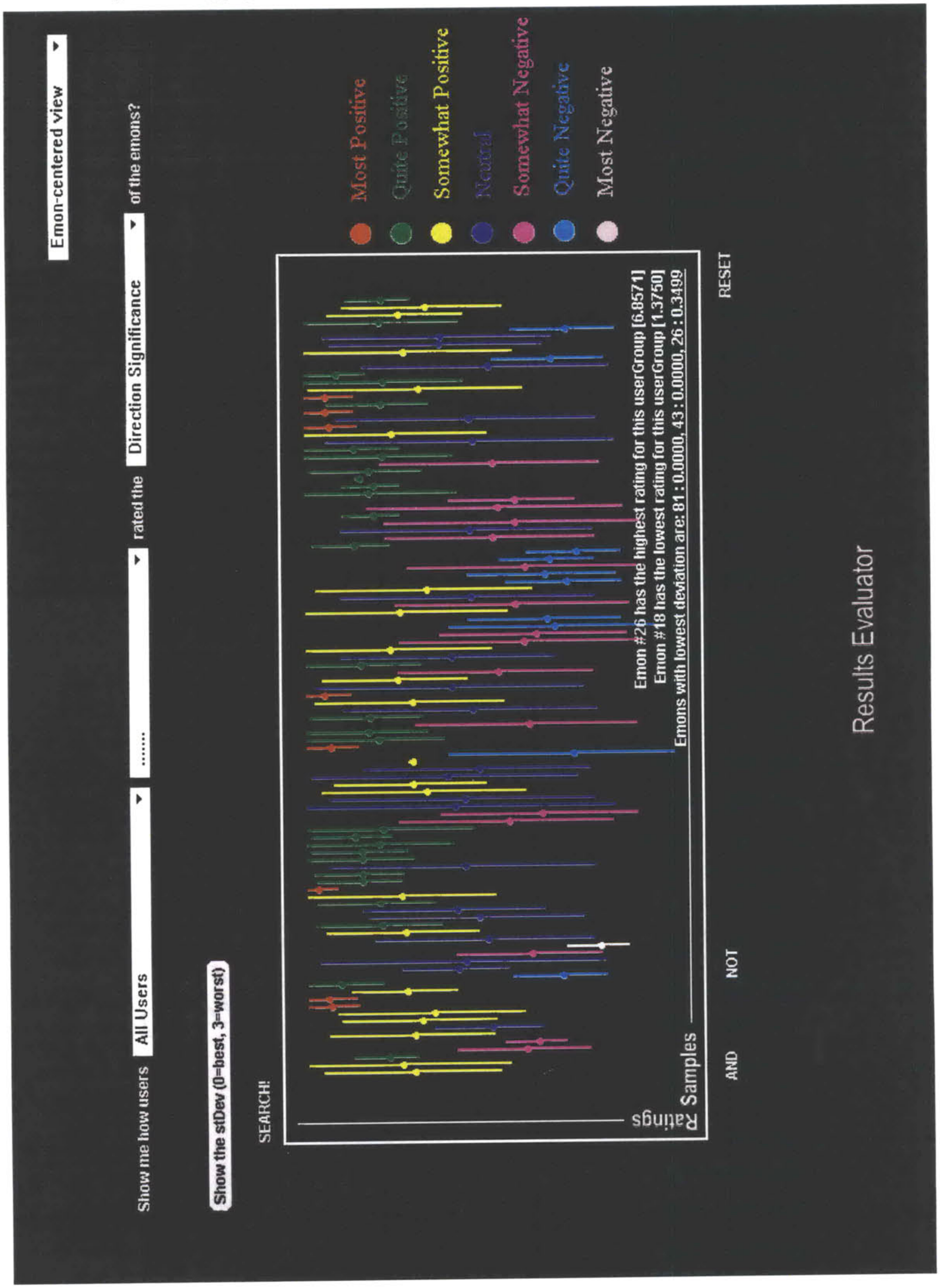
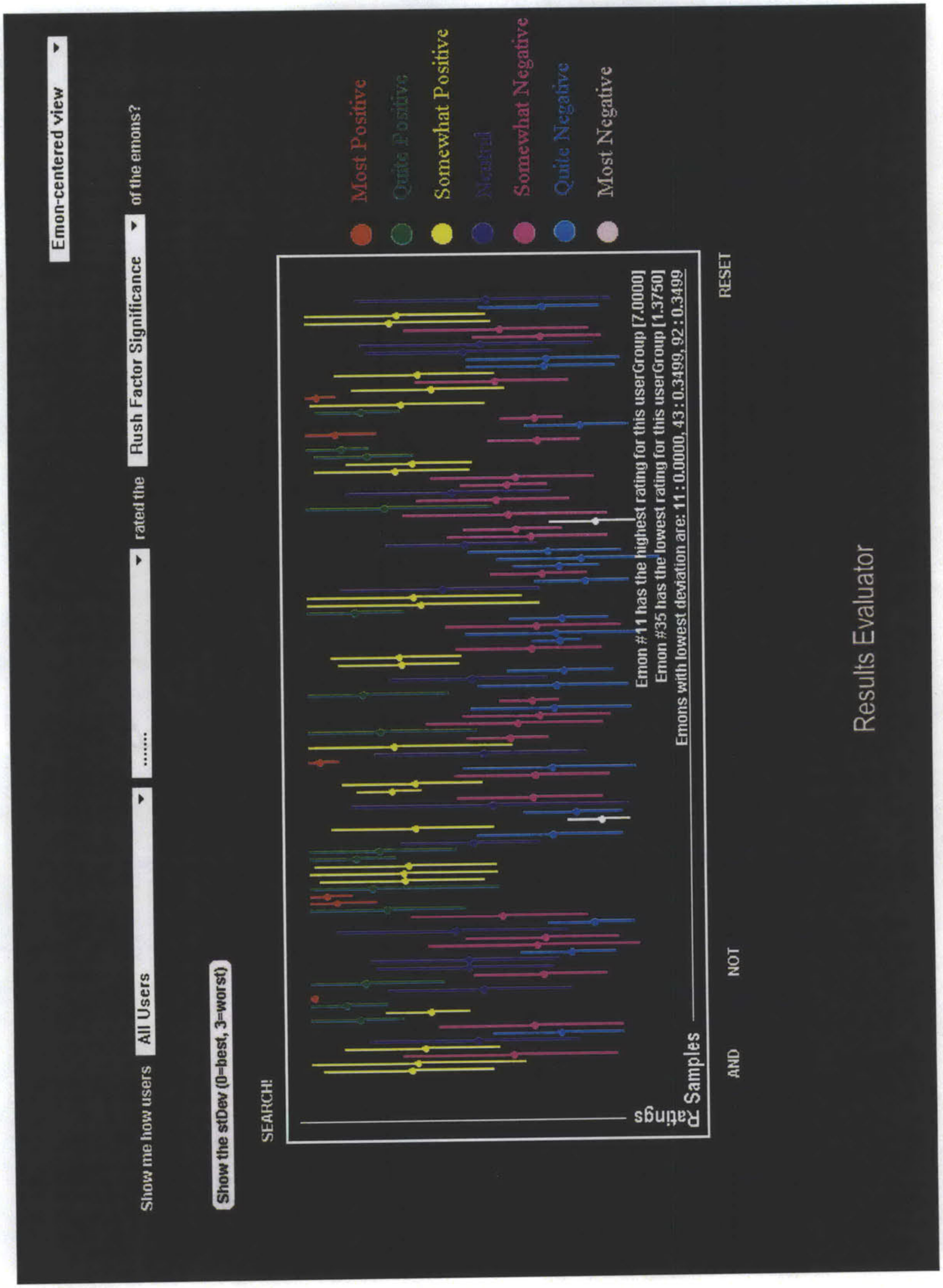


Figure 18.2: Aggregation of users' responses acc. to time-rush factor



The test results were evaluated by studying the mappings between the demographic details of the user profiles (provided using the Questionnaire tool, fig. 4) and the ratings they provided for various candidate emons using the Categorization tool (fig. 5). The similarities/patterns found in selections made by users (when grouped by their questionnaire responses) are described here, and are also to be used as the basis for future work. There are good and bad things to say about the testing process, and the reality vs. expectations check:

Testing Process / What didn't work

It proved to be hard to design a solid evaluation for the results of the users' testing and produce a meaningful analysis of these results given a small group of samples/subjects. Writing the analysis tool (defining the search parameters & making it work) required more time than planned. The categorization tool still seems to have some issues with running over the network (it runs for some users, but not for others).

It is hard to evaluate qualitative mediums in an exact way, because of the ambiguity of such, especially with an abstract medium like music. Finding the balance between understatement and over-claiming is indeed a tricky one.

The system would truly benefit from a significantly higher number of subjects. It was hard to find enough people even for the experiment with a limited number (120) of candidate emons. The session was expected to take around one hour but in reality took from 40 to 110 minutes (with the average being around 80). Some participants reported being tired after going through ¾ of the session. This represents a problem as planning of testing a larger library for subsequent research in the future is in works.

Testing Process / What worked

People didn't report any problem interacting with the software. An option to intercept the testing session and resume from that point on later has been added and it successfully addressed the needs of the users who weren't able to complete the entire testing in one hour. The programs have not crashed, and the testers observed only two minor bugs while using them, which were fixed. The programs are designed in an easily expandable way, so that the following results can be easily incorporated into the subsequent studies of emons.

Results of the testing

It is too early to state the results in definite terms, but taking the limitations of testing with a small group, overall, the results are surprisingly promising;

Despite the fact that the emons were composed with *no* intent of addressing particular navigation-related qualities of the emons (their directional, proximity and other ratings), a surprisingly high number of candidate emons were rated as either "completely right" or "completely wrong" (values in [6.5000-7.0000] & [1.0000-1.5000] ranges respectively) on all the scales (direction, proximity, etc.)

The characteristics most accurately conveyed by the emons were directionality and time-rush. The accuracy can be seen across the subject groups, with 8% of the emons rated in the highest ("most positive") range (top 15%) by the directionality factor (fig. 18.1) and 6% by the time-rush factor (fig. 18.2) (2% for proximity & 1% for environment factors). The highest value for the navigation factor (as rated by *all* subjects) was [7.00], and the lowest was [1.33]. While presenting a basis for an interesting hypothesis, these results should be tested with a far larger group of users. It does seem possible however to state that users seem to agree on certain musical fragments in relation to their direction- and time- related characteristics. As soon as a group is defined as anything demographically narrower than "all", even more extreme values show up.

Here's the full output of the testing procedure for *all* users selection:

	%by Direction	**by Time Rush**	**by Proximity**	**by Environment**
Top/Bottom 15%	*8/1*	*6/2*	*1/0*	*2/0*
Top/Bottom 30%	*36/11*	*20/22*	*20/4*	*26/9*
Top/Bottom 45%	*57/27*	*42/48*	*50/27*	*61/19*
Neutral	*21*	*15*	*27*	*25*

The emons that scored a high correlation on the extremes among all users' groups had their emotion mostly rated as "annoyed" (negative), or "relaxed"/"happy" (positive). The table on the right shows the percentage of each of the emotions happening in the total amount of responses. As seen from that table, the kinds of emotions most frequently conveyed were "annoyed", "relaxed", "happy" & "anticipatory". The negative emotions showed as much more consistent among various groups of population; The level of similarity at emotions such as "annoyed", "bored", "sorrowful" were significantly higher than for "happy". The only positive emotion with high correlation of user responses was "relaxed". The emotions of "annoyed", "disgusted", and "fearful" were steadily associated with the wrong direction. "Excited" was steadily associated with the right direction.

Emotion	**%**
Annoyed	15
Relaxed	10
Happy	8
Anticipatory	7
Bored	7
Indifferent	7
Excited	6
Eager	5
Fearful	5
Disgusted	3
Sorrowful	3
Angry	2
Other	15

All the subjects mentioned that the choice of emotions wasn't large enough to properly reflect their feelings. With this study aimed primarily at gathering data for the subsequent projects, users were given an option to specify their own emotions instead of being limited to the predefined ones. Some of the most popular "other" emotions included "eager", "energized", "anticipatory", "engaged", "indifferent", "intrigued". Users also reported a wide variety of less frequent emotions such as "reluctant", "romantic", "self-satisfied" and others. There were no users who went through the entire test without specifying at least some custom-defined emotions. The average amount of custom emotions per user was 15% (with some of the users specifying up to 70% of their emotions as "custom".

Gender seems to play a bigger role than age in categorization differences, particularly in the ratings provided for direction and time-rush factors. Male subjects reported 9% of the candidate emons to be absolutely positive direction, compared to only 1% of the female subjects. Time-rush factor also seemed to be affected by this, with male 14% vs. female 5% categorized as related to the feeling of "I'm in a total rush". Female subjects showed less fearful view in the ratings of the Environment factor (friendly/unfriendly) with 3% female vs. 5% male in the top 15% ("most friendly") and female 1% vs. male 10% in the low 15% ("most unfriendly"). No substantial differences can be seen in responses to the proximity (close/far from destination) factors.

The deviation among the patterns has also been computed (standard deviation of the characteristic being rated for each emon as rated by all the categories of users). During the testing users were given 7-degrees scales (6 interval units) to operate (from "Very Negative" to "Very Positive") (fig. 5). Musical qualities are virtually impossible to quantify precisely, and therefore we considered a deviation of less than ½ a unit (in the range of [0.0000-->0.4999]) as significant. I looked at the deviation for each of the characteristics. Most of the emons that were given a "very positive" directional characteristic also had a low deviation: 81 - [0.00], 43 - [0.00], 26 - [0.35], 76 - [0.43], 80 - [0.43], 52 - [0.45], 92 - [0.47], and 90 - [0.47]. It is also true for the emons rated as "very positive" for the time-rush factor: 11 - [0.00], 43 - [0.35], 92 - [0.35], 59 - [0.37], 25 - [0.43], and 51 - [0.45]. As of now, the only compositional parameter that has shown a direct effect on one of the factors, was a tempo of steadily fast or accelerating nature – it is present for 70% of the patterns rated in the top 15% of the time-rush factor. The other factors of possible affect (when tested by a larger group of subjects) would possibly be abrupt changes to the rhythmical structure, use of distortion, and also such parameters as dynamic pan setting and progressively rising or falling tonal sequences.

While the current limited user base doesn't allow us to state the received results as stable enough to generalize beyond more than a limited group of users, a good basis can be seen from the initial tests for future research regarding the use of emons as information cues affecting users' behavior. The initial tests show that the emons have the potential of becoming useful for information delivery. As of now, ~10% of the emons were defined by the subjects consistently as either "very positive" or "very negative", which holds the premise of filling the first part of an emon grammar. Several candidate emons were consistently rated as neutral or assigned other values, thus satisfying the definition of emons as well. More work is required to design additional libraries of emons and to understand the correspondence between the compositional factors and users' ratings.

GuideShoes System Run

An initial version of the GuideShoes system has been created. Its components and operation are described in the *Implementation* chapter:

Wearable system / What didn't work

The malfunction of a commercial beacon receiver still prevents us from running the proper location test, and we are limited to a precision of 100 meters (non-differential GPS). We also have had trouble making the commercial serial library that we are using report complete data in all the situations. These problems will be resolved in the near future. As with emons' testing, to get solid results with ratings of navigation-related actions performed based on listening to emons, we expect to need about fifty subjects to run the tests.

Wearable system / What worked

In the scope of this thesis, the GuideShoes system is capable of operating in a 1½-mile radius from the base station. The base station had no problem establishing contact with the wearable. The GPS initialization sometimes took longer than expected, and the spread spectrum radio had to be switched off during the initialization process. The software running on the base station accounted for this interrupt in communication and didn't crash. Providing the emons in a timely manner based on the user's actions has been performed with a certain degree of success – the failures in navigation were mostly related to the slow performance of the Klynas's Streets On Disk (about 2 sec. to calculate the optimal path). The only available way to interface with the program is through the file I/O synchronization (which is slow); the entire path has to be recalculated upon each path optimization request (no interface for partial recalculation is provided).

The base station performance has been fairly stable during the initial test runs. Unless the data coming from the wearable was completely corrupt, the base station would ignore the bad parts of the serial input (that make the base station to appear stuck) and would continue after a while. The musical emons' database was interacting with the GSCommander through SQL queries, but the actual degree of match between users and the patterns received remains to be improved (with the main problems being insufficient number of subject runs, and limited number of emons available for precise matching). A few miscellaneous agents to retrieve/display information regarding user's actions were written but some of them (such as the GPS visual update tool) were not included in the compiled version of the GSCommander as it showed to slow the StreetsOnDisk down even further. We hope to improve the overall performance over the next few months.

Future Research

Continued development of the GuideShoes system

There is more to be explored using the GuideShoes system. To further demonstrate & develop the foundational principles of emons I plan to develop a larger library of emons for navigation-related purposes. This library combined with a larger amount of test subjects will allow us to further study the relationship between the emons' compositional parameters, their navigational ratings by the test subjects and the effect of such on GuideShoes' users.

The GuideShoes system itself is also going to become more robust in its operation. This will be achieved by putting the hardware in a pack with individual hardware elements secured in their position. Charging the batteries is also to be made easier.

This thesis describes the process of selecting musical emons to deliver navigational cues and describes the ongoing development of the GuideShoes system as the first artifact that utilizes the idea of emons. What other kinds of information can be delivered by emons and what kind of emons that would be? To answer this question, I'm going to use the results of the current testing in application to creating emon-based objects and interactions. The directions of this research are:

1. Merging between the emon approach and the recent psycho-physiological research.
2. Enhancing the emons approach to create complete aesthetic musical-informational spaces by assigning emons to physical objects.
3. Developing additional applications based on the approach.
4. Expanding the emon approach to other olfactory domains.

These research directions will hopefully lead us to the creation of emon-enriched space that will be capable of monitoring and affecting the emotional state of its inhabitants and will be used as a support system for educational and stress-relief purposes.

Merging between emon approach and psycho-physiological research

It is common to smile involuntarily at the telephone receiver only to immediately realize that this will convey nothing to the hearer at the other end of the line. If we would talk using music that wouldn't be the case. What are the questions where the aesthetics and physiology research can be brought together?

The next stage of the emon development could involve tracking of physiological response to the emon stimuli of diverse olfactory sources. I hope to establish a close working relationship with MIT and other schools' researchers from the fields of affective computing and psychophysiology. It is my hope to bring new insights on the role of aesthetic forms for information delivery in the framework of inclusive systems merging between the aesthetic and psycho-physiological views of emotion synthesis.

Historical and sociological functions of emons

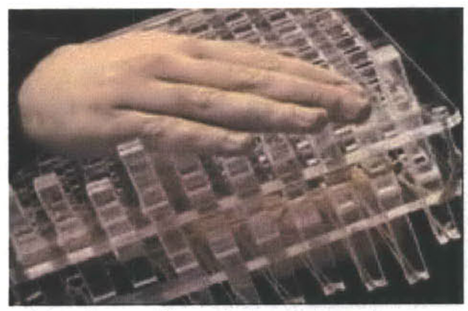
This research direction is going to address the notion of object-embedded emons both by the history of use and by the state of other emon-enhanced objects around (active/inactive), time of the day, and other factors related to user's profile.

Merging emons into a location-aware wearable can potentially allow us to use emons to learn about a place, and to remember it. We can possibly develop patterns for a specific destination, based on additional qualities such as the number of visits to a place, the time of day visited there, the priority the user had to get there (mapping the priority to the speed he traveled), and other items of historical significance. These can then be used to suggest alternate paths, to advise the user on speed of travel, and so forth. If GuideShoes is enhanced with more personalizable capabilities, it can possibly acquire extra-navigational functions, such as social and historical ones. When you meet someone unknown, GuideShoes could potentially act to initiate an acquaintance; when you come home, you would be able to retrieve the history of your daily travels by listening to the emons that were delivered to you over the day. Upon your request GuideShoes would share information with people that have something in common with you – family, or members of your interest / background groups. Populating tangible illustrations of emon approach with sociological/historical functions can allow us to tell stories of our actions (e.g. travel), thus producing emons' sets unique for a specific community.

Emon-based interfaces in works

During the testing process, it took the subjects a few minutes to get comfortable with the idea of using music as an information source. After that initial stage, they didn't have problem relating to emons in the context of direction correctness, environment friendliness, and other scales. Most of the users (12 out of 14) described their feelings toward a future emon-based interface as "fun". Most of them also mentioned that the sound has to be used in a cue format, rather than continuos play, which would be "annoying". Based on that notion and the consistent results of the initial emons' testing (with some emons consistently described as "very positive" or "very negative" on various scales), it is really interesting to see how emons can be used for many tasks where the need exists for multi-channel information delivery.

Figure 19: Emonator prototype system.



To further define the mappings, I'm currently working on the Emonator Interface, another artifact for emotionally enriched human-computer interaction. One of the main aspects of emotion is touch, but today's computers' ability to interact in the tangible domain is quite limited. In this system, built together with Dan Overholt, I'm looking at ways to use the expertise developed in the auditory/visual domains and apply those principles to the development of a new generation touching device – the Emonator. We also work on a number of other systems exploring the connection between emotion, music (and other aesthetic mediums), and information delivery.

The artistic value of sport games can be explored by assigning every player with an ID, and every team with a specific group of emons. As the game progresses, the leading team will be assigned more "active" emons, and the sound characteristics of the winning team will be an emon-based reflection of the game. This provides us with opportunity to redefine the fluidity of an entertainment form. Sport becomes an artistic tool, and music becomes a tool for the visually impaired to "feel" the game…

Demonstrating the emon approach to the Media Lab sponsor companies as well as to a line of educational institutions over the world produced a lot of interest in emons & availability of applications based on them. People who saw my demos suggested many useful applications. A few worth mentioning include monitoring stock exchange's executive cockpits (a Wall Street company), ease of navigation & training of personnel in highly dynamic supply areas (Sansbury chain), and more.

Concluding thoughts

This thesis represents a work in progress. While the current user base is small and the received results cannot be generalized beyond more than a limited group of users, a good basis can be seen from the initial tests for future research regarding the use of emons as information cues affecting users' behavior. According to the initial tests the emons have the potential of becoming useful as information delivery units. As of now, ~10% of the candidate emons were defined by the subjects consistently as either "very positive" or "very negative", and this holds the premise of filling the first part of an emon grammar. More work is required to design additional libraries of emons and to understand the correspondence between the compositional factors and users' ratings.

In the last year the work on emon approach and GuideShoes system has produced two publications – one for the conference on Human Computer Interfaces (CHI'99), another for The Eighth International Workshop on the Cognitive Science of Natural Language Processing (CSNLP-8). I have also given a number of talks on the subject – some of them in the Media Lab, others at ATR in Kyoto, Digital Hollywood in Tokyo, Hebrew University in Jerusalem, and more.

The emon approach is still in its early development stage, and GuideShoes is the first tangible illustration of this approach, with other projects utilizing emons being in development. These include using emons for feedback in sport games, emons for emotional clothes, creation of emon-enriched spaces and more. It is my hope that by careful study it will be possible to explore the various uses of emons as affective elements in human activity. It holds the premise of providing us with an additional information channel and users' feedback data, potentially facilitating the community of affective computing with tangible ideas. It is my hope that continuing research in this field will change our relationship with computational objects and give us more insight into the field of merging between aesthetic mediums and computation.

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