Innovative Information Visualization Techniques for Representing Pairs of People in a Face-to-Face Dating Relationship, Generated from Speculated Data Sets

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Declaration

I, Fei ZHANG hereby certify that except where due acknowledgement has been made, this work is mine alone.

The work has not been submitted previously, in whole or in part, to qualify for any other academic award.

The content of this project is the result of work that has been carried out since the official commencement date of the approved research program.

Signed: Zhang Fei

Date: 02/07/2008
Abstract

As we move further into the information age, increasing amounts of data are being collected by computers to help people deal with various tasks in their daily lives. Over the years in order to better cope with this growing load of information, information visualization techniques have been developed as a bridge between abstract complex data and human cognition. With the increase in affective wearable computers we are becoming more capable of recording continuous streams of human physiological data. Coupled with the developing science of mapping human emotion to physiological information, it is possible to see we are not far from being able to continuously record human emotions across long periods of time. This master project seeks to speculate on the convergence of these new developments and through visualization techniques explore how the resultant information might be effectively represented. Specifically, this project will focus on possible data from couples in a face-to-face dating relationship, and the various ways their dating experience can be visualized. It also looks at how the process of romance might be represented, and whether this visualization can be used to provide answers to various concerns on relationship development and management and highlight growing needs.
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Introduction

Chapters 1 Introduction

1.1 Background

As we move further into the information age, increasing amounts of data are being collected by computers to help people deal with various tasks in daily life. Information visualization techniques are being used to help create rich visual interfaces which connect human cognition with modern computers - two very powerful information processing systems. Large, complex sets of data are compiled and reduced to graphical elements that enable viewers to observe, browse and understand broad ranges of information quickly and intuitively.

The usage of information visualization techniques is broad and has resulted in research literature across a large number of subject domains from computer graphics, statistical graphics, graphic design, databases, computational geometry, cartography, psychology, semiotics and art. Most notable of these are the areas of Information Retrieval, Hypertext and the World Wide Web, Digital Libraries and Human-Computer Interaction (Chen, 2006), all of which deal with the creation of effective visual interfaces. They help people interact with a large amount of data rapidly and effectively, and to discover additional information through its patterns and trends.

With the growing use of desktop computers, mobile phones and other computerized devices either carried or worn, increasing amounts of information are being recorded about different aspects of our daily lives. Our interactions with other people are being logged and often entirely recorded through text messages, emails and telephones. Digital cameras are readily available to capture everyday images. Positional data, where we are currently standing and where we have been, can be stored for later retrieval. Even our body temperature, heart rate and blood pressure can be constantly measured. It is this last area - the recording of human physiological data through wearable computerized devices - that suggests even more ways our daily lives can be recorded and analyzed.

People have long sought ways to measure the intangible aspect of human nature through measurement of physical aspects. An old and debunked example of this is the Victorian art of phrenology where the shape of the human skull was measured to determine someone’s personality. A more modern representation of this pursuit is the “lie detector”, which seeks to determine a person’s honesty by measuring their physical condition. Today, more ways exist to measure people’s physiological state. Also emerging are new theoretical models for decoding emotional data from physiological signals.

The convergence of these new theories and developing technologies suggests the ability to record the human emotional state. There are already early art works and studies that explore the measuring and representation of emotions. However these examples deal with rather crude decoding of emotions and rarely deal with a continuous record of emotional data in people’s day to day life. This gap inspired us to think about people’s various needs in real life, and to consider how to make use of this potential new data stream to meet these needs.
An example of where the understanding of emotional data becomes very important is in a basic dating scenario. Generally people may have little difficulty in reporting a very recent dating situation, however when examining their dating experience over a long time span, the problems of memory load and cognition of events become apparent. Their description of emotional states is generally inclined to be indistinct and subjective. Added to that is ever-important question of accurately determining the other partner’s emotional state.

Hence we seek to explore in this project a possible scenario, where the physiological data of two persons involved in a face-to-face dating relationship is recorded using wearable computing devices. This data is then mapped into emotional information, using current emotion decoding theoretical models. Then, using information visualization techniques, this data is presented back to the involved parties in order to help them remember and better understand their past and current experiences, hopefully leading to improved management of their relationship.

1.2 Purpose and Hypothesis

The purpose of this project is to develop various visualizations of speculated emotional data generated by the couple in a face-to-face dating experience. This visualization is meant for use by the people in the relationship to assist recollection and understanding. The two primary objectives are:

- To establish what emotional data is significant in reflecting people’s dating experience
- To explore the optimal techniques for visualizing this data to aid analysis and recollection.

Our hypothesis was that this visualization of the emotional data could be valuable as a mirror of their and their partners’ inner and elusive emotional situation and also help increase their awareness of emotional experience.

1.3 Approach

In our research approach, we combined technological advances, theoretical guidelines and user needs to establish our project and to develop visualization design. The basic steps are listed below.

We looked at what existing affective computing techniques could be used to measure human emotion and the ways they measure, by combining people’s lack of cognition to set up a speculated scenario to work out a couple face to face dating relationship. We studied related relationship theories and made a script of what relationship happened and speculated this amount of data for data representation. This data set included the critical points and the most common stages of overall dating relationship from the start, development, to the break up. Finally we use this speculated data as a base to develop data mapping and visualization exploration to best interpret data.
After the data was modeled, we investigated the end results of current theoretical mapping to see what emotional data could be modeled for emotional relationship visualization. As real experimental data sets were unable to be accessed, we mocked up a speculated data set.

To continuously facilitate data transition, we explored various visualization techniques and viewing structures to facilitate data representation. A series of graphics and interactive structures were created and developed.

After each phase of design, we evaluated our project outcomes to identify problems and to establish a direction for redesign. In early stage of design, we mainly used self-reflection and analysis to evaluate our graphics. In later evaluations, we recruited participants to execute usability test to objectively examine our outcomes.

It is worth mentioning that in this project, the information visualization is the main focus. And even due to some technical restriction, we cannot practically collect some actual data in this user case, the speculated data will not an obvious impact on visualization technique exploration. Especially for an early visualization development, the speculated data set help provides an ideal base to develop and explore the core visual languages. On the contrary, the visualization will centrally reflect the key data which covers critical points and the most common stages in two-person face-to-face dating relationship.
Chapters 2 Scope of this project

In order to focus this project in its design goal and target audience, we identified two conditions to help limit its scope: 1) a focus on the dating relationship only 2) data collected in face to face interaction time.

2.1 Why the dating relationship

In this project, we identified target users as people in a dating relationship and this visualization is designed for them to primarily monitor and measure their dating relationship.

There are three reasons for this limitation.

Firstly we thought lovers generally have a greater need to know their partner’s emotional situation. They expect their partner to share their emotional state, amplifying emotional awareness and avoiding potential risks. Lovers in dating relationships generally have a higher level of trust and intimacy. They are more inclined to express their emotions, which strengthens the bond and intimacy in the relationship.

Secondly, we thought dating relationship need a temporally continuous data collection and data representation to measure and monitor its development. Dating relationships are a process where strangers develop a connection to the most intimate level. In this process, it can be more unstable and volatile than other types of relationships. An emotional data visualization, which records and reflects this, could aid in identifying problem areas and assist in managing the relationship more successfully.

Thirdly, other types of relationships are so independent on temporal data. For example, companionship is a loose peer bond of social functioning, which consists of mutual love, trust, and respect. It does not particularly require any specific attachment or continuous contact to maintain its intensity. These relationships are established by common ground between the individuals involved. In this case its risk and life-span was less relative to temporal scale but more relative to belief, value, interests and other long term stable factors. Data collection and monitoring would be useless in reporting and reflecting.

For another example, in family relationships, family members have a blood bond that is persistent and solid, rather than temporary. Thus the relationship might not be as easily dismissed. Temporal factors would not influence this relationship as much. They do not need timeline based data to monitor or measure their bond.
2.2 Why face-to-face

Face-to-face dating provides much room for people to express their true selves and to observe their partner’s emotional responses. It allows people to become more aware of and foster their emotional situation. It provides a chance for people to distinguish between their perceived realities created in situations when they are dating online or through the phone and the actual situation.

Secondly, when a couple meets face-to-face, they tend to share their emotions more readily and get intimate. Their situation naturally turns to dating situation and the emotions evoked are more related to a dating relationship. This means that data collected during this time reflects more on their dating situation and relationship. Outsides of the face-to-face dating relationship, their emotional feelings are less likely to relate directly to and reflect their dating relationship.

2.3 Why a speculated data set

A reason of why we used speculated data is because when we started exploring this project, we were unable to obtain resources to practically collect emotional experience in two-person face-to-face dating time. The doable way we can do is to develop a speculated data set according to romantic relationship theory and regulation principle to let it cover the main phases of its lifespan as much as possible, therefore to ensure the data set was adequate and comprehensive enough to reflect the various situations of relationship development. This will be a good base to develop visual exploration.

However, speculated data has its own limitation. In this project, data can be thought to collect from an ideal social environment where two lovers fully enjoy their dating time. They are both turned on by their partners and fully fall in a dating atmosphere when they meet each other; they are completely absorbed by their partner, and address emotional influence to their partner through time.

However in realistic daily life, it is not very often to see such user case. Most likely is that people work and live in a complex social environment. Information extracted from people may reflect the complicated nature of modern society and the varying influences that may determine a person’s emotional status. In this case, lover couples use affective computing tools to collect their emotional experience in their dating time, the collection must be diverse and include rather amount of variables. The variables that may occur that influence how people may respond emotionally. For example, they may feel unhappy at a particular stage during the research. This may have nothing to do with their romantic relationship but triggered by other issues such as work, family or friends on emotional feedback. From data recording, we cannot judge which romantic relationship oriented emotions are and identify the rest triggered by random facts that are not substantially impact on relationship development and lifespan.

Additionally, since we cannot use a real affective computing tool to practically collect data, in speculated data we cannot tell if the real emotional fluctuation works as we simulated. This could be a limitation as well.
But as we say, in early stage we still focus on a speculated data which fully covers and reflect various possibility of romantic relationship situation. This is helpful to develop visual exploration.
Chapters 3 Literature review

Since affective wearable technology and its application are still in an early stage of development, relatively few works of emotional relationship visualization can be found, particularly dating relationship visualization. We broke down our project into several involved areas, by looking at relative works in each area to construct a theoretical foundation to develop our concept.

This project is mainly concerned with

- Emotion data collection and interpreting techniques
- Relative visual and interactive techniques in information visualization
- General ideas of emotional relationship theory

3.1 Emotion data collection and interpreting techniques

There are two major ways to collect and map emotional data: subjective evaluation and objective physiological measurement.

3.1.1 Subjective reporting and measurement

Subjective reporting means that using cognitive recognition and introspective evaluation to report emotions. People manually label their own emotional states through questionnaires and interviews. Generally people work as two roles: “participants” or “observers” (Ron and Arnir, 2006). As “participants”, they take part in the experience and have a physiological response to the emotional event. As “observers”, they see themselves on the television taking part in the event, with little or no physiological response evoked to report emotions. The evaluation results are along category judgments (fear, anger, disgust, sadness, surprise, joy, interest) or along dimensions such as positive and negative emotion (Huang and Alessi, 1999).

There have been some existing visualization designs using subjective reporting to collect data. For example, Wefeelfine (Harris and Kamvar, 2006) uses an automatic online data collection engine to scan a large number of blog posts, to harvest people’s feelings. Blog content as a typical self input data source contains people’s feelings and attitudes regarding their own experience. Moodstats™ (2003) is software application that allows people to subjectively record and rate how the day has been in six different categories, therefore developing a personal emotional visual diary.

Subjective reporting is a good approach when trying to understand the attitudes of the people. However, sometimes people’s responses may not correspond with the actual experience. People could summarize the experience as a whole, but may have difficulty in continuously reporting emotional changes over time, hindering successful cognition upload, continual reporting would
also cause serious interruption to their normal activity. It is also possible that people would not accurately identify moods and may perhaps be unaware of emotional changes (Plutchik, 2003).

Using video to code gestures, body language, facial expressions and verbalizations, is a rich data source; however, there is an enormous time commitment, which requires between 5 and 100 hours of analysis for every hour of video. Also, the analysis is generally event-based (user is smiling now), rather than continuous (degree of smile for every point in time) (Mandryk et al., 2006).

Considering these weaknesses of subjective evaluation, we turned to look at the other evaluation approach.

3.1.2 Physiological measurement for emotion recognition

3.1.2.1 Physiological data collection

Objective physiological measurement depends on a physical detecting system with bio-sensors automatically collecting and recording physiological signals. And then, using established theoretical models, the data is transformed into recognized emotions. An automatic detecting engine could provide rich, continuous, objective information about people’s emotional experiences.

A number of bio-sensors have been established to measure physiological data. Galvanic skin response as skin conductance has been proved as having a linear correlation to arousal (Lang, 1995). Heart Rate could reflect emotional activity and has been used to differentiate between positive and negative emotions (Papillo, 1990; Winton, 1984). Electromyography has been used to measure muscle movements. When used on the face, EMG has been used to distinguish between positive and negative emotions (Stern, 2001). Surface electrodes could be used to detect smiling activity from zygomaticus major activation and frowning activity (EMGfrowning) from corrugator supercilii activation (Cacioppo et al., 2000). From this sensor, people’s facial expression could be detected.

With computing engineering development, some effective wearable computers (MIT Affective Computing Research, 2006) have seamlessly blended bio-sensors into people’s working and living environments to collect and provide rich, continuous and objective physiological metrics. These wearable computers could be made in various forms like clothing or bracelets to handle the data collection in a non-invasive manner.

3.1.2.2 Physiological data interpretation

As for physiological data interpretation, there are a lot of theoretically established models to identify emotion or emotional relative interpretation. Commonly there are two steps in the decoding process: 1) the physiological signals to modeled arousal and valence (AV) values and 2) modeled AV values to modeled recognized emotion.
Modeled arousal and valence values

Firstly, collected raw physiological data such as heart rate, skin temperature, or facial muscle movement is projected and modeled into arousal and valence two dimensional space (AV space) (Bradley, 1994; Lang, 1995) (see Figure 1). AV space is thought to be the most common multidimensional model along which the entire range of human emotions can be arranged. Arousal describes the degree of activation ranging from sleep to excitement. Valence describes degree of the pleasantness of the stimuli, such as positive (happy) and negative (sad). In this model, output data is seen as a combination of arousal and valence. It is called modeled arousal and valence values. The third, less often mentioned dimension is dominance (ranging from in control to out of control).

![Figure 1. Arousal and valence two dimensional space](image)

Modeled recognized emotion

In the second step, data is continually transformed into emotional descriptive language, such as happy, sad, angry or calm. In this stage, there are two kinds of modeling approaches; discrete emotional approach and dimensional emotional approach.

The discrete emotional approach is a categorical way of measuring emotion in defining specific categories (Ortony and Turner, 1990; Izard, 1977; Plutchik, 1980).

It suggests that there are a few basic emotions (estimates range from 3 to more than 20), which combine to produce all the emotional states which people experience. Among the emotions most often designated as basic emotions are disgust, anger, happiness, grief, and fear. In this approach emotions are depicted in one data point for an entire condition but can not reveal people’s entire pattern of emotional variance. For example, we may know a person is happy, but do not know how happy he is, and how and when the emotion starts, develops and ends.

Thus we thought we could not apply this approach to our visualization.
On the other hand, the dimensional approach (Bradley, 1994; Lang, 1995) identifies emotion as having two or perhaps three basic underlying dimensions along which the entire range of human emotions can be arranged. AV space is still used and it is one of the most common models to map multidimensional emotions.

In this approach, AV space emotions can be only decoded with simplified levels in two dimensions such as very low, low, mid low, mid high, high and very high. These results are broad and are not clearly defined. To define the levels, guidelines from the circumplex model of emotions (Russell, 1980) are required. Due to technological limitations, there is no established model for transforming the level of arousal and valence to the level of emotions in a continuous manner (Mandryk et al., 2006).

Thus, from this approach, we assumed we probably determine further levels of emotion. However, we could not check its change in the temporal dimension. This approach still has the restriction in detecting emotional experience in time continuity.

![Figure 2](image-url)  
**Figure 2.** The whole emotional modeling process from raw physiological data to modeled AV values and leading to modeled recognized emotions

### 3.2 Relative visual techniques in information visualization

Information visualization is a process of transforming information into a visual form enabling the viewer to observe, browse, and understand the information (Chen, 2006). Its research challenge is how to create visual metaphors for presenting information and to develop ways to manipulate these metaphors to make sense of the information (Eick, 2001). Successful visualization could reduce the time it takes to receive and understand the information and enhance creative thinking (Gershon et al., 1998).

Although currently there are few visualization works relative to two persons’ dating relationship; we have looked at some areas with related work to develop our visualization design.
### 3.2.1 Emotional metaphor used a visual technique

#### Graphic Emoticons

In virtual space, graphic emoticons are a representation of emotion used to enrich online communication. Their purpose is to avoid misunderstandings due to the lack of contextual information (Emoticons, 2006). The graphics have been simplified to an emotional sign to deliver emotional information (see Figure 3 and 4).

![Graphic emoticon](image1.png)

**Figure 3. Graphic emoticon (Zhang, 2003)**

![Graphic Emoticon of MSN messenger 7.5](image2.png)

**Figure 4. Graphic Emoticon of MSN messenger 7.5 (2005)**

#### Color

Color inherently is a feature in emotional metaphor. Many applications use color to improve emotional information perception. Figure 5 and 6 are two example of using colors to improve emotional data reading in textual context.

In Figure 5, an emotion recognition technique (Liu et al., 2003) uses colors bar to visualize the affective structure of a text document to facilitate emotion-based content perception and learning.

![Color visualization](image3.png)

The text visualized:

```
The wolf pulled the baby, and the door opened, and then he immediately fell upon the good woman and ate her up in a moment, for it been more than three days since he had eaten. He then shut the door and got into the grandmothers bed, expecting Little Red Riding Hood, who came some time afterwards and knocked at the door, too, too.
```
Figure 5. Visualizing the affective structure of a text document in color (Liu et al., 2003)

Figure 6. Color attached text message in eMoto (Sundström et al., 2005)

eMoto (see Figure 6) (Sundström et al., 2005) uses colors and non symbolic shapes as text message backgrounds, which conveys and enhances emotional expressivity.

Figure 7. Using color to achieve emotional expression in affective clothing (Emotional Fashion, 2006)

Color is also used in other media to help with emotional message representation. In affective wearable clothing (Emotional Fashion, 2006) colors are also the main visualization technique used to express people’s emotional situation. Through changing colors in LED lights attached in people’s suits, it intuitively delivers on emotional message to disclose a person’s interior state (see Figure 7).
Empathic painting (Shugrina et al., 2006) addressed emotional information by rendering pictures using only color and texture (see Figure 8).

Affective diary (Lindström et al., 2006), as “affective body memorabilia” used different body postures and colors to transmit emotional information (see Figure 9).
3.2.2 Emotional data display in temporal scale

One of the more traditional ways in reflecting emotional data over time is the photo album. They can be used as an archive to record two lovers’ emotional moments, dating events and the relationship process for memory storage and re-experience in the past.

![Photo based emotional data structure](image)

Figure 10. Photo based emotional data structure (Flickr Photo Album, 2007)

Photos are recorded in real time (the date attached in each photo corners labels its specific position in the timeline) and are usually arranged in chronological order (see Figure 10). This could be thought as a realistic prototype, inspiring us to construct our idea of what its visualization could be like.

Certainly it has a limit in that it could possibly contain more positive emotional experiences than negative ones. This would limit the database when reflecting a real relationship situation.

As well as photo albums, other systems have been developed to record and display people’s emotions over time. Moodstats™ (2003) and Moodgrapher (2005) (see Figure 11 and 12) are two examples of emotion categorized display.
Figure 11. Emotional data display in Moodstats™ timeline (2003)

Moodstats™ is a personal, visual diary, displaying six different categories of achievements in terms of emotional flows. It is able to synchronize people’s data with the global Moodstats server, inviting others to see how their moods have been and compare their own moods with others.

Figure 12. Emotional data display in Moodgrapher timeline (2005)

Moodgrapher is a graphical representation showing the moods reported by Livejournal users in their posts during the last 7 days, updated every 10 minutes. These blasts showed both the rate of change and the absolute counts of moods recorded. In Figure 12, it shows the sharp spike for the keyword 'shocked' just after the London blasts.
There are other visualizations grouping emotional data collected over time, which do not use a timeline display. Wefeelfine (Harris and Kamvar, 2006) is a project organizing quantitative data from a large number of blogs published in the last few hours (see Figure 13). Emotions expressed in the blogs (e.g. sad, happy, depressed, etc.), are presented in terms of their quantity and the emotional nature of the feeling is presented by a series of particular properties (color, size, shape, opacity).

### 3.2.3 Comparison technique of multiply layers of information in Timeline

Dating relationship visualization requires two set of data (one set from each person in the couple) having parallel display. Considering this point, we collected some related works to show visual techniques that represent multiple layers.

History of Programming Languages (2005) is a visualization diagram which plots over 50 messages on a multi-layered, color coded timeline, providing a solution for dense content presentation (see Figure 14).
Timeline Compare (Mukherjee et al., 2005) explores a visualization enabling the comparison of timelines of similar domains, or of vastly different domains. It skillfully solves some problems such as overlapping and different domains comparison (see Figure 15.).

Google Trends (2005) provides an interface with a set of simple lines and bar graphs that enable users to compare two topics in parallel. It shows how often these topics have been searched for on Google over time and how frequently they have appeared in Google News stories (see Figure 16.)

3.2.4 Visualizing two persons’ conversation history

Considering our visualization aims to display two sets of data, we also explored some interaction dynamics patterns in a small group or between two persons. The emphasis is to show how people alternately lead and host in their interaction and communication.
Chat Circles (Viegas and Donath, 1999) is an online chat room which provides history thread interfaces to visualize archival Chat Circle logs (see figure 17). Color and form are used to convey social presence and activity in conversational clusters. A thread of conversation is recorded in a vertical timeline where each participant's comments appear in a short horizontal line.

VisiPhone (Donath et al., 2003) is a graphical interface for mediated audio conversations, designed for people in different locations (see figure 18). Its visual graphics enables users to perceive conversational patterns from two-person real-time audio parallel data and a rhythm of the conversation.

3.3. Relative emotional relationship theories

We also explored emotional theories and relationship theories that might help us deepen an understanding of emotion data ensuring a more beneficial display. In theoretical research, we
mainly targeted a connection between emotions and relationships to see how to use emotions in interpreting and labeling significant findings.

We studied the adult attachment theory (Bartholomew and Horowitz, 1991; Hazan and Shaver 1994) that studies people’s interaction models with their stability in romantic relationships. Four attachment styles are identified in this theory. These are 1) secure attachment 2) anxious-preoccupied attachment 3) dismissive-avoidant attachment and 4) fearful-avoidant attachment. Attachment styles reflect the quality of romantic relationships and emotional experience (Simpson, 1990). This theory also introduces how attachment impacts relationship outcomes and how attachment functions in relationship dynamics.

We also looked at the reinforcement theory (Miller and Siegel, 1972) that shows people reinforcing their relationship when they receive rewards or relief in their interaction. Rewards or relief (pleasant feelings) could become hopeful signals in evoking behavior that drives people to strive for more of the positive experience. On the other hand, if a person receives punishment (unpleasant feelings), fear signals and avoidance behavior are created, as a result, this person will withdraw from the situation in order to minimize further negative experiences. The objective results of their approach behaviors and avoidance behaviors show that they significantly influence people’s emotional bond.

Besides, two persons had the same approach or avoidance behaviors, this theory also introduces the situation of when two persons have different interaction situations, for example, one approaches in active and preoccupied situation and the other stays lazy in low response. If approaching with no reward is repeated, negative experience will increase. It will also result in avoidance behaviors in the two persons’ relationship when unpleasant experiences become overwhelming.

This theory discloses an individual’s emotional regulation and the action and response interaction model of two persons.

Certainly this theory can not summarize all principles of a romantic relationship as interpersonal relationships are complex. Individual factors might not follow all these rules; however it provides a broad guidance for a general social interaction model in human relationship and emotional management.
Chapter 4 Methodology

4.1 Overview of visualization design process

Once a visualization goal was identified, the research process required a method to identify the range of collected data and to transform it into a readable model.

A typical information visualization design process (Aigner 2003; Wakita and Matsumoto, 2003) was used to carry out our design. We listed its steps below (see Figure 19) with a brief interpretation of its process.

![Diagram of Information Visualization Design Process]

Figure 19. Information visualization design process (Aigner 2003; Wakita and Matsumoto, 2003)

In this process, there are two main steps. The first step is to identify the range of collected data and to transform it into a readable model. After the data has been prepared, visualization techniques are used to improve its display and to identify regions of interest for more focused reading.

Data mapping and visualizing were manipulated many times in the design process until a satisfactory design solution was achieved. After each design was finished, there was an evaluation to summarize design findings and to identify design problems for the improvement.

Four steps are carried out in this design process as follows:

- Data collection
- Data mapping
- Data visualization representation
- Design evaluation
4.1.1 Create application scenario to identify data collection

We investigated current affective computing technologies with their various wearable devices and sensors that could be used for emotional data collection and measurement.

We also looked at people’s various needs in real life considering how to make use of this potential new data to meet these needs. We noticed people generally had memory cognition trouble when dealing with long term experience and had limitations in clearly identifying other people’s emotional situation.

Thus, we combined affective technological advances and user needs together by creating a speculated scenario to facilitate people’s emotional cognition. This speculated scenario is about a couple in a face-to-face dating relationship. We assume that each of them is carrying a wearable affective computing device carried to continuously measure their emotional states when they are in a face-to-face dating relationship over a period of time. The speculated data of how long and how often they meet each other and what emotion they feel during that time is made in every day. Then that is mapped into the general trend with the critical points and the most common stages of dating relationship based on relative emotional relationship theories for decoding.

4.1.2 Data mapping and theory researching

After the raw data was modeled, data mapping is then manipulated.

In this step, we mainly addressed theoretical research and analysis issues to explore and choose a useful data structure to help facilitate emotional relationship representation. We analyzed a broad range of relative theories and established theoretical models that might involve different theory areas, such as emotional recognition and social relationship interaction. In terms of the destination of data application, we chose the adaptive mapping models to guide the data when it is being transformed into an understandable model.

Currently, we could not access any data resources that have a real data set collected from a couple’s face-to-face dating relationships. Thus we mocked up a speculated data set by simulating the real data attributes to foster our visualization exploration.

4.1.3 Design researching and visualization exploration

To facilitate data transition, we targeted in a design research, by investigating and exploring various emotional information visualization techniques and interactive viewing structures to facilitate data representation. A series of graphics and interactive structures were created and developed.
Considering the relationship based data set probably had a large amount of information, in early visualization exploration, we worked with a small data set to explore various visualization techniques for emotional data representation. A series of symbols and graphics of emotional metaphors were developed and chosen for supporting data represented in timeline based structure.

We then moved into a global view to explore relationship based data visualization. In terms of mapping relations between emotional data and relationship, we developed some design guidelines to organize data in order to properly respond to people’s reading needs and understanding.

After each phase of design, we evaluated our design outcomes and identified problems and design direction.

4.1.4 Evaluation

In evaluation work, we mainly used two evaluation methods to measure our design. They were subjective reflection and usability study. In early design steps, we used subjective reflection. Through creative analysis and comparison we judged design direction and identify design result. In later evaluations, we would recruit participants to carry out usability tests. Through objective feedbacks and comments we examined our outcomes and to define design problems.
Chapter 5 Design Process and Discussion

5.1 Phase 1 Data mapping - Identify data used in visualization

5.1.1 Define preliminary significant components of a two-person dating relationship

In terms of intuitive cognition of a couple’s face-to-face dating experience, we quickly identified some preliminary components in its data structure that we thought significant in developing its visualization design.

They include

- Emotion visualization in temporal dot
- Emotional visualization in reflecting change and trend
- Two person data

Of them, the second component implied the need for continuous emotional data collection to reflect change during that time period. Considering this requirement, we looked at wearable affective computing technique that might be able to support continuous, objective emotional data collection and also to record couple’s dating events and experience. It was required to be able to record data 24 hours 7 days in a non intrusive manner to reflect person’s emotional change and development over a period of time.

5.1.2 Identify emotional data used for visualization

Emotion has a significant physiological, bodily reflection and it is a reaction evoked by a stimulus from the environment. When this environment is introduced to the face-to-face dating scenario, its stimulus will become relatively consistent and closely related to their loved partner and relative relationship events. Their bodily reaction might be used as emotional reflection of their dating relationship experience. We imagined affective computing devices to be worn by the two lovers’ bodies non-intrusively, continuously collecting their physiological signals from bio-sensors in their face-to-face dating time and through Blue tooth techniques to achieve a mutual relationship data set.

After establishing a raw physiological data set, we looked into the established theoretical mapping models to decode the data into basic emotional data interpretation. From raw physiological data to recognized emotion data, theoretically there are two steps involved: 1) the physiological signals to modeled AV values and 2) modeled AV values to recognized emotion.

Intuitively we thought that the second mapping step - recognized emotion, would be better than modeled AV values because it is easier to read and understand. However, we noticed that
currently due to an early stage of emotional mapping study, there is not an established model of
transforming the level of arousal and valence to the level of emotions in a continuous manner
(Mandryk et al., 2006). This meant recognized emotions could not be used to explain emotional
change and trends across time. Thus we moved back to looking at modeled AV values.

Modeled arousal and valence values, as the result from the first emotion mapping step,
technologically do not have a limitation for producing continuous emotional data over time. Peer
works have been done by using modeled arousal and valance values to record and reflect people’s
emotional experience over time. For example, affective diary (Lindström et al., 2006), as
“affective body memorabilia”, has applied this data to achieve personal experience expression and
the re-living of memories.

5.2 Phase 2 Visual metaphors of emotional data

When the data was established, it could be collected to handle our visualization. We started to
explore the visual technique of emotional metaphors in temporal dots. We connected emotional
temporal dots into a temporal span to test their performance with the timeline.

5.2.1 Concrete, complex visual metaphor

We started from concrete, complex visual metaphor to explore visual metaphor of emotion in
temporal dot patterns.

Graphic

Initially, we developed a concept of using flowers (see Figure 20).
A bunch of flowers were used to represent a couple’s dating experience and process. Its petals were assumed to simply grow to bigger and flourish if they were happy in their relationship. However, its petals would fall and wilt if their relationship fails. In this visualization, the data in all temporal dots was accumulated and transformed to one picture. It means that there is no timeline to check the data in different temporal dots and the current picture represents the latest dating history.

**Iconic graphic**

Then we experimented with other works. Weather broadcast theme icons naturally deliver emotional information (see Figure 21).

![Figure 21. Weather broadcast iconic graphic](image)

Also we saw emoticons through iconic facial expression could strongly and effectively transmit emotional information (see Figure 22).

![Figure 22. Emoticon structured timeline](image)

In each emotional situation, Iconic graphics may provide a much clearer and board range of emotional expression than the flower idea. However, in a case of a large amount of emotional data being required for display, this visual language seemed to have a high cost. Each emotional dot requires certain space for displaying and it required reading effort. That means its timeline data is not easy to read. High aesthetics and vitality do not contribute to information transition; therefore, we targeted simple and abstract visual languages to realize their potential in emotional trend display.
5.2.2 Simple, abstract visual metaphor

Staff & Note

We explored the staff & note metaphor (see Figure 23). The staff could be treated as a timeline whereby each note represents one emotional feeling. We felt as a temporal dot, each note did not contain obvious emotional information. In very simple sense, we could sense dating flow from this pattern. We found simple symbol that could effectively reply on the spatial qualities to display more data.

![Figure 23. Staff looking timeline](image)

Barcode

Thus we continued to explore visual metaphor in this direction to improve the whole data representation. We were inspired by barcodes and developed a barcode looking pattern (see Figure 24). In it, a set of colorful strips varying in width represented a series of emotional feelings it also reflects varying periods.

![Figure 24. Barcode looking timeline in color version](image)

Color seemed to better support intuitive display in emotional trend and its timeline properly allows rich information in dense display.

We explored visual metaphors by combining emotional temporal dots into temporal span. We found simply and abstract visual element versus complex and concrete visual element. The former was more promising displaying a large amount of data. A clear timeline flow with specific time points may help the user view the data history more successfully.
5.3 Phase 3 Visualization explorations in a small data set

5.3.1 Setup a small data set and develop scientific graphic visualization

Considering that collected data would be arousal and valence two dimensional data, we decided to set up a small data set to develop our design with regard to the design issues.

![Arousal-valence two dimensional space with eight scaled values](image)

**Figure 25.** Arousal-valence two dimensional space with eight scaled values

In AV space we set up a data scale with value in arousal and valence dimensions (see Figure 25). We defined the bottom left corner as the origin and the adjacent two lines as zero based line axes with eight scales to qualify data projected into AV space.

<table>
<thead>
<tr>
<th></th>
<th>Arousal</th>
<th>Valence</th>
</tr>
</thead>
<tbody>
<tr>
<td>She</td>
<td>5 1 1 7 2 3 5 4 4 2 6 3 2 2 3</td>
<td>1 2 2 8 6 7 6 5 3 4 6 6 5 6 5</td>
</tr>
<tr>
<td>He</td>
<td>6 2 2 7 4 4 6 6 7 2 8 4 2 2 3</td>
<td>3 4 4 8 7 6 2 2 1 1 8 7 6 5 6</td>
</tr>
</tbody>
</table>

**Figure 26.** A small speculated data set where two-person modelled arousal and valence values were arranged in time series for representing two-person dating experience

We added values into AV space and speculated a small data set to develop and explore partial view of relationship visualization. Two-person’s four streams of modelled arousal and valence numbers were seamlessly arranged in a time series to construct the basic data set for representing a couple’s dating experience (see Figure 26). It included a two-person mutual emotional trend and obvious emotional difference. Data was extracted from full range of AV space, from positive response to negative response and from high response to low response, thereby to simulate all possible emotional situations. In this data set we only provide data order, but we did
not specially define temporal data such as how long each emotion lasted. Thus this data set could be interpreted as a three hour dating experience and a three week dating story. There was no temporal data involved. (However after we realized its presence in its following visualization design, we added a bit temporal variation in the timeline to visually simulate a real data situation).

This small data set properly achieved the three conditions we defined at the start.

- Emotion in temporal dot
- Emotional change and trend cross time
- Two-person data

In order to quickly transform these numbers into a visual pattern to better understanding the relationship situation, we used Microsoft Excel™, to input data and quickly launching two graphs (see Figure 27 and 28). From its visualization, we identify relative design issues and see where we should go about on next design.

![Figure 27](image1)

**Figure 27** Two-person emotional data displayed in stacked line graph

![Figure 28](image2)

**Figure 28.** Two-person emotional data displayed in radar line graph
In these two patterns, when four streams of emotional values were displayed in parallel, they were separate from what people felt in real emotional experience. Line graph-looking display seemed to create a disembodied experience and had a low readability. We could not perceive how their relationship was going and also we could not capture information in arousal and valence dimensions.

This visualization was too complex to read. It was more successful to use certain visual techniques to combine both modelled arousal and valence values into an entity, helping reduce the reading load.

5.3.2 Color coded technique and basic color coded timeline

Thus we track back to our current design experiments in simple, abstract visual metaphor. In bar code pattern, we noticed colors have an inherent feature in emotional state expression. Colors also have innate warm-cold and dark-light dimensions. We tried to connect color and emotion to create a mapping pattern to see if color could integrate arousal and valence values in one visual form to intuitively transmit emotional information.

In AV space, we used Russell’s circumplex mode of emotion (Russell, 1980) as a guideline to improve AV two dimensions understanding of how they are theoretically associated (see Figure 29). Figure 30 displayed Itten’s color circle (Itten et al., 1971). We found that it basically matched AV space and emotion terms from Russell’s circumplex mode of emotion. Thus we adjusted Itten’s color circle and transformed colors to represent AV 2D space. In the horizontal dimension, we used the warm-cold color scale to represent the pleasantness-unpleasantness scale. In the vertical dimension we used the dark-light color scale to represent the high activation-low activation scale (see Figure 31).
Design Process and Discussion

Figure 31. Using colors from Itten’s circle to fill in AV space in a seamless manner

In Figure 32, from the center to the edge, we continued to add white-to-transparency gradient pattern to depict the third dimension: neutral - dominant dimension in AV space. In the center, bland white colors were placed to depict the neutral emotion and for the outermost edges, pure colors described the dominant emotion.

Figure 32. Adding the third dimension to Itten circle’s color filled AV space

In Figure 33, we simplified the color pattern to respond to the original values we set up in AV space. We plotted over the color pattern into eight orientations with four transition degrees each. As a result, we attained thirty-two color codes.
Figure 33. Simplifying color-emotion mapping index pattern into thirty-two color codes
We used these thirty-two colors codes to transfer the small data set into visualization and
displayed two persons’ emotional data in parallel (see Figure 34).

Figure 34. Two-person thirty-two color coded parallel timelines
From this Figure, we thought color was a proper visual metaphor because we could perceive
basic emotional flows of both the individual and two persons combined in high-low response
and positive-negative response and we could see their emotionally similar parts and emotionally
different parts clearly. It effectively combined two dimensional emotional data into one entity
for facilitating emotional information delivery. Thus, we decided to use color coded technique to
carry on our design.

However, we also noticed some problems in color division. For instance, color divisions on the
outermost were too rough. In addition, in the red section, its representative emotions consisted a
range from exultation to pleasantness. Although these two qualities represent dominant positive
emotions, there is still difference between these two emotions in terms of arousal values and
their meanings. If we used the outermost colors to record and reflect people’s responses, it could
not accurately show people’s real response and may cause misunderstanding.

White color placed in the center seemed to divide one-dimensional data into two parts, which
meant that we had to use two colors to display data values change in one dimension. This
definitely added the cognition load and reading effort. Thirty-two color codes also seemed too
many in perceiving the emotions.

Considering these issues, we decided to redesign the visual design to develop a simpler color-
emotion mapping index pattern.

Redesign of color-emotion mapping index pattern
We started from Figure 31 to redesign color-emotion mapping index pattern. From the center to
the edge, we added one grey to transparent gradient filled pattern to depict the third neutral -
dominant dimension. We plotted this AV space into five major emotional categories: high active
positive, high active negative, low active positive, low active negative and neutral / no emotion.
Then we subdivided five major categories into sixteen fine grids averagely to improve resolution
of data representation. Each grid was filled with one color and we adjusted all colors as close as
possible to match their own category to emphasize coarser category belonging.
Thus we could read subtle emotional dynamics from a sixteen color codes, but also in a coarser view, we would easily perceive the rougher trend and rhythm (see Figure 35).

**Add a fuzzy expanded semantic**

Considering that it will turn out to be overly simplistic, and the need to improve semantic understanding of the colors, we added emotion terms from the Russell circumplex model of emotion (1980) and Whissell’s model (1989) to the color-emotion mapping index pattern (see Figure 36). From these two models we picked fifteen adjectives relating to emotional terms that were evenly distributed in AV space to cover the four orientations. Even though there was no one-to-one matching between colors and terms, we assumed this guideline in each category would help people develop fuzzy index in their mind to improve color cognition. This also meant that our visualization has to be read in a rough and concise manner. Note that this added semantic annotation would only appear in the color-emotion mapping index pattern that would be used aside of the main visualization pattern to qualify these colors and assist people’s reading, but would not appear on visualization pattern itself.

![Figure 35. Simplifying color-emotion mapping index pattern in sixteen color codes](image)

![Figure 36. Adding semantics annotation into five major emotional categories in simplified color-emotion mapping index pattern](image)
We used these new sixteen colors to construct two-person dating experience timelines (see Figure 37). Compared with the thirty-two colors in the last version (see Figure 34), this new color-coded timeline had a higher readability and their positive or negative inclination could be perceived more easily and intuitively. Thus we completed the color-code technique and used it to develop the most basic visualization pattern for representing two persons emotional data in their dating experience.

![Figure 37. Two-person sixteen color-code parallel timelines](image)

5.3.3 Explore variations of basic color-code timeline

Based on this most basic timeline pattern, additional information was extracted from the present AV data. We attempted to develop some variations on the timeline patterns to reflect hidden information, enabling better data understanding.

From relative emotional social interaction theories (D’Ydewalle et al., 1985; Hebb, 1972; Milner, 1991), we learned that arousal value is associated varying degrees of attention. High arousal commonly means a kind of cognitive focus or sharpness and implies an active and positive reaction to the environment. Moderate arousal value could be interpreted as self-control or an attempt to balance between the internal and external world. A low arousal value implies indifference and being self contained.

In our dating scenario, people’s emotional trigger was generally related to their partner and related issues. The arousal value of their emotions could be used to interpret their responses towards their partner and relationship. When one person appears indifferent and if the situation lasts for a long period, this will imply that the person’s focus on the relationship has shifted. This data can evaluate potential relationship risks. When two persons’ arousal values were put together, the difference between the values may disclose information of their situation in their interaction balance, at the same time disclosing relationship risks also.
**Height technique**

In the original color-code timeline, the colors represent both arousal and valence values. Arousal value can also be shown by using height technique to shape the timeline, highlighting their interaction balance. As a result, in Figure 38 we saw two-person mutual emotional trend was highlighted.

![Figure 38. Two-person color coded timelines shaped by arousal value in height technique](image)

In this pattern, when both had peak values, whether positive or negative, we assumed that they remained in an active situation because they were both emotionally activated and paid a lot of attention to their partner. Therefore peaks reflects a positive dating situation. When both values of the couple plunge, we assumed that they were showing little interest in the relationship and they were inclined to slow down or stop any activities in their relationship. If this kind of situation happens frequently, extra attention should be paid. This meant their relationship lacked vigor, therefore possibly causing relationship risk.

From this pattern, we could easily perceive a two-person mutual emotional trend. Emotional difference could also be read, but this was not as obvious.

Besides mutual emotional trend and two-person emotional difference of the couple, obvious emotional difference of the couple is the other factor that plays a significant role. It is hidden clue in two-person interaction balance and potential emotional risks. Generally in an unbalanced interaction relationship, there is a person who demands more attention and is more inclined to feel anxious or excited. When this situation was repeated frequently with no alternation or reward, this negative experience would transform to negative reinforcement experience (Miller and Siegel, 1972). As a result, this would seriously influence people’s emotional interaction relationship.
Splitting line technique

Next we converted two-person percentage arousal values into percentage with splitting line to highlight the interaction balances. Arousal value of two persons was displayed in percentage color coded timelines. As a result, a 100% stacked graph was created (see Figure 39).

![Figure 39. Two-person color coded timelines shaped by 100% arousal value in splitting line technique](image)

When this splitting line was not placed in the middle, it implied that people are prioritizing their interest and attention in their partners or relationship. Generally the person with a high response were the emotional approach people. They demanded more attention and were more inclined to be anxious or excited. Generally emotional difference between the couple is in the high active or moderately active emotional range, would offer meaningful data as opposed to a reading from the low active range.

However we also noticed its limitation. When two of them remained in the high active emotional situation, the visualization difference in their arousal values would be less obvious than that of the low active emotional situation.

An obvious uneven division pattern might disclose information of the couple who is in low emotional range with certain difference in activation. Also a balanced division pattern may cover the fact that they are on the high active or moderate active situation with the same, but seemingly the more important is the activation difference.

Thus the ratio of the arousal values could not be used to disclose interaction balances of the couple, and also it could not predict relationship’s potential risk. Intuitive cognition from this pattern could not always meet the description of people’s real situation. If it was being used, we had to check the color codes to confirm our initial guess. Hence, we thought this visualization technique was unsuccessful and we discontinue further exploration in this direction.

We went back to the default timeline pattern (Figure 37) and arousal value oriented height technique shaped pattern (Figure 38). If subtle differences and obvious differences were displayed together, we suggested setting up a thresholding value to filter out the obvious differences only for display, reducing reading efforts and better facilitating data understanding.
Polygene technique

In order to highlight significant information to facilitate reading, especially when a large amount of data was displayed, we used the polygon technique to extract key dots from the timeline so as to highlight each turning point in people’s dating experience.

We began with the two-person height technique with shaped timelines. By extracting each turning point from the timeline, we develop a new polygon technique timeline pattern (see Figure 40). Arousal value continued to be used and was associated with the polygon size. The bigger the polygon, the more intense the emotion. To label the emotion valence value, circles were used to present positive emotions and diamonds were used to present negative emotions. By default, two series of polygons were displayed on either side of middle line.

We realized that bilateral symmetry doubled the space of the design without providing new information (Tufte, 2001) and it created redundancy. In Figure 41, we developed half polygons shaped timeline pattern. However the two-person mutual emotional trend was not easy to perceive, and also the couple’s emotional difference was not easy to read. This visual technique limited the amount of the data in interface display because each polygon would take up some space in the interface display.
Thus in this phase, we identified color coding as a successful technique when transmitting emotional data into visualization and speculated a small data set to develop two-person color coded timelines along with some variations. By comparison, we chose two patterns that were thought to be promising. One pattern showed two-person in sixteen color coded parallel timelines (see Figure 37); the other one was two-person color coded timelines displayed in absolute arousal value oriented height technique (see Figure 38).

**5.4 Phase 4 visualization explorations in global structure**

After exploring visualization in local context, we would then target to explore a global structure of data representation and solutions.

**5.4.1 Identify a global data scale**

An overview data span should provide the most relevant messages for couples to monitor the development of their relationship. What will be an ideal duration of the couple’s relationship to be put on display? To find out, a few expanded questions needed to be addressed in order to develop a deeper understanding of the dating relationship.

1. How long does an average relationship last?
2. How long does a rocky relationship last before it falls apart?
3. What is an overview function?

We identified the goal of a global overview visualization was to help people monitor their relationship situation to avoid risking any moves that will lead to failure, and to develop positive engagement results.

Relationship spans are usually different, however if we setup a test in the monitoring span, which was able to disclose enough significant information to report risks before the relationship fails. We chose to study the relationship development of the couple over a year’s time.

**5.4.2 Analyze data characteristics and setup design guidelines**

Dating relationships are constructed by a series of dating events, whereby emotional feelings are most active. Based on this understanding, we provided a draft to describe the visualization structure of the dating relationship.

In Figure 42, a thread of dating events (blocks) was presented in timeline so as to show the dating process. In each event (the lines in each block) emotional details and changes were contained.
This draft inspired us to develop a rough idea of what our visualization design should be. Firstly, an overview was necessary to help the viewer see how the relationship forms and develops. Secondly, detailed view was needed to provide a chance to see detailed emotional dynamics in each dating event.

However we could not redesign our visualization in these two views only. Emotional influence is continuous and could be transmitted over time. Using fixed limited view to see flexible data might restrict this data from being fully understood. In order to properly evaluate emotional data significance and function in relationship development, we thought a large amount of contextual data should be set in each data view.

Data viewing and understanding was associated with its viewing scale. Under different data views, dating events could not only be read as a point but also be read as a span. For example, an intensive quarrel occurs at one point. If viewing this event as a single incident, it could be imagined that it would cause problem in the relationship. However when the contextual data is taken into account, it can be seen when the view is zoomed out. This particular event’s significance and influence were not same as what we imagined. We realized that preclusion was unlikely to happen in their dating history and it would probably only create minor emotional wave before it was being dismissed. Thus we suggested ample contextual data should be added to create a broader perspective in order to better judge the data. High resolution should be set up in order for the data to be clearly read.

Considering that the data we represented was relationship based, we gathered that a large amount of data would be needed to better achieve relationship based presentation. This probably would result in complex data structure and emotional data especially significant data would be possibly distributed into different hierarchical levels. Discontinuous data reading would require additional reading effort and cause heavy memory load. The reader may possibly miss significant data while they were looking at it. A potential solution was to provide simple hierarchical structure or even linear timeline to arrange rich data economically so that users could capture adequate significant information at a glance to form a correct interpretation and avoid misreading.

Thus from data attributes and reading needs, we listed three major design guidelines to create our data interaction structure.

- Global overview + detail view
- Data display in rich context and high resolution
- Simple hierarchical structure
5.4.3 Develop a calendar based overview + detail view hierarchical structure

5.4.3.1 Analyze and compare two data structuring techniques

According to these two design guidelines, we introduced two data structure techniques, overview + detail view technique and focus + context technique (Takashima, 2005) that we thought could be used to build this data and navigate browsing. Before making the choice, we had to look to their definition and characteristics.

Focus + Context
- represents a focused part and its context in a single window by enlarging a focal point and distorting the surrounding area
- is appropriate when distortion does not change the semantics
- shows superimposed frames into a single frame

Overview + Detail
- represents an overview and a detailed view in separate windows
- represents preceding/succeeding frames in separate window
- maintains the original spatial relationships without any distortion

Based on their definition, we simply predicted two techniques usability. If we chose focus + context technique to organize complex data, this could reduce complexity of hierarchical structure and reduce additional reorienting effort in browsing through hierarchical structure, since two views are composed within one single window.

However because focal view is mobile and temporal that does not allow people to breakdown the data by opening a new window to see more details. Potentially it caused information density in display, particularly when a large amount of data was addressed.

If we provided an advance function to allow people to manually control selection range and to support data resolution, the visualization automatically adjusted to suit people’s reading needs.

People’s different data selection strategy might directly influence this technique usability. This could cause interaction result into two opposite ends. Proper data picking strategy might help people create some proper data views to better data understanding. However, improper data picking strategy might make people suffer and hold on in their browsing way.
Even overview + detail view technique could have some usability problems, such as complex hierarchical structure or unnecessary interaction effort. However, compared to focus + content interaction technique, there were less potential problems. Hence we decided to choose overview + detail view technique to structure data to develop dating relationship visualization.

5.4.3.2 Develop a calendar based overview + detail view hierarchical structure

We quickly developed a calendar-based overview + detail hierarchical structure.

![Calendar based overview + detail view hierarchical structure showing different browsing steps from on years, through months, weeks to days.](image.png)

![Color coded calendar based overview + detail view hierarchical structure showing different browsing steps from on years, through months, weeks to days.](image.png)
We employed calendar based overview + detail hierarchical structure to categorize data into four different time unit levels: one year, one month, one week and one day (see Figure 43 and Figure 44). Starting from an overview of the detected data span, zooming in on the overview provided greater detail. Color coded techniques were continuously employed to display emotional information.

In an overview of color coded hierarchical structures, we arranged all dating codes together with no consideration of the representation of non face-to-face dating time to reduce data density. As a result, different data amounts in each month reshaped the time unit into an uneven manner. Although it did not support data represented in an exact time, it effectively used interface space and improved the information readability.

At this point we thought this calendar based overview + detail view structure was promising in effectively breaking down the content into comprehensible time levels to support smooth information transition. It is also promising in revealing their interrelationships to the user and also keeping both levels visible for quick iteration (Tidwell, 2005).

**Significance of temporal data**

From overview design, we noticed temporal data. Temporal data may include non-meeting time, meeting time and meeting frequency. Compared with emotional data, temporal data was not easy to find and realize instantly, however it had significant meaning in interpreting dating experience. How frequently and how long people meet each other may reflect a situation in the dating relationship. A social behavior research result showed that in early reinforcing interaction, too frequent or too rare meets might cause the romantic relationship to become bland or aggravate an unreal fantasy (Miller and Siegel, 1972).

The non-meeting time is also significant. No face-to-face meeting time may also influence the relationship. For example, two lovers stopped meeting each other for a period, but their emotions actually didn’t stop processing. After three weeks when they met again, they may feel they were not attached as intimately as before.

Thus we assured we had two sets of data: emotional data and temporal data to present. They are associated each other to collectively function and process people’s emotional relationship.

**Reduce redundant week time unit level**

Also we noticed the one week scale was redundant in this structure. From the one month level to reduce down to one week level, the latter seemed to only provide a finer scale to category data, but did not make specific contribution to facilitate people’s browsing process. If we removed it, directly going to the one day scale, it did not seem to result in a too wide gap.
Identify the finest detail view

Another issue was whether one day scale was appropriate to serve as the finest detail view. According to our second design guideline, one day scale has an obvious limitation in providing rich contextual data. Also we noticed that data in one day scale had a relatively emotional independence. No matter how many intervals in this day, its emotions had a tight consistency and integrity, even thought this data scale seemed too limited to meet our design guideline of “data display in rich context and high resolution”. We suggested temporarily keeping it for later examinations.

Current this one year to one day hierarchical structure properly met our first design guideline. We then continued to develop it to meet the second design guideline: data display in rich context and high resolution.

5.4.4 Adjust data structure to meet rich context and high resolution display

Considering various potential reading needs, we speculated two month amount of data needed to be viewed therefore developing our current data structure. If this amount of data was viewed in the original structure (see figure 44), it would probably cause a high data density. We provide two vertical expanding techniques to display this large amount of data in broader space with a proper resolution.

Figure 45. Developed calendar based hierarchy structure with two vertical expanding techniques for reading a large amount data in high resolution
- a. Multi-week timelines technique
- b. one week expanding technique
In Figure 45, we used multi-week timeline technique (a) to transform two month data display to nine week data display. This technique did not cost too much additional space; however, it improved data display resolution from month level to week level.

On the basis of multi-week data display, we continuously provided one week expanding technique (b) continue to improve data resolution from week level to day level. We rotated each day data vertically and expanded for more detail display.

Thus these two techniques could be used to organize flexible view for user to freely view their data.

At this stage, we thought it basically met the requirement of data display in rich context and high resolution. However there were still some parts that need improvement.

- Non linear timelines with separated hierarchical levels added reading efforts and interrupted from a coherent reading.
- Different data resolution in one screen display caused confusion in reading data.

The data structure was simplified to address this in order to refine our design.

**5.4.5 Reset data scale of each level to simplify hierarchy of data structure**

Firstly, we adjusted hierarchical structure with data scale of each level. We shrank global overview from one year scale to half a year. This new scale was thought to be still adequate and proper to contain signs of risks and emotional regulation findings. This rescaling might help reduce hierarchical complexity. Secondly, we removed one week scale and continued to keep one month scale and one day scale and renamed them the middle view and the detail view. What was left were three views in total: half a year overview, one month middle view and one day detail view.

**5.4.6 Set up a speculated data set to support the whole visualization exploration**

In the global structure, we setup another large speculated data set to explore relationship based visualization structure. This was a dating journal that roughly contained the best possible stages of a relationship and its critical points to help our visualization structure designed to meet various data display. In this new data set, a full range dating trend and two persons’ obvious emotional difference were set up. Firstly, in terms of adult attachment theory (Hazan, 1994) (see 5.4.13.4 for more information), we setup a full range of dating relationship process from approach-sweet attachment-argument-fear-dismissive that included all steps from development, through to maintenance, to collapse. Secondly, we arranged some two persons’ obvious emotional difference in early and late periods, as a possible factor to negatively influence relationship development. All emotional data was setup in day based time units.
The whole dating trend

From April, this couple started seeing each other, but with infrequent contacts. From middle to late May, their meeting times increased and both people had common positive mood time in their relationship. One unpleasant event happened during this period, but it did not influence the relationship too much. In the middle of June, they underwent their first low tide. A couple of days after one argument, they tried to spend longer together to warm up the relationship. The passion was not as intense as before but still positive. Following this, they were inclined to settle in a calmer rhythm. However later, they experienced some short arguments. After that, a positive stable situation occurred followed by longer happy periods. This situation lasted until the middle of July. This time frame was out.

At the end of July, after a break, new argument occurred. In order to avoid more possible arguments, they stopped meeting for a few days to calm down. In August their relationship recovered over a few frequent and longer duration meets. Unfortunately this did not stop the arguments (in the middle of August). This time they avoided frequent meetings but still expected their relationship might recover. However, this was not the case as in September the relationship lost its energy.

Two-person obvious emotional difference

Some two-person obvious emotional difference was placed in the early attachment period (April to May) and late dismissive attachment period (September) and in early August before the biggest argument started.

After setting up the data, we started refining our design in three views.

5.4.7 Detail view design

In detail view, we directly used two design patterns we explored from the last phase to achieve its visualization. In this view, we continued to use parallel technique to display two-person color coded timelines from left to right, to reflect their one day scale’s activity (see Figure 46). Also we added a variation by using two-person arousal values to shape two parallel timelines for spotlighting their attention in dating (see Figure 47). Two views were provided together for users to choose.
5.4.8 Middle view design

We rotated one day view to the vertical manner and arranged thirty-one vertical detail views from left to right, to form the one month data view. In each one day column, from the top to the bottom, dating events were presented in twenty-four hour exact time. Thus in this pattern, by using the folded timeline technique, we could get an overview of how the relationship was going during this month not only horizontally, but also vertically. We could also see more concrete emotional details in each day column (see Figure 48).

![Figure 48. Expanded one month scaled middle view](image1)
![Figure 49. Collapsed one month scaled middle view](image2)

We created a collapsed view (see Figure 49) where all dating events collapsed to the bottom with a black line to divide each single meet within the day. From this view, we could get a straightforward view of how long they stayed with each other each day and how often they met or not during this month period. This view responded and highlighted temporal data in a display we mentioned in early data structure design.

Considering limited interface space and data readability, we did not add arousal values to shape the middle view timelines. We thought that in a limited interface space, this visual technique would not facilitate data transition. On the contrary, it would possibly reduce readability in the basic color code perception. Therefore we only displayed full filled color codes timelines (in fact, color codes inherently have already included all information in data transition). For data representation in middle view, we used the same resolution as the detail views.

In this middle view, we identified its data scale was one month fixed and we did not use a multi-week technique to open several week views was we found this middle view could support data displayed in rich context and high resolution. Compared to the calendar based hierarchical structure we developed, (see Figure 45), this middle view did not require additional operational efforts to organize data views and all data was displayed in the same resolution. Contextual data was also much easier to read in its timeline. We gave up the multi-week timeline technique and
the one week vertically expanding technique and used the folded technique to construct a one month scale middle view.

**Add external data**

Currently emotional data was used directly to interpret cause or effect of other emotions in context. To some extent, using the contextual emotions to explain the cause and results of this emotion is not very reasonable because there was not necessary bond in context. Changes in people’s dating situations are complex and depend on multiple factors. We added some external data in order to better interpret the reasons why dating relationships sometimes changed randomly and unpredictably.

![Figure 50. Adding external data in middle view](image)

In our visualization, some information could be attached to the emotional data pattern. Its content included blogs, photos, email and Instant Message (IM) history. We assumed two persons might have a virtual communication history in their non meeting time using Email or IM. They may also have a Blog and online photo album to record their ideas and dating events. These messages might contain some factors to interpret emotional changes that people can not interpret from emotions in context. We recommended adding these links to the visualization timeline (see Figure 50).

**5.4.9 Overview design**

**5.4.9.1 Overview design in different time units**

In a global view, the graphical visualization should undertake two tasks: perceiving the global overview and addressing specific interests to break down. We setup its visualization resolution lower than the middle view and the detail view (see Figure 51) in order to disregard the tiny emotional changes and to highlight the globally significant information.
Next we used various time units for organizing data, to explore a proper visualization solution.

**Day time unit overview**

Firstly we created the most basic day-based time unit pattern (see Figure 52). We connected six middle views in a horizontal manner to achieve it. In Figure 53, from left to right, it displays two persons’ dating experience in the six months from April to September. In each column, from top to bottom, one day data was linearly displayed in a 24 hour time scale. This pattern provided all the emotional and temporal data. However from its visualization we found it was a bit too raw to read since color codes were distributed everywhere in the interface. Thus we developed some variations to improve its readability.

In Figure 53, we collapsed all data to enhance color readability, which also kept events in their occurring sequence. Collapsed columns formed a temporal data pattern that could intuitively reflect dating amount each day at a glance. Considering the events happening in one day might have emotional continuity, removing dating interval space seemed to not distort data.

In Figure 54, to continue to improve data readability, we simplified the sixteen emotional reactions into five coarser emotional data categories and labeled each category by picking its representative color to continue to improve data trend reading. We called it the five coarser emotional data categories technique. Data resolution was reduced and global overview reading became apparent. Low resolution resulted in making it difficult to display two persons’ obvious emotional difference, so we removed this information from the display.
Comparing these three patterns, we found the two collapsed views in Figure 53 and 54 were easier to read than Figure 52, the first expanded one. However their readability was all still weak. A large amount of blank space diluted the color power, which prevented color codes being perceived effortlessly. Hence we decided to develop the week-based pattern as the solution.

**Week time unit overview**

In this step, we tried to use a week time unit to organize data (see Figure 55), where each column represented one week in the dating experience and was displayed from bottom to top. Although this collapsed layout blocked dating interval information, this pattern looked better than day based patterns.

Then we continued to develop its variation in five coarser emotional data categories technique (see Figure 56). As such, the color code resolution was a bit rough and the two persons’ obvious emotional difference data was left out of the display.

**Month time unit overview**

Figure 54. Day time unit collapsed overview simplified in five coarser emotional data categories

Figure 55. Week time unit overview

Figure 56. Week time unit overview in five coarser emotional data categories

Figure 57. Month time unit overview
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We used the same techniques to create month time unit patterns (see Figure 57 and 58) to determine data readability.

Through comparison, we thought the week based pattern was the most promising one. It effectively made use of vertical and horizontal dimensions in the interface space. People could have a global cognition in emotion trends, while being able to peer into the small details for further information.

Day time unit patterns, although they highlighted daily experiences, were difficult to read. Month time unit patterns were successful at rough dating experience reading, however, in terms of extreme information density or extreme brevity, they could not give enough details to lead people to address a target to break down.

Thus we chose two week time unit emotional patterns (Figure 55 and 56) to use for an overview.

5.4.9.2 Create an independent temporal data overview

In the current overview design, we only displayed emotional data. Next we tried to add temporal data to integrate the overview data display. Initially we tried to overlap temporal data with the week time united overview patterns.

In week time unit emotional patterns, collapsed columns already represented meeting numbers, so we only added the week time meeting frequency line (see Figure 59). In their patterns they did not contain day time unit temporal data. Considering our middle view was a day time unit pattern, we thought the day time unit temporal data was necessary for an overview, to develop smooth data transition between the two views.
We decided to create one another independent overview pattern to display temporal data specifically (see Figure 60). How long and how often two persons meet were quantitatively displayed in week time and day time, both as two different time units and overlapped. How long the two persons’ obvious emotional difference was in each day was added and labeled in the daytime unit columns. From the day time united pattern, we could roughly perceive how long they did not meet.

Figure 60. Week time unit and day time unit temporal data plus labeling how long two persons have obvious emotional difference in each day

Thus we had two kinds of overview patterns: two emotional data patterns (in different color code resolution) plus one temporal data pattern.

5.4.10 Hierarchical Connection

After finishing the design in three different hierarchical views, we connected the overview (bottom), the middle view (middle) and the detail view (top) into a proportional, vertical hierarchical structure (see Figure 61). In it, when selecting a one month region in overview, the middle view would respond to this selection. When picking one region in middle view, the detail view would be updated to show its details.

In each level, we had multiple interface design options. At this point we thought these designs were all significant and each one had a specific function in data transition. It was hard to pick any one to meet all application needs. Thus we left a blank hierarchical structure for people to choose at will to achieve their interaction needs. In the overview, we thought it was necessary for people to view temporal data and emotional data, at the same time, we provided two places for overview patterns. We also added a grey background to each view to improve the color code readability in a global view.

Design interfaces for each view are:

- Two detail views: color coded filled detail view and arousal valued shaped detail view
- Two middle views: expanded middle view and collapsed middle view
- Three overviews: temporal data overview, week time united emotional data overview, five coarser emotional data category organized week time united emotional data overview.
Currently we felt it was hard to evaluate and improve our design using our subjective reflection. Thus we recruited participants and organized a usability test. We then addressed their comments when further evaluating our design results.
Figure 61. Hierarchical structure and its interface options in each level.
5.4.11 Usability Test

Participants

Four participants, from 24 to 34 year old, one female and three males were employed in our test. Two came from a computer sciences background; whereas the other two came from design and media backgrounds. We chose people from different backgrounds to examine if the visualization was commonly readable for most people.

Method

We employed “think aloud” (Ericsson, 1993), a subjective qualitative methodology to test our design. We provided a blank hierarchical frame and prepared a series of still interfaces options in each level for people to choose when filling out the blank space. We did not require people to achieve a specific combination to identify our final design, or did not ask them to finish filling the blank space. We were concerned with gathering comments as they managed the views or just compared the views. Participants were encouraged to express all their thinking, feelings, and suggestions orally.

Experimental setting and Procedure

We employed Macromedia Flash 8™ to build our prototype and projected it using in a 17inch LCD with 1600*1200 screen resolutions for user operation. People were allowed to drag and move the interface options freely.

Before the test started, we explained it to the participants and allowed ten minutes for them to learn the color-emotion mapping index pattern. We allowed the pattern to be used through the whole test to facilitate data reading. Each participant was given one hour to have their “think aloud”. They were allowed to finish at any time if they thought no more comments could be given.

During the test, we made observers’ notes to collect all feedback from participants and later grouped the notes for analysis.

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1 Think aloud (also spelled think-aloud) protocols involve participants thinking aloud as they are performing a set of specified tasks. Users are asked to say whatever they are looking at, thinking, doing, and feeling, as they go about their task. This enables observers to see first-hand the process of task completion (rather than only its final product). Observers at such a test are asked to objectively take notes of everything that users say, without attempting to interpret their actions and words. The purpose of this method is to make explicit what is implicitly present in subjects, who are able to perform a specific task.
5.4.12 Findings and discussions

5.4.12.1 Hierarchical structure

Regarding the whole hierarchical structure, people thought it was basically successful. However, they did not think the one day detail view was very necessary in visualization representation because it only repeated data from the middle view with no additional information addressed. Regarding the arousal valued shaped detail view, people reported they could not make sense of it intuitively. When asked if higher resolution should be added, people reported they could not imagine what purpose it could serve. It seemed that high detail emotional data did not contribute to relationship based interpretation.

5.4.12.2 The layout of overview and middle view

Comparing the layouts of the overview and middle view, participants thought the middle views looked much clearer and were easier to understand.

Looking at the middle view, participants showed a liking to the collapsed view and the expanded view. Some people preferred the collapsed view because it was thought it made it simpler to tell how long the couple met in each day. It also visually responded to the temporal data overview in navigation and helped facilitate orientation and reduce cognition effort. The other participants showed a liking to the expanded view and they were interested in regular observations such as “whether morning times would be more possible for this couple to have a good time than in the evening.” They thought the external data supply was helpful in providing contextual factors to better interpret the reasons why the relationship changed.

Regarding overviews, all participants showed a liking to temporal data pattern and thought it could disclose a more realistic dating experience. One participant pointed out he liked this pattern more than emotional data patterns because, “it is very clear and simple to see data.” This opinion was a surprise to us, because we thought its content had limitation in navigation.

From this point, we realized the layout of week time unit overview patterns was not very easy to read. Folded timeline technique saved interface space and helped organize data in a compact view, but did not help facilitate reading. People reflected it involved some reading effort to view the data change in context. As a solution, a linear pattern might fix this problem.

From their reports, we noticed people did not mention those high active emotions that were generally thought to be a very significant influence in relationship development. We thought the reason was generally they occurred and finished in a very short span and the compact layout of overview with its disconnected timelines (columns) resulted in the detailed information being hard to read.
5.4.12.3 Color recognition

Regarding detail design, people mainly reflected that the color codes were hard to read. In the sixteen color emotional data overview and middle view, all people reported they got a basic idea of what was going on in this relationship, such as developing, maintaining or collapsing. They did not have difficulty in judging positive and negative reinforcement episodes and stable and instable situations.

However from people’s descriptions, we noticed colors were read as each discrete entity but were less often perceived in coarser categories or even in the whole warm-cold or dark-bright dimensions. In each specific color code, only some colors could be recognized intuitively.

A participant said in overview he got confused because too many colors were presented in front of him. He could only intuitively perceive the emotional meaning of red, blue, and green and yellow. Compared with orange, yellow was thought more impressive in visual perceiving. On the contrary, orange, in his opinion, was thought as a common one to ignore.

We thought there were two reasons. Firstly, too many colors were presented. When color data was over presented, only the most obvious data could be recognized. Secondly, a fuzzy mapping index establishing ambiguous connection between color and emotions with no one-to-one specific association aggravated cognition work. Even though this index pattern could be used through the whole testing for reducing thinking load, in the test, we found people did not like to use it. They were more inclined to intuitively decode colors. This was also evidence that colors were over provided.

In the sixteen color emotional data overview patterns, people reflected they found it difficult to focus on color coded patterns. They had difficulty in interpreting color codes for relationship understanding. From this feedback, we realized there was one other data mapping process between emotional data and relationship and it had not been done well. We had not contributed very much in helping to improve data understanding and reading in relationship based mapping. Even though colors could be roughly perceived, there was still a cognition gap between emotional data meanings and relationship interpretation. Our participants even suggested a system capable of automatically labeling the significant information for reading.

5.4.12.4 Color-emotion mapping index pattern

From people’s feedback on the understanding and cognition of emotions, we found they did not treat all emotional situations equally. They reflected they were more sensitive to high active and moderate active emotions than low active and they thought the former had more influence and more significance in dating relationship development. Compared to neutral emotions (in the center of color-emotion mapping index pattern), they thought outermost dominant emotions were much easier to perceive.
Thus, we summarized that high active and moderate active dominant emotions might be much easier to perceive and more functional than low active and neutral emotion (See Figure 62). In color-emotion mapping index pattern, our color settings basically match to people’s cognition priorities, however, we thought the five coarser emotional data categories were not designed properly.

With low activation emotions, people reflected it was hard to map them to specific emotional situations in their mind and it was not easy to distinguish their negative or positive inclination. People tended to equate low active emotions to neutral emotions because both of them were thought unhelpful to relationship development.

At this point, we felt we presented too many colors to label and distinguish low active emotions. In presenting the color-emotion mapping index pattern, we averagely divided colors into four orientations plus central neutral emotion group. This did not completely follow people’s emotional recognition priority. It seemed unnecessary to divide low active emotions into finer negative and positive categories. In two low active emotional categories, they contained part of moderate active emotions. Five colors from five coarser emotional data categories could not properly summarize people’s emotional experience (and were considered too rough to lead navigation). We needed to redesign our color-emotion index mapping pattern to more accurately represent the data.

5.4.13 Redesign

Next we redesigned our visualization to fix the problems we mentioned above.

5.4.13.1 Redesign hierarchical structure and interaction

When reconstructing the hierarchical structure (see Figure 63), we continued to use two-person emotional data pattern and temporal data pattern; two overview timeline patterns to lead navigation. We put two timelines on the top and bottom and enlarged them to improve data readability. We removed the one day detail view and instead the one month middle view was
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inserted between two overview timelines to work as the detail view. The collapsed view and the expanded view were kept. A button was placed on the top right corner for view switching.

In the two-person emotional data overview pattern, we rearranged all emotional data in a linear manner to better display emotional progress for easy reading. The two-person data was arranged in parallel where two persons’ emotional difference could be viewed much more clearly.

This new data arrangement resulted in the data amount varying in one month time unit. In order to avoid misunderstanding of event happening times and to better connect the two overview timelines to work together, we added time scales to the two timeline to assist visually.

When picking one month data in one timeline, the other timeline and the middle view would respond. Also we placed two scrolling arrows on both sides of the middle view to pan data for contextual viewing. This action would be associated with two overviews in interaction. We added a grey band to visually solidify connection between two overviews and middle view. When data was picked either in the overview or in middle view, the junctions of the grey band and the two timelines would respond and slide to the relative position.
Figure 63. Redesigned hierarchical structure of two overviews and two middle views.
5.4.13.2 Redesign color - emotion mapping index pattern

We followed people’s cognition model to re-plot over the color-emotion mapping index pattern. We grouped the four low active emotions (four colors on the bottom) and the four neutral emotions (four colors in the middle) into two categories with one typical, representative color from them to label the whole group respectively. Even though people subjectively equated the low active emotion with neutral emotions, we still suggested displaying them separately because technically they had specific meaning and function. Low active emotions generally mean no interest to outside; neutral emotions could be read to control the balance between self and outside. To the left, the eight high active and moderate active dominant emotions were thought as having greater function in emotional development, so they would be displayed independently. Thus finally we got ten colors codes (see Figure 64) that more accurately responded to people’s concern of emotional experience. We used them to update our overview and middle view.

![Image of color-emotion mapping index pattern]

Figure 64. People’s cognition priority in AV space and redesigned color-emotion mapping index pattern

5.4.13.3 Labeling significant negative emotions

In order to help people quickly target the significant information, we used a labeling technique to label significant negative emotions in the emotional data overview pattern. In social interaction theory, Waters, Weinfeld and Hamilton (2000) proposed that negative emotions often cause changes in dating relationships and reduce their stability. Reinforcement theory (Miller and Siegel, 1972) also shows that continuous negative emotional experiences might become fear signals to cause people to withdraw; minimizing further negative experience.

![Image of labeling significant negative emotions]

Figure 65. Labeling significant negative emotions in emotional data overview

To highlight significant information and reduce the cognition load of emotions, we labeled high active and moderate active dominant negative emotions in our visualization as risk signs to improve data understanding and reading. We marked them with block dots and block lines (if in lasting continuity) and revealed the date on a mouse over function (see Figure 65). In order to
respond to labels of significant negative emotions in overview, the same marks were placed in middle view to reduce orientating effort. These could be turned off when not required.

5.4.13.4 Label attachment styles

When people had difficulty in decoding the emotional pattern to relationship findings, we added more direct interpretation to amplify and deepen emotional data understanding. For this a labeling technique was used again. We marked four adult attachment styles to reflect the quality of romantic relationships and emotional experience (Simpson, 1990) and aligned them to a time scale of temporal data overview for better display (see Figure 66).

![Figure 66. Labeling attachment styles in temporal data overview pattern](image)

Four adult attachment styles were defined from adult attachment theory, which studies people’s interaction models with their stability in romantic relationships (Bartholomew and Horowitz, 1991; Hazan and Shaver, 1994). Adult attachment styles were 1) Secure 2) Anxious-preoccupied 3) Dismissive-avoidant, and 4) Fearful-avoidant.

Some relative research and decoding models in exploring the connection of emotional experience and attachment styles has been theoretically established (Pietromonaco and Barrett, 1997). Each attachment style is associated with deductive interpretation from emotions.

Secure attachment: is associated with a moderate arousal and balanced in positive and negative emotional responses. It has greater frequency of positive emotions and lower frequency of negative emotions than other attachment styles. (Feeney and Noller, 1990).

Anxious - Preoccupied: is associated with high active negative emotional responses and relatively low positive emotional responses. (Collins, 1996; Pianta, et al., 1996). Intensive emotionality and over-activated emotional responses in easily “go with the flow” (Miller and Noirot, 1999).


Fearful - Avoidance: is characterized by typical negative emotions with moderate arousal between anxious - preoccupied and dismissive (Collins, 1996).

Secure and Fearful - Avoidance have unisonant valence in both parties with moderate arousal. Anxious - Preoccupied is typical moody situation and would be more inclined to have two people individual emotional reaction difference than Dismissive - Avoidance. Dismissive - Avoidance is the more indifferent attitude (Collins, 1996).
According to these interpretations, we assumed a fuzzy algorithm could run through a long term data collection to work out attachment styles and label them in the timeline. We assumed this information would not be produced during short time data collection or updated daily because emotional interpretations of attachment styles describe long term interaction situations but not short time situations. Thus it could not serve as an alerting sign to report relationship risk in the early stages; but it could serve as a statistical report, summarizing previous dating situations or predicting its development in near future.

5.4.14 Evaluation of redesign

From the participants

People were satisfied with this redesign and they showed an interest in the new interaction structure. They thought its layout was innovative and made the data much easier to view. They also believed the interactive relation among two overviews and the one middle view was interesting. The flexible browsing was also deemed successful.

The two expanded timelines were thought to improve data readability and provide more space to add further information. Regarding the different time units of the two timelines, we asked participants if it caused confusion. The answer seems very positive. They thought the middle view could effectively connect the two different overviews in working together. No matter which overview they started on, it was not hard to orient in the middle view. The grey band was also helpful in improving visual connection.

As for the linear emotional data overview pattern, people were very satisfied. One participant stated, “There I can perceive the relationship in its trend straight away.”

We used ten the color codes to construct the overview and the detail view. As a result, participants showed a liking to the simplified color codes. Compared to sixteen colors, ten color coded views were much clearer and made it easier to see the high active and moderate emotions and two persons’ obvious emotional difference.

Participants labeled information, including significant negative emotion and attachment styles, people thought it helped them extract the significant information. This avoided unnecessary wandering and facilitated understanding of the whole data pattern.

We asked whether there was a need to add one more one month detail view to allow highly detailed data comparison between different months. People thought that one was proper, and that no more were needed. They reported they could not imagine what the data comparison was for. Our current visualization span was half a year. This limited the possibility of seeing similar patterns. In the current interaction structure it was easy to see contextual data; so pattern comparison was deemed unnecessary.
From the designer

Finally, we used our initial design guidelines to evaluate our design results.

- global overview + detail view
- data display in rich context and high resolution
- simple hierarchical structure

Firstly, our hierarchical structure met the requirement of global overview + detail view. Secondly, only two hierarchical levels were set up that met the simple hierarchical structure. Thirdly, the folded technique supported middle view data displayed in rich context and high resolution. Thus from our subjective evaluation, we thought this present design result responded to our design guideline.
6.1 Key findings and conclusion

The purpose of this project was to develop various visualizations of speculated emotional data generated by two persons in a face-to-face dating experience. Two major objectives addressed have been explored and discussed.

- Studying what emotional data is significant in reflecting people’s dating experience
- Exploring the optimal techniques for visualizing this data for analysis and recollection.

As a result, we summarize our significant findings as follows.

Significant findings in representing the dating relationship
- It is important to make two persons’ significant emotional differences obvious.
- Temporal data of how long and how often two persons meet is useful for understanding the dating relationship process and management.
- Adult attachment theory with its four emotional attachments styles is useful for interpreting a large amount of emotional data for relationship level understanding.
- High active and moderate active dominant negative emotions are important to highlight to evaluate relationship risks.
- External data is useful for adding contextual information of factors for emotional changes and relationship changes.

Visualization techniques to represent these data points were as follows
- Color coded technique
- Parallel technique
- Labeling technique
- Adding technique
- Two overview technique
- Overview + detail view interaction technique and their view scales
- Folded timeline technique
- Collapsed middle view

Color code technique

Color, as the simple abstract emotional metaphor, inherently has two dimensions, the bright-dark dimension and the warm-cold dimension. They might be able to effectively map arousal and valence dimensions and transform a pair of AV numbers into an intuitive emotional expression. As the emotional metaphor, it can effectively combine two dimensional emotional data into one simple and single entity, reducing visualization complexity and facilitating intuitive emotional information perception, especially when a large amount of data is to be displayed.
In order to respond to people’s emotional recognition and facilitate significant data reading, we grouped neutral emotions and low active emotions into two groups disregarding their positive-negative values.

**Parallel technique**

Regarding two-person relationship data, we displayed it in parallel, where not only can we track their mutual emotional trend, but also we can see two persons’ obvious emotional differences in order to identify potential relationship risks. Also, when the user reads his/her own emotions, it is always in contact with their partner’s emotions as well. It is thus a good way to display relationship based information.

**Labeling technique**

When a large amount of color data is displayed, people have cognition limitation in retrieving the relationship based findings. In order to improve the color code mapping, we added a labeling technique to assist the significant data of the relationship to be viewed quickly.

Some significant information was highlighted, including high active and moderate active dominantly negative emotional situation and dating relationship attachment styles. The former reflects the potential relationship risks; the latter transforms emotional data into relationship based interpretation and summarizes the relationship in different attachment situations. This helps people amplify data reading and understanding, and fill in a cognition gap of emotional data understanding. The latter is limited in serving for risk signs; however, according to its summary, people can predict a relationship developing trends in the near future.

**Adding technique**

As we use emotion to interpret other emotions in context, in order to better interpret emotional experiences and changing reasons, we added external ambient data in order to help people have better understanding and interpretation of emotion and relationship changes. This external data may include factors such as two lovers’ communication history in non-meeting time such as IM, email, blogs and online photos, being incorporated in our visualization timeline. These messages might record some of their dating events and may contain some factors which may be useful in interpreting emotional changes that can not be interpreted through contextual emotions.

**Temporal data and two overviews timelines technique**

In our relationship visualization, we present emotional data and temporal data as two sets of data to represent people’s dating experience. Temporal data is thought to be easily ignored but is
Conclusion and Future Work

actually very significant for reflecting on a relationship situation. In our project, this temporal data is associated with how long and how often people meet each other and is displayed in day time unit and week time unit. These two sets of data are associated with each other and mutually progress relationship development.

In overview, two independent timelines patterns were used to specifically highlight emotional data and temporal data separately in order to get them to be viewed much more easily and directly.

**Overview + detail view interaction technique and their views scales**

We set up three design guidelines to guide the viewing structure design. They are

- Global overview + detail view
- Data display in rich context and high resolution
- Simple hierarchical structure

We connected two overviews and one detail view to construct a simple two level interaction structure. We identified half a year and one month as the overview and middle view data scales. We thought the half a year data scale might be able to contain enough risk signs to alert people before the relationship collapsed. The one month detail view data scale with the folded timeline technique could have data viewed in rich context and high resolution to see relationship details. This interaction structure might effectively support emotional data reading for relationship interpretation.

**Collapsed technique**

In the detail view, not only did we provide an expanded display to view data in exact time, but we also provided a collapsed view to quantitatively view temporal data. These two views respectively respond to emotional data and temporal data overviews and reduce orienting efforts in switching between the two hierarchical levels.

**6.2 Limitation**

In this project, our visualization design has a limitation. We temporally used speculated data to develop our design. However, we did not measured how it really works in the graph. We do not know how wildly emotions would change if real data was used.

We assumed it would not all look like our visualization. If its resolution becomes very subtle, the visualization would be unreadable. If its resolution becomes broad, average technique would make its visualization flat. In this case, some significant emotional data such as sudden high active emotions would possibly be missed thereby to cause improper interpretation of data.
Improper resolution would not effectively reflect the real dating relationship situation for people to have correct reading and understanding.

6.3 Future work

Currently we have finished a series of prototypes in exploring the two persons’ face-to-face dating relationship visualization. Currently the result is thought to be satisfying. However we think there is still some room for improvement. Some ideas for approaches to future work include:

Allow users to customize their own algorithm for more accurate measuring

We noticed an issue of individual personality diversity. For example, in a couple, one is usually introverted and likes to stay in a calm and low active situation while the other is inclined to be extroverted and more easily activated emotionally. If the personality difference is not a problem in their relationship, our fixed thresholding value could mark this difference as problematic. In order to more accurately reflect this data, we suggested an algorithm, inviting the user to customize their threshold values.

Allow personalization on visual representation

User from different countries and cultures may have their own preference and choices between colors sets or icons to interpret data. This may allow them to feel they have more control over the information being presented. For example, in some cases user would like to use red to represent issues and problematic parts and use green to represent a good period. In certain levels, red becomes a negative visual hint and not emotionally positive any more.

Furthermore, people from different age groups may prefer different ways to present their data. For example, the young people would prefer to use vivid metaphor symbol with bright colors, for example, emoticons to visualize their emotional experience. Whereas someone more middle aged would prefer a serious application of visual information. We suggest providing personalization features to allow them to create and use their visual presentation techniques to better interpret the data.

Considering more emotional situations in different scenarios details

Currently our project is roughly made in two-person face-to-face scenario; however, we have not identified more details in this scenario. Imagine a situation when two lovers were watching a film in the theater and were moved, they might be both evoke a high response. However, this emotional data would not be a result of their relationship experience. Once this record is projected in the dating relationship visualization with no additional label, people would directly associate it into their emotional relationship interpretation. This might cause data misunderstanding.
More situations should be considered. How to identify the influence of less relative information on relationship development should be addressed in future study.

**Produce more data sets to explore new discoveries and application.**

Our design was built up in one speculated data set only. We can not guarantee it has definitely included all stages and key points of a dating relationship. More diverse data sets should be recruited to continue to test our visualization. Considering the distance between technological development and technology application, to see a wearable device with specific bio-sensor applied in this dating scenario to collect emotional experience of different types of couples in their real life is still in the future. A low cost method is to study relative emotional theories and social interaction theories to theoretically setup more types of dating situations and relationship models to examine and enhance our design.

One of possible new study areas could be color schema. Specific attachment relationships might be associated with specific color schema. Also, different people’s personalities would probably be reflected on specific color schema. For example, introverted people often have grey colors or negative people may frequently have cold colors.

Another area for future examination could be whether it is possible to successfully establish a connection between some color schema and the two-person relationship model or people’s individual personalities. If long term data could be symbolically simplified into a color schema, we can then test the readability of the color schema to see if people can intuitively understand its meaning. And we then can expand its applications in quick information delivery, like improving self-awareness of what type of person I am, asking suggestion from the psychiatrist for a relationship better management or seeking a matching partner to establish a more successful and stable relationship.
References

Books


Online Resource


Moodgrapher (2005) Information and Language Processing Systems Informatics Institute, University of Amsterdam, retrieved August 8, 2006, from http://ilps.science.uva.nl/MoodViews/Moodgrapher


