

Available online at [www.sciencedirect.com](http://www.sciencedirect.com)**SciVerse ScienceDirect**

Procedia Technology 5 (2012) 670 – 678

**Procedia**  
Technology

CENTERIS 2012 - Conference on ENTERprise Information Systems / HCIST 2012 - International  
Conference on Health and Social Care Information Systems and Technologies

## A Description of the Development and Architecture of an SMS-Based System for Dealing With Depression

Elizabeth M. La Rue<sup>a\*</sup>, Yunzhe Li<sup>b</sup>, Hassan A. Karimi<sup>c</sup>, Ann M. Mitchell<sup>a</sup>

<sup>a</sup>*School of Nursing, University of Pittsburgh, 415 Victoria Building, Pittsburgh, PA, 15213 USA*

<sup>b</sup>*Software Management Inc., 250 Mt. Lebanon Blvd, Pittsburgh, PA USA*

<sup>c</sup>*Geoinformatics Laboratory, School of Information Sciences, University of Pittsburgh, 713 IS Building, Pittsburgh, PA, 15213 USA*

### Abstract

Depression is one of the leading mental health disorders in the world. With an exponential rate of growth the disease will soon surpass the ability for health care professionals to monitor and treat individuals with the disease. This paper describes a software system that continuously monitors an individual's emotional state through SMS and responds to the individual with supportive text messages. The development of the queries and responses is described along with the functioning hardware and software for the system.

© 2012 Published by Elsevier Ltd. Selection and/or peer review under responsibility of CENTERIS/SCIKA - Association for Promotion and Dissemination of Scientific Knowledge. Open access under [CC BY-NC-ND license](https://creativecommons.org/licenses/by-nc-nd/4.0/).

*Keywords:* Mobile phones, Depression, Health monitoring, Mobile Monitoring

### 1. Introduction

Depression, currently affecting 121 million people [1-3] is one of the most common mental health disorders in the world. This has led the World Health Organization to predict that by 2020, depression will be the leading cause of disability worldwide [4]. Fortunately, this mental health disorder is one that can be effectively treated through antidepressant medications and/or psychotherapy (talk-therapy) [5]. But, with the exponentially increasing number of people suffering from depression and needing treatment, it will soon if it

\* Corresponding author. Tel.: +0-000-000-0000 ; fax: +0-000-000-0000 .

E-mail address: [eml17@pitt.edu](mailto:eml17@pitt.edu).

is not already, be greater than the supply of clinical specialists available for treating it. In order to extend and enhance existing forms of care offered for individuals with depression, we present in this paper a SMS-based software system (COMPANION) that monitors in real-time, an individual's subjective emotional state and provides appropriate emotional support through clinician built SMS. The intent of this COMPANION is to provide a new means of assisting people in coping with mild to moderate depression.

Differences in depression can signal different stages of disease progression or different degrees of symptoms. For instance, individuals suffering from major depression will experience an inability to function in normal daily activities and have a combination of symptoms that may include disturbances of sleep, changes to appetite, and fatigue, to name a few [6]. Treatments for this level of depression can be a single mode (medication) or a combination (medication with talk therapy). COMPANION is intended to be used by individuals with a lesser degree of depression, labeled mild to moderate depression. Some of the symptoms these individuals experience are persistent sadness, feelings of emptiness, decreased energy, difficulty concentrating, and loss of interest in activities [6]. Assistance through SMS is the idea that by receiving personal inquiries about one's health and immediate feedback through a personal mobile phone, the individual will feel: 1) they are valued, 2) someone is expressing genuine concern in them, and 3) they too have a reason to interact with another via their mobile phone.

This paper will contribute to the science by presenting a description of COMPANION. It will cover the following: the technical components, the development of emotional state queries and the support text messaging system. The paper is organized into the following sections: Section 2 discusses the concept of COMPANION; Section 3 presents the technical components and the development of COMPANION; Section 4 discusses the unforeseen difficulties in implementation; and, Section 5 concludes by discussing future work.

## **2. COMPANION-SMS: Concept**

The concept behind COMPANION-SMS is to simulate a spontaneous communication exchange with an individual who provides genuine interest, meaningful feedback, and support to the receiver (who has mild to moderate depression). To do this, two things must happen. One, the user must put forth some effort in communicating with the system through their mobile phone and two, COMPANION-SMS must act spontaneously to maintain the user's interest while not over burdening them with queries. The ultimate goal is to have the user build a rapport with COMPANION so the system can learn and adapt to the user's needs and routines while providing constructive behavior modifications that may positively reduce their depression symptoms.

### *2.1. COMPANION-SMS Content Development*

To develop the queries, answers and responses for COMPANION-SMS, three mental health clinicians and three validated questionnaires were utilized. Fifteen emotional state queries with multiple choice answers were ultimately developed with the clinicians, the Beck Depression Inventory II, the UCLA Loneliness Scale, and the SF-12v2 (a quality of life questionnaire). All questions and answers were modified to fit the 160 character limit for SMS transmission. The modifications consisted of abbreviating words in ways that have become appropriate in SMS and sometimes leaving out words and punctuation to fit the query and answers into a single text message.

After an individual responds to a query an emotional state support response message was automatically delivered to the user. The user was provided a minimum of four answers that were tailored to each query. Each answer had a minimum of four customized emotional support responses. Depending on how a user answered a query, there were some answers that resulted in a response that engaged the user in a sequence of

questions and answers. This was created to simulate more of a human-2-human conversation. For example, if the user received the query, “How depressed do you feel now?” and responded with the answer, “A great deal,” COMPANION-SMS might respond back to the user, “It sounds like u need a little help today. May I provide a hotline number for u so u may talk to a person?” If the user then responded, “Yes,” COMPANION-SMS would then send the phone number via text.

The emotional state support messages were intended to positively support an individual’s response if they responded in a positive way. If their response was not emotionally positive, then the emotional state support messages offered reminders for positive behavior change or a simple message of reassurance. An example of a reassuring message is, “Don’t push yourself too hard. Do what u can do.”

To ensure minimal user effort to interact with COMPANION through a mobile phone, an alphanumeric code was established for each optional answer provided with the query. For instance, on a multiple choice test answers are usually listed as A, B, C, and D. Because COMPANION-SMS was built to be platform as well as device independent, using A, B, C, or D would not work as a defining text message response; nor would 1, 2, 3, or 4. Mobile phone keyboard designs and the need to create unique identifiers for each query response mandated that all guided answers be presented with 1A, 2B, C3, or 4D for submitted responses. In this way, flip phone models and third generation smartphone users could respond with minimal typing to COMPANION-SMS queries.

## 2.2. COMPANION-SMS Message Frequency

To make COMPANION-SMS unobtrusive, SMS queries were sent only during appropriate communication times, 8am to 8pm Eastern time, four times a day. The first message was sent at 8am every morning. Because 200 minutes were allocated for a user to respond to a query, communication had to begin at a set time and end at the established time. The remaining three messages for the day were randomly sent. This was done to ward off user complacency with COMPANION. If the user did not respond to a query within 90 minutes COMPANION would send a SMS saying, “We have not heard from you...” then resend the unanswered query. If the user did not respond to the resent query no more requests were solicited for that response and the system noted the interaction as incomplete. One hundred seventy minutes after the incomplete conversation, the system would send a different query.

To simulate a human responding to a text, COMPANION was programmed to send its emotional support message in 7 or so seconds after the user answered a query. This helped to simulate a typical text message interaction. The delay also inferred that the response to the answered query was actually read, considered, and typed.

## 3. COMPANION-SMS: System Architecture

The COMPANION-SMS system consists of five components as depicted in Figure 1: the Server, XML Question file, Database, gateway, and smartphone.

System functionalities are programmed primarily with the Java programming language. A MySQL database hosts data storage and querying. In the MySQL database the phone number acts as the unique identifier for each subject. Time stamps for each message transmission are stored and the time stamps are associated with the phone numbers in the database. A gateway server is used to transmit messages to and from personal mobile phones and the MySQL database hosting server. Because a large quantity of text messages would be delivered and received, COMPANION-SMS, required a third party SMS gateway server software company. This permitted COMPANION-SMS to be scalable and a method for managing contacts (phone numbers) as well as the content of messages sent. Using the third party SMS gateway server also

enables SMS to be sent to mobile phones without requiring knowledge of the mobile carrier. e.g. Verizon, Sprint. The gateway server pushes all data from the users to the MySQL database.

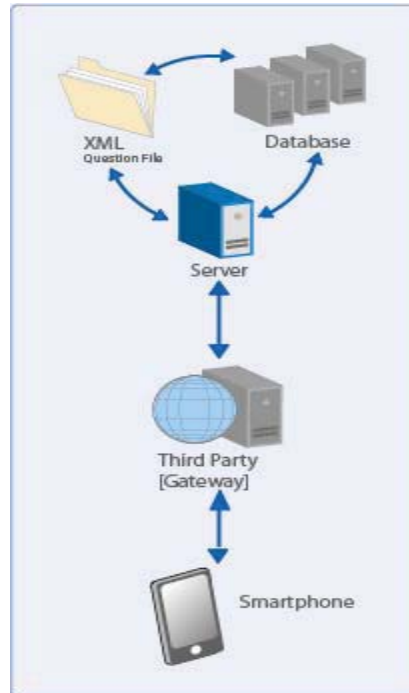


Fig. 1. COMPANION-SMS architecture

Using Java the random message selection and delivery time is controlled through the Quartz job scheduler [7]. Anytime a phone number is added to the system the Quartz job scheduler randomly assigns four of the 15 queries to be sent. The 15 emotional state queries and guided responses are coded in XML so they could read by the application.

### 3.1. XML Question File Structure

Using a tree structure for the XML encoded emotional state queries and guided responses permitted each query to have a unique ID for easy identification. Because COMPANION-SMS is a query and response system for emotional health, there are multiple roots in the tree structure. Each root targets a specific aspect of an emotional health message identified by a representative ID for the message content. For example, an emotional support response message that is a question is labeled with the letter 'R.' An emotional support message that is not a question is labeled with "S." Any message labeled with an 'S' signals to the server that the conversation has been completed. The nodes of the tree structure are shown in Figure 2. The queries and guided answer options are stored in the leaves (an index table).

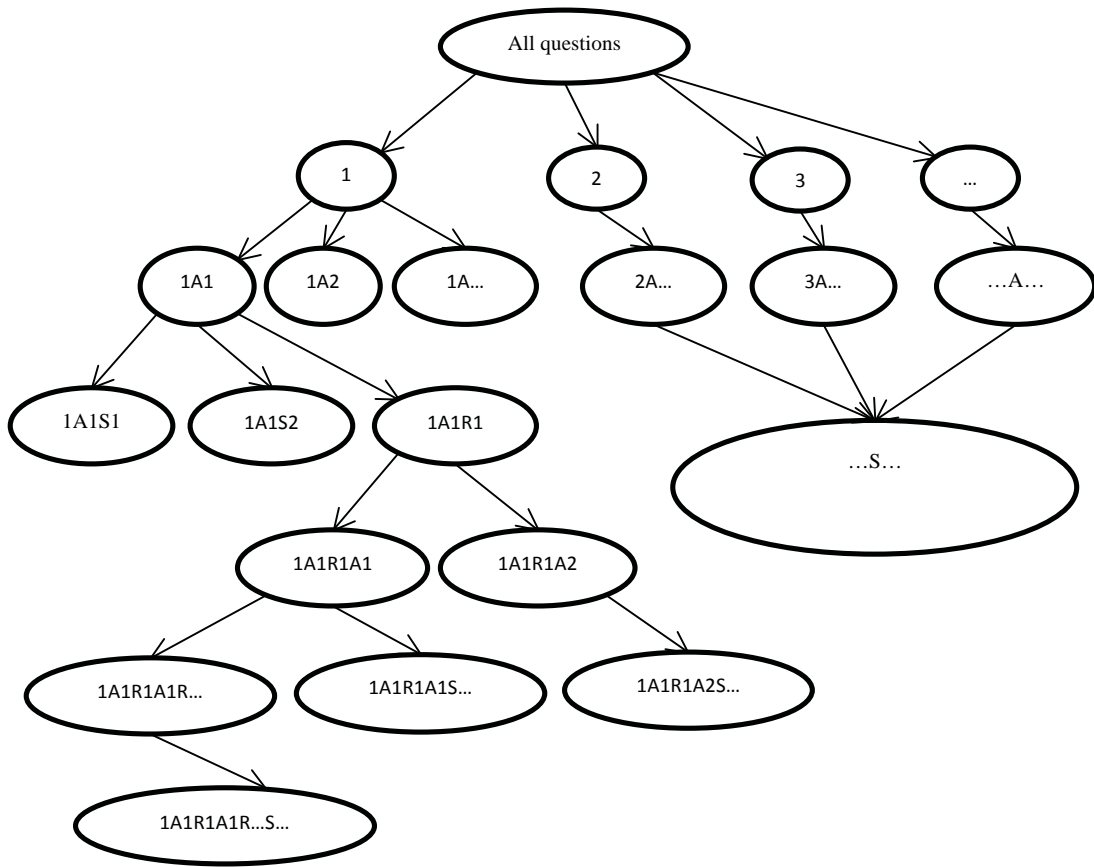


Fig. 2. Emotional State Query and Response Tree. The numbers represent the query. A to D represent the guided answers while R and S signal the form of communication.

### 3.2. Database

The database, in MySQL consists of four tables: Constant table, Users table, Questions table, and Output table.

Constant table: To send queries at a random time a number x between 160 and 200 is generated. The value of x number then regulates the delivery time of the queries. For example, after x minutes of the last query being sent, the application will wait before sending the next pre-determined query. Since this information will be read many times, it is stored as a constant value in a table. Another attribute in the Constant table is labeled 'index' to record how many queries had been sent during a day. This is necessary because some initial responses have follow-up questions that simulate a 'real texting' conversation. If COMPANION-SMS has four randomly pre-selected queries and the user answers all four of them, it can be determined that the time of day the messages were sent was appropriate. If the user does not respond to the initial query but responds to the second, then an analysis of the delivery times can demonstrate the time of day the user is more likely to respond or need an simulated social interaction.

Users table: Only data used for communication such as phone number and responses are stored in the Users table. The day individuals begin to receive COMPANION-SMS and stop receiving SMS are kept in the table. Keeping track of the start and end dates assists in the collection of the number of messages exchanged between COMPANION-SMS and the user during a specified period of time.

Table 1. Questions table

Column Name	Type	Null
phonenumber	varchar(45)	No
day1	varchar(45)	Yes
day2	varchar(45)	Yes
day3	varchar(45)	Yes
day4	varchar(45)	Yes
day5	varchar(45)	Yes
day6	varchar(45)	Yes
day7	varchar(45)	Yes
day8	varchar(45)	Yes
day9	varchar(45)	Yes
day10	varchar(45)	Yes
day11	varchar(45)	Yes
day12	varchar(45)	Yes
day13	varchar(45)	Yes
day14	varchar(45)	Yes
currentquestion	varchar(45)	Yes
timesent	varchar(45)	Yes
currentday	int(45)	Yes

Questions table: To ensure server stability, all queries are stored outside of the database. This minimized the data load on the server. As noted earlier the Quartz job scheduler controls the timing of messages delivered but it does not assist in selecting questions. To ensure delivery of the randomized questions delivered to the user, a function which is activated anytime a new phone number is entered into the system, was developed. After the function has selected questions from the xml question file it populates the Questions table. The sequences of questions (see Table 1) are stored as one record in the questions table with the phone number used as the primary key. Because each day is represented as a column with 4 IDs, a query index needs to exist as an index in the constant table. This helps the application which substring to look for in a day. The value in the currentday column works the same way as the index by helping to locate which day the corresponding subject is active.

Output table: This table (see Table 2) stores all the conversations. Except for the primary key phonenumber, smsid sent, is the most used value read within the system. It helps the application in knowing the next step when a message comes from a certain phone number. The table also holds a record for every message the application sends to a subject. Through the tree structure created for the messages, the system knows when a response is expected from the message code. When the subject responds to the query, the application updates the response value and takes the next action based on the situation.

Table 1. Output table

Column Name	Type	Null
phonenumber	varchar(45)	No
smsidsent	varchar(45)	No
Senttime	varchar(45)	No
response	varchar(45)	Yes
Day	varchar(45)	Yes
receivedtime	varchar(45)	Yes
transactiontime	varchar(45)	Yes

There are four types of message codes: Incomplete response (CODE: 250); Complete response (CODE: 500); Voluntary message (CODE: 401); Repeat query (CODE: 100). The message code can be easily used for categorizing messages and providing quick support. These codes will be discussed in the next section.

### 3.3. Information flow

A successful communication transaction involves the user responding with one of the provided answers to the emotional state query, followed by a support message. This would result with the code 500 in the Output table.

When a user does not respond to a query the code 100 appears in the Output table and the query is resent. After a user does not respond for 90 minutes, the system sends, “We haven’t heard from you,” then repeats the unanswered message. If there is no response then the conversation will be closed and response code 250 signals an incomplete communication transaction. If at any point during the three hours between messages the subject responds and completes the conversation, the response code will be set to 500. This process occurs four times a day for each subject.

After 8pm COMPANION-SMS runs a system back-up and stores all communications for that day. Any changes to the system can only occur during 8:00pm and 5:00am. To ensure data integrity new phone numbers can only be entered between 5:00am to 8:00am (see Figure 3). Any newly added number will begin receiving queries on the day of its entry into the system.

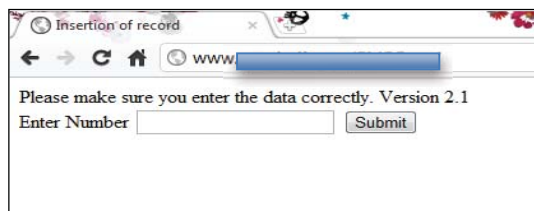


Fig. 3. Interface for activating phone numbers to receive text messages from COMPANION-SMS

## 4. Server Consideration and Issues

To ensure user privacy, three layers of security are established for every SMS transaction through the system. The data is not available for viewing, or accessible, by anyone other than the research team. All data is stored locally and only data IDs are passed through the gateway.

Because COMPANION-SMS's queries are sent through a third party gateway server, a six digit ID number attached to the SMS appears to the receiving phone instead of a standard ten digit phone number. If a message does not get delivered to the users phone, there is no way for the COMPANION-SMS system to know this. Only by manually inspecting the transmission data was it noticeable that some individuals were not responding to any of the emotional state queries. After directly contacting the users and speaking with them was it discovered that the users had sent, 'STOP' as a command to cease text message delivery from gateway servers. This prohibited COMPANION-SMS text messages from successfully reaching the users. To reactivate the receipt of gateway server delivered SMS the users sent 'HELP' as a text message to the gateway server. This released the hold on their phone number by the gateway server and permitted delivery of SMS through the gateway server. Without human data monitoring, there is still no way to confirm delivery of SMS via the gateway server.

Some mobile phone service providers place blocks on 'premium text messages' unbeknownst to the customers. The definition of what a 'premium text message' seems to change between service providers. What is the same though is that the service providers stop the transmission of text messages from a gateway server from reaching the mobile phone. Again, there is no way to detect that messages are not being received unless the user reported that they were not receiving messages or the manual inspection of data transmission showed a stream of unanswered queries. To verify that no COMPANION-SMS was being transmitted, direct contact was made with the user to troubleshoot the delivery issues. Ultimately the solution was for the user to call their service provider and explain that they wanted to be permitted to receive 'premium text messages.' Once their service provider removed the lock, COMPANION-SMS's messages transmitted easily to the user.

Some of the emotional support messages instigated unforeseen text responses from the users. For instance, the emotional support response, "How about trying a walk around the block?" was intended to be a rhetorical question not needing a response. The clinicians feel that presenting a behavior change as an option has a greater likelihood of the individual actually doing the activity instead of telling the individual what to do. While this may work in voice-to-voice or face-to-face communication, it was not 100% via SMS. Some users sent a text response to COMPANION. The system was able to collect the text responses and also insert the code 300 to signal an unauthorized data entry. COMPANION-SMS responded to any unsolicited SMS from the user with, "Thanks. We hope you are doing ok!" While it may not have made sense to the user it was felt that receiving a response to an unsolicited text was better than no response.

## 5. Conclusions and Future Work

More emotional state queries and responses will be designed and added to the COMPANION-SMS database. As users begin to interact more with COMPANION-SMS intelligent functionality can also be added to the system. For instance, prediction algorithms can be designed to forecast what type of query a user needs at a specific time of day to provide emotional support or behavior change.

A second area of development for COMPANION-SMS is the design of location- based monitoring to provide context-aware messages. By knowing the users physical or geographic location, COMPANION-SMS could correlate the users emotional response to the environment and send an appropriate text messages to assist the user in real-time. This SMS could then either be a behavior change suggestion or an emotional support message.

COMPANION along with these additional features hold the potential to aid in indicated prevention efforts for depression. They may also extend existing mental health professionals treatment approaches and reach for individuals who have mild or moderate depression.



## References

- [1] American Psychological Association, *Publication Manual of the American Psychological Association*. 5th ed. 2001, Washington, DC: American Psychological Association. 439.
- [2] National Institute of Mental Health. The numbers count: Mental Disorders in America. [Internet] September 6, 2007, May 22, 2008 [cited 2008 May 23]; web page]. Available from: <http://www.nimh.nih.gov/health/publications/the-numbers-count-mental-disorders-in-america.shtml#MajorDepressive>.
- [3] World Health Organization. Depression. 2008 [cited 2008 November 16]; web page]. Available from: [http://www.who.int/mental\\_health/management/depression/definition/en](http://www.who.int/mental_health/management/depression/definition/en)
- [4] Lopez, A.D. and C.C.J.L. Murray, The global burden of disease. *Nature Medicine*, 1998. 4: p. 1241-1243.
- [5] National Institute of Mental Health. The numbers count: Mental disorders in America. 2009 July 23, 2010 [cited 2010 July 27]; web page]. Available from: <http://www.nimh.nih.gov/health/publications/the-numbers-count-mental-disorders-in-america/index.shtml>.
- [6] National Institute of Mental Health, What is Depression, N.I.o. Health, Editor 2011, NIH: Bethesda, MD.
- [7] Terracotta I. Quartz: Enterprise Job Scheduler. 2012 [cited 2012 June 21]; web site]. Available from: <http://www.quartz-scheduler.org/>.