UNSAID: a Universal System for Auto-Detecting Cognitive Impairments

**1. Automatic Task Assistance for People with Cognitive Disabilities in Brushing Teeth- A user Study with TEBRA system.**

People with cognitive disabilities such as dementia and intellectual disabilities have problems while performing ADLs (Activities of Daily Living). ATC (Assistive Technology for Cognition) aims to compensate for decreased cognitive functions. ATC systems must be context aware which means feedbacks from the users is not necessary to provide assistance. ATC must also handle spatial and temporal variance in execution of behaviors such as different movement characteristics and different velocities. Similarly, TEBRA (TEeth BRushing Assistance) system assists people with moderate cognitive disabilities to brush teeth. TEBRA systems handles spatial variance in a behavior recognition component based on a Bayesian network classifier. A dynamic timing model deals with temporal variance by adapting to different velocities of users during a trial.

Implementation of context aware systems is difficult since the ATC system must deal with spatial and temporal variances shown by people with cognitive disabilities during execution of tasks.

Spatial variances refer to the differences in the execution of behaviors due to different motor abilities which result in different movement characteristics amongst individual users.

Temporal variance refers to the differences in velocities of task execution.

In this article, the design, development and evaluation of a novel context aware ATC system is described. This ATC system is robust with regard to spatial and temporal variance of users.

TEBRA system consists of a normal washbowl with single-lever mixer tap and mirror, a TFT display, speakers as prompt devices. To identify the user behaviors a set of unobtrusive sensors for environmental perception were used. Therefore, the user does not wear any sensors but sensors are placed into the environment around users. Two cameras were used. One camera was used to observe the environment from an overhead perspective and captures the counter and sink region. Another camera observes the users upper body and face. To determine the tap condition, a flow sensor was installed at the water supply for tap. It measures the water flow and provides binary on/off signal. An x-imu sensor was installed in the handle of an electric toothbrush and transfers data through Bluetooth connection. The sensor has nine degrees of freedom, a gyroscope to measure angular velocity of the change in orientation, an accelerometer providing gravitational acceleration and a magnetometer measuring the earth’s magnetic field in the x, y and z axes.

Prompting in verbal medium rather than the visual medium provides more direct augmentation of executive function due to close relationship between language and executive function in the human brain(Simulating naturalistic instruction: The case for a voice mediated interface for assistive technology for cognition: O`Neil and Gillespie).

A male voice was preferred to a female voice.

Short commands were preferred over long commands.

Visual cue alone was not found sufficient and audio command was also needed to grab attention of users.

Either pictograms or real life videos were found to be useful.

**2. Critical review: Cognitive Function and Assistive Technology for Cognition: A systematic review**

ATC (Assistive Technology for Cognitive Impairments) still contain problems such as novelty and complexity of ATC for people with cognitive impairments(LoPresti et. al. 2004) and mismatch between users cognitive profile and prescribed ATC (de Joode et al., 2010). The conclusion of LoPresti et al. (2004, p. 25) to their review of the field remains valid: “very little is known about the relationship between, on the one hand, the clinical characteristics of persons with cognitive impairments, and on the other hand, the specific characteristics of ATC interventions that are most suitable for those individuals.”

International classification of Function (Utsun, Chatterji, Bickenbach, Kostanjsek, & Schneider, 2003; World Health Organization, 2002). The ICF is a framework for measuring health and disability at individual and population levels.

ICF classifies cognitive functions into 10 categories:

1. Attention Function
2. Memory Function
3. Psychomotor Function
4. Emotional Function
5. Perceptual Function
6. Thought Function
7. Higher Level Cognitive Function
8. Calculation Function
9. Mental Function of sequencing complex movements
10. Experience of self and time function

Similarly, activity domains for ATC support are classified as following:

1. Learning and applying knowledge
2. General tasks and demands
3. Communication
4. Mobility
5. Self-care
6. Domestic Life
7. Interpersonal interactions
8. Major life areas
9. Community, social and civic life

ICF does recognize assistive technologies however, does not classify assistive technologies for use.

ISO (International Standardization Organization) does classify assistive technologies however, the classification is not relevant for cognitive function. Therefore, a new classification is created which is more relevant for cognitive functions and disabilities.

1. Alerting: Devices which draw attention to a stimulus that is present in the external or internal environment

2. Reminding: Devices which provide a one way usually one-off time dependent reminder about something(eg: reminder of an appointment)

3. Micro-prompting: Devices which use feedback to provide detailed step by step prompts guiding user through an immediately present task

4. Storing and displaying: Devices which store and present episodic memories, without being a time-dependent impetus to action

5. Distracting: Devices which distract users from anxiety provoking stimuli such as hallucinations

**Devices created for cognitive functions:**

**1. Attention Functions:**

**a. Neglect Alert Alarm: This alarm is activated when the user has not moved their neglected limb within a prescribed period of time causing the user to attend to neglected space to terminate the alarm(Robertson, North, & Geggie, 1992; Robertson, Hogg, & McMillan 1998).**

**2. Calculation functions:**

**a. No particular ATC however, a single case report of ATC successfully assisting with subtraction in a participant with dyscalculia (Martins, Ferreira, & Borges, 1999)**

**3. Emotional Functions:**

**a. Personal Stereos: Used to manage the distressing affects of auditory hallucinations in people with schizophrenia (Feder, 1982; Johnston, Gallagher, McMahon, & King, 2002; McInnis & Marks, 1990; Nelson, Thrasher, & Barnes, 1991)**

**b. Bio-Feedback Devices: These devices are used for people with anxiety related conditions (Reiner, 2008)**

**4. Experience of Self and Time Functions:**

**a. Only ATC which supports this cognitive function impairment is related to awareness of location (i.e. Navigation)**

**Robinson et al. (2009) describe the development of two devices which use GPS to locate the user.**

**Chang, Tsai and Wang(2008) used a series of tags**

**Kirsch, Shenton, Spirl et al. (2004) symbols in the environment to provide basis for context dependent navigation using a PDA.**

**Morris et al. (2003) developed an intelligent mobility platform that generates a representation of location using sensors and guides the user on this basis.**

**Liu et al. (2008) developed an ATC that guides user based on an internal map of the environment.**

**5. Higher Level Cognitive Functions:**

**a. ICF divides higher level cognitive functions into 7 categories:**

1. **Abstraction**
2. **Organization and planning**
3. **Time management**
4. **Cognitive Flexibility**
5. **Insight**
6. **Judgment**
7. **Problem-solving**

**Various ATCs are developed for time management (33 studies) and organization and planning (25 studies).**

**Aural and visual reminders such as:**

**i. Voice recorders with timer functions(Van den Broek, Downes, Johnson, Dayus, & Hilton, 2000; Yasuda et al., 2002)**

**ii. Text messaging to mobile phones (Pijnenborg, Withaar, Evans, van den Bosch, & Brouwer, 2007)**

**iii. Voice messages to phones (Leirer, Morrow, Tanke, & Pariante, 1991)**

**iv. Reminder function on a smartphone (Svoboda & Richards, 2009)**

**v. Schedule software on a PC (Flannery, Butterbaugh, Rice & Rice, 1997; Kim, Burke, Dowds, & George, 1999; Kim, Burke, Dowds, Boone, & Park, 2000)**

**vi. PDA (Davies, Stock, & Wehmeyer, 2002; Ferguson, Myles, & Hagiwara, 2005; Giles & Shore, 1989; Gillette & Depompei, 2008; Inglis et al., 2003; Sablier, Stip, Franck, & Mobus Group, 2010)**

**6. Memory Functions:**

**Two main types of ATC supporting memory functions:**

**1. Cameras 2. Multimedia reminiscence devices**

**a. SenseCam (Vicon Revue): Still camera with a sensor worn around the neck and facing outward to augment long-term memory by taking regular photographs (Berry et al., 2007).**

**b. Alm et al. 2004, developed a touch screen interactive multimedia reminiscence tool. The user can interact with system to activate particular image or sound samples. These samples can then trigger personal memories.**

**7. Cognitive Functions Not assisted:**

**No ATCs available for:**

1. **Psychomotor functions**
2. **Perceptual functions**
3. **Though functions**
4. **Mental functions of language**
5. **Mental function of sequencing complex movements**

In this research paper, only those studies which investigated electronic technologies as compensation for cognitive impairments to enable or enhance task performance have been included.

**CONCLUSION:**

Three major contributions:

1. Recognizes ICF (International Classification for Functions) as the basis for evaluation and prescription of assistive technologies for cognition (Bauer et al., 2011; Scherer, 2005; Steel et al., 2010)

2. A new way of classifying ATC (Assistive Technology for Cognition) based on cognitive functions.

3. The findings of this research suggests that a majority of work (i.e. 63% of reviewed literature) is focused on development of reminding and prompting ATCs. But there needs to be further research on other cognitive impairments related to thought, recognition, perception and identification. Technologies related to facial recognition, voice recognition, object recognition are available which can be used. Furthermore, augmented reality systems can be used to embed information in visual and auditory fields. Smartphones are becoming ubiquitous and increasingly powerful, hosting a range of sensors and supported by development kits and online stores which can easily distribute specialist “apps”. As a technology platform, Smartphones can support the ATC functions of alerting, distracting, navigating, reminding, prompting and storing and displaying information. Therefore, research must focus on providing a generalized ATC systems which can cater to multiple cognitive impairments using a common device rather than creating specific devices for specific cognitive impairments.

**3. Computer Based Cognitive Prosthetics: Assistive technology for Treatment of Cognitive Disabilities**

**Target Group: Acquired cognitive disabilities due to:-**

1. Traumatic Brain Injury
2. Stroke
3. Various types of dementia and Neurological conditions

**Most Widely accepted Cognitive dimensions in Neuroscience : -**

1. Executive function: Problem Solving, Planning, Self-monitoring, Task Sequencing, Prioritization, Cognitive flexibility
2. Memory: Short, Long-term memories, Visual, Verbal, Procedural, Declarative and Implicit memory
3. Orientation and Attention: Focused attention, Freedom from distractibility, Divided attention
4. Visual-Spatial Processing: Perception and Integration of visual information in space
5. Sensory-Motor Processing
6. Emotions: Control of and expression of emotions, detection and understanding of emotions, frustration tolerance

**CBCP (Computer Based Cognitive Prothetic)** are designed and developed according to the types of cognitive disabilities and needs of such users. A target user group is identified consisting of specific cognitive disability. Then a specific task is targeted for CBCP. The environment for CBCP is targeted as the environment where the user will perform particular activity.

Telemedicine is used to deliver CBCP services by a therapist into homes. Coupled with videoconferencing technology, cognitive rehabilitation therapists can work fact to fact with their patients.

**CBCP are therefore customized according to specific needs of cognitive impaired users. Therefore, it is specific to problems of each individual. However, for our research we are in search of an Intelligent system which can automatically assess and identify different types of cognitive impairments and adjust itself according to their requirements**.

**4. Detecting cognitive impairment by eye movement analysis using automatic classification algorithms**

* 1. VISUAL PAIRED COMPARISON (VPC) is a recognition memory test which is used to detect memory impairments associated with MILD COGNITIVE IMPAIRMENT (MCI) leading upto Alzheimer’s disease
  2. Differentiation between normal users and MCI users was done by using algorithm such as SUPPORT VECTOR MACHINES (SVMs) with modeling patterns of fixations, saccade orientation, regression patterns.
  3. Eye detection was done through PUPIL RECOGNITION (PR).
  4. The research did not collect data for random eye movement. Rather the data was collected for eye fixations only as prescribed from previous research by Scinto et al., 1994.
  5. Dispersion based fixation detection algorithm (Salvucci and Anderson, 2000) is used.

MACHINE LEARNING BASED CLASSIFICATION METHODOLOGY AND ALGORITHMS.

**Training Stage:**

1. In the training stage, a classification algorithm is provided with a set of training data values (features), and the correct outcomes (labels).
2. The classifier then tunes the parameters of a classification model, to minimize the error on he predicted vs. actual labels in the training data.
3. The parameters of the classification model are fixed at the end of the training stage.

**Prediction Stage:**

1. Pre-tuned classification model is presented with a new example datapoint.
2. The test subject is then classified under a particular class (e.g., NC or MCI)

**Three methods which are used for classification are:**

1. **Naïve Bayes**
2. **Logistic Regression**
3. **Support Vector Machines**

**1. Naïve Bayes:**

It is based on Bayes theorem.

In the training stage, the prior probabilities and feature likelihood are estimated based on training data.

In the prediction stage, the posterior probability that a given subject belongs to a particular class is computed for every class and the class with greatest posterior probability is chosen as the prediction.

**2. Logistic Regression:**

The set of parameters *w* of the logistic function correspond to the feature weights.

In the prediction stage, the optimal parameters are used to compute the most likely class.

**3. Support Vector Machines:**

Given a set of training examples the SVM algorithm finds a hyper-plane decision boundary which separates the two classes with minimal error, while maximizing the distance from each class of data points to the decision boundary.

To find out which among the above mentioned 3 methods is superior for classification purposes, Evaluation Metrics were established:

1. Accuracy
2. Sensitivity
3. Specificity
4. Area under the ROC (Receiver Operating Characteristic) curve (AUC)

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**Most medical studies to classify MCI (Mild Cognitive Impairments) have depended upon technologies such as fMRI, EEG, Invasive surgeries and explorations, Hippocampal shape analysis for Alzheimer disease, SPECT brain images, Boston Naming Test for memory**

**5. The Montreal Cognitive Assessment, MoCA: a brief screening tool for mild cognitive impairment**

**MoCA is a screening tool. It is scored out of 30 points. It is a brief test of cognitive functions taking 10 minutes to administer(Ismail, 2010). It assesses short-term memory, visuospatial function, executive function, attention, concentration and working memory, language, and orientation.**

**MMSE (Mini Mental State Examination) is another screening tool.**

Design an interactive game which replicates the questions in the tests such as MoCA, MMSE, CAMDEX, CERAD, Boston Naming test, Constructional Praxis, Word list recall.

**6. Computer Assessment of Mild Cognitive Impairment**

**CAMCI is targeted towards old users, therefore, the response format for CAMCI is kept very simple. The response format is as simple as hitting keys on a telephone. The test is administered on a tablet computer allowing greater portability and flexibility than desktop computers. It takes about 20 minutes to complete and all tests are presented both visually and orally.**

**2 major approaches were used for the development of the CAMCI tests.**

**First, Standard neuropsychological tests of attention, executive abilities, working memory, and verbal and visual memory were modified to allow administration and response via computer format. All modified tests were scored for both accuracy and reaction time.**

**Second, virtual reality technology was used to develop a test in which the individual moves through a virtual world on a shopping trip that resembles an everyday experience.**

**7. Automatic Detection of Mild Cognitive Impairment from Spontaneous Speech using ASR**

**MCI causes changes in the speech of the patients. Therefore, an automated system of Automatic Speech Recognition (ASR) is developed in this research.**

**1. The speech recognizer was trained on the BEA Hungarian Spoken Language Database consisting of around 7 hours of speech data. Although the BEA dataset contained spontaneous speech, the annotations did not suit our needs as it lacked fill pauses and other non verbal audio segments (coughs, laughter, breath intakes, sighs) etc. Therefore, the researchers had to add these segments to the transcription.**

**2. The ASR system was then trained to recognize the phones in the utterances, where the phone set included the special non verbal labels listed above.**

**3. Acoustic modeling was done using special convolution deep neural network based technology. With this technology, the researchers managed to get one of the lowest phone recognition error rates on the TIMIT database (Convolution deep maxout networks for phone recognition, L.Toth, 2014).**

**4. As a language model, a simple phone bigram(including all non-verbal audio tags) was used.**

**5. 8 biomarkers used for MCI classification:**

1. **Articulation rate: number of phones per second during speech(excluding hesitations)**
2. **Speech tempo: number of phones per second divided by the total duration of the utterance**
3. **Length of utterance**

**4-5. Duration of silent and filled pauses was calculated as the total duration of filled and silent pauses**

**6-7.Number of silent and filled pauses reflects the absolute occurrence of silent and filled pauses, respectively**

**8. Hesitation rate reflects the ratio for pauses and speech, which was calculated by dividing the length of the utterance by the total duration of pauses**

**6. Total number of recordings was more than 100 however, for various reasons, the researchers had to filter out some recordings and only 51 recordings were used. From them, 32 had MCI and 19 were control subjects.**

**7. Each subject was asked to create three recordings for three different tasks.**

**8. Using the 8 bio-markers listed in bullet 5, 24 features were obtained for each patient.**

**9. As the dataset was small, separate training and test sets were not created but applied the method of leave-one out.**

**10. Leave-one out: One subject was withheld, the classifier was trained on remaining participants. This was repeated for all examples and aggregated the results into one final score.**

**11. Weka Tool (WEKA Data mining software: an update) which is a free and open source collection of machine learning algorithms was used. Due to the small sizes of the dataset, we restricted ourselves to simpler methods like linear SVM (Estimating the support of a high-dimensional distribution), Random Forests(Machine learning vol. 45, no. 1, pp.5 – 32, 2001).**

**8. Decision support system for the diagnosis of schizophrenia disorders**

**SADDESQ** is a decision support system for the diagnosis of schizophrenia disorders:

This study consists of 4 principal phases:

i. Knowledge acquisition

ii. Knowledge organization

iii. Knowledge modeling

iv. Evaluation of system’s performance

1. Knowledge acquisition : This was done by the help of 3 experts. These 3 experts and their similarities in the clinical and diagnosis decision making process for 4 vignettes of schizophrenia were studied:

Graph methodology was used to induce experts to design graphs with associations of symptoms which was necessary to reach a diagnosis.

Two aspects of these 3 experts were studied:

i. How they identify schizophrenia symptoms ?

ii. How they use them to diagnose schizophrenia ?

The 3 experts could not provide conclusive symptoms. Due to these disagreements, only one expert was chosen as the source of knowledge. The expert who chose disorganization as the triggering symptom was chosen because this symptom was considered broader and simpler to describe than the others.

The second phase was to collect and organize data from open interviews with this expert over an 18 month period. Same method for data collection as used in first phase was employed. Seven other vignettes elaborated from the schizophrenia charts were presented to the expert. A qualitative analysis was also employed to identify the key elements in the graphs and to construct algorithms corresponding to each phase of the diagnostic decision-making process.

Series of open interviews were conducted to define the concept of disorganization and to identify how the expert had reached this construct. The interviewer was a psychiatrist with expertise in schizophrenia. The interviewer constructed operational rules to identify the disorganization symptom based on the expert’s discourse. Once the concept of disorganization was represented, the algorithms for schizophrenia were constructed according to the eight different clinical contexts identified in discourse analysis. Finally, all the data was discussed with the expert who was asked to comment on them.

The third phase was transferring clinical model to a computation representation. The technological approach adopted in this system is based on the concept of parsimonious cover (Machine Learning, McGraw-Hill, New York, Mitchell T (1997)). The parsimonious cover theory defines a diagnosis as the smaller set of diseases that explains all symptoms known to be present. For example:

If disorder D1 can cause symptoms S1, S2 and S3 and D2 can cause S3 and S5, then if a patient is known to have symptoms S2 and S3, the two plausible diagnoses are (D1) and (D2), that is to say there are two competing diagnoses, one states that the patient has only disease D1 and another that states that the patient has only disease D2. Both diagnoses “cover” all symptoms known to be present.

Fourth and final phase was the evaluation of the systems performance (SADDESQ). It consisted of two tests:

i. Laboratory test

ii. Field test (clinical setting)

i. Laboratory test consists of assessment of RELIABILITY and INTERNAL VALIDITY.

**RELIABILITY:** It means same input originating same output.

**INTERNAL VALIDITY:** It measures the agreement between the system output and the gold standard (expert).

**INTERNAL VALIDITY** was used to evaluate if the domain knowledge was accurately represented.

Thirty eight vignettes from the charts of the Outpatient Program of Schizophrenia and Affective Disorders were prepared according to the completeness of the data.

The expert analyzed the 38 vignettes and the results were compared with the output from **SADDESQ**. The expert who was the source of knowledge was considered to be the gold standard for the diagnosis of schizophrenia in 38 clinical vignettes. The expert should diagnose the following five categories:

I. Schizophrenia present

ii. Possible schizophrenia

iii. Schizophreniform present

iv. Schizophrenia absent

v. Inconclusive

As the sample size was small, we analyzed only dichotomous variables (positive and negative cases of schizophrenia). The Phi coefficient (for Normal variables) was used to measure the correlation between the expert and SADDESQ and the Cohen kappa coefficient was used to measure their agreement.

The methodology needed to develop an expert system is complex and controversial. The usefulness and the impact of such systems in medicine are unclear (Medical diagnostic decision support systems – past, present and future: a threaded bibliography and brief commentary: Miller R (1994), Can computerized decision support systems deliver improved quality in primary care?: Delaney BC, Fitzmaurice DA, Riaz A et al. (1999)). In Psychiatry there are additional hindrances such as the lack of valid constructs of mental disorders, the subjective assessment of psychiatric symptoms, schizophrenia as a heterogeneous phenomenon , the absence of biological markers, and finally the absence of a gold standard(Clinical models of schizophrenia: a critical approach to competing conceptions: Peralta V & Cuesta MJ(2000), Recognizing psychiatric symptoms: relevance to the diagnostic process, Berrios GE & Chen YH (1993), The concept of Schizophrenia: the conflict between nosological and symptomatological aspects: Stromgren E (1992), Toward reformulating the diagnosis of schizophrenia: Tsuang MT, Stone WS & Faraone SV (2000)).

The two main issues are:

i. Consequences of developing a model based on one expert and the evaluation of the system.

ii. The first issue deals with how to select the best knowledge available concerning the diagnosis of schizophrenia disorder in order to construct a knowledge base.

The operational criteria and structured interviews do not allow psychiatrists to recognize schizophrenia but can help them to classify it(The concept of Schizophrenia: the conflict between nosological and symptomatological aspects: Stromgren E (1992), Toward reformulating the diagnosis of schizophrenia, Tsuang MT, Stone WS, Faraone SV(200)).

**The main focus of this study was to identify the patterns of reasoning used by different experts and to determine if the experts share common reasoning shortcuts in the decision-making situation.** However, in this study the experts did not share a common reasoning, therefore, only one expert was kept in consideration. Experts may reach the same diagnosis by using different pathways. **The main question that was to be answered was to know which of these different pathways were more feasible to construct a clinical model of schizophrenia.**

The methodology for knowledge acquisition is still an open question(Science and Practice: a case for medical informatics as a local science design: Patel VL & Kaufman DR (1998), Knowledge acquisition for expert systems: some pitfalls and suggestions: Forsythe DE & Buchanan BG(1993), Modeling expert Knowledge: Shaw ML & Woodward JB (1993))

There are **two theoretical approaches** to the knowledge acquisition domain:

1. First one from Cognitive Sciences

2. Second one from Mathematical and Logical Models

Cognitive science involves study of concepts and analysis of protocol languages and of the psychological aspects of discourses. However, complex techniques derived from mathematical models do not solve problems such as the usefulness and usability of such systems. In other words, if the end-user does not understand how the data output was processed in terms of neural network systems, the system will probably be abandoned. These types of systems are useful in situations in which humans have difficulty to calculate or to process a large number of variables. **However, in diagnostic decision context, the problem is not to process quantity but to identify quality and relevance of information within a changeable context. In the first and second phases of this study, we have employed the cognitive approach but in the third phase a mathematical approach was used for modeling knowledge.**

**Evaluation of the system (Development measurement technique: Friedman CP & Wyatt J (1997), The Research methods knowledge base: Trochim W (1999), Quantitative evaluation of clinical software exemplified by decision support systems: Wyatt J (1997), Evaluation of inherent performance of intelligent medical decision support systems utilizing neural networks as an example: Smith AE, Nugent CD & McClean SI (2003))**

**Wyatt suggested three fundamental measures to evaluate these systems:**

**1. Structure**

**2. Performance**

**3. Impact**

**1. Structure: The system should contain the correct knowledge.**

**2. Performance: The system must run adequately (speedy, accurate etc). This can be done by using vignettes to compare the results of the diagnoses generated by the system and those of the gold standard (expert).**

**3. Impact: The impact (external validity) of the system must be measured so as to assess its efficacy and effectiveness regarding the physician’s decision and consequently patient care.**

**In this study, the evaluation of performance is only performed. The main challenge remains to be the lack of a gold standard to establish diagnostic validity focusing on the problem of how to test these tools. Vignettes were used to evaluate these systems leading to additional bias, lower reliability between psychiatrists to recognize psyhopathological symptoms and insufficient information to allow an expert to make a valid diagnosis. The sample size of vignettes was also too small to detect more detailed differences concerning the eight categories of psychotic disorders. The complete evaluation of this system should be made in a real clinical context (to avoid diagnosis and interpretation bias), against external validations (expert panels or other intelligent systems as gold standard) and obviously, by selecting a more representative sample.**

**The limitations of this study are concerned with the knowledge acquisition phase which is dependent on the qualitative approach which was used to collect data based on a single expert. As a result of this limitation, the data collected and the final model of schizophrenia have a low generalizeability.**

**9. A review of wearable sensors and systems with application in rehabilitation**

**The data gathered by various sensor based network can be transmitted remotely through an information gateway such as a mobile phone or personal computer. For in home monitoring this can be achieved with a personal computer and transmitted through the internet. While the patient can also be monitored in the outside environment by the help of mobile devices and such data can be transmitted over the standard telecommunications standards such as 4G.**

**The global smart phone market is growing at an annual rate of 35% with an estimated 220 million units shipped in 2010 (iPhone smarter than the average phone, Want R: Pervasive Computing (2010)). Besides being an information gateway for transmission of information, mobile devices also function as information processing units. Mobile devices have significant computing power (When cell phones become compuers, Want R (2009)) which makes it possible to envision ubiquitous health monitoring and intervention applications.**

**Besides these facts, the storage and computation becomes more and more cloud based, health monitoring systems can become low-cost, platform-independent, rapidly deployable and universally accessible ( Cloud computing architectures for the underserved public health cyberinfrastructures through a network of health ATMs: Botts N, Thoms B, Noamani A, Horan TA (2010), An ecosystem approach for healthcare services cloud: Chang HH, Chou PB, Ramakrishnan S (2009)). Monitoring systems can be cheaper and simpler with the use of cloud and it also enables us to buy off-the-shelf devices and access customized monitoring applications via cloud-based services (Mobile cloud for assistive healthcare(MoCAsH), Hoang DB, Chen L (2010)).**

**Different types of sensors for rehabilitation:**

**1. Wearable sensors: Physiological measure of interest in rehabilitation include heart rate, respiratory rate, blood pressure, blood oxygen saturation and muscle activity.**

**For example: Ring sensor design for measuring blood oxygen saturation and heart rate which was entirely self-contained. It was worn on the base of a finger, it integrated techniques for motion artifact reduction, which were designed to improve measurement accuracy. It was used for a range of applications ranging from diagnosis of hypertension to management of congestive heart failures (Mobile monitoring with wearable photoplethysmographic biosensors, Asada HH, Shaltis P, Reisner A, Rhee S, Hutchinson RC(2003)).**

**The same researchers also developed a cuff-less photoplethysmographic (PPG) (Wearable, cuff-less PPG-based blood pressure monitor with novel height sensor, Shaltis PA, Reisner A, Asada HH (2006)) based blood pressure monitor. The sensor integrated a novel height sensor based on two MEMS accelerometers for measuring the hydrostatic pressure offset of the PPG sensor relative to the heart.**

**Another example is the system developed by Corbishley et al. to measure respiratory rate using a miniaturized wearable acoustic sensor (i.e. microphone). The microphone was placed on the neck to record acoustic signals associated with breathing, which were band pass filtered to obtain the signal modulation envelope. By developing techniques to filter out the environmental noise and other artifacts, the authors managed to achieve accuracy greater than 90% in the measurement of breathing rate (Breathing detection: towards a miniaturized, wearable, battery operated monitoring system, Corbishley P, Rodriguez-Villegas E (2008)).**

**An ear-worn flexible, low-power PPG sensor for heart rate monitoring was introduced by Patterson et al. It is suited for long-term monitoring due to its location and unobtrusive design (A flexible, low noise reflective PPG sensor platform for ear worn heart rate monitoring, Patterson JAC, Mcilwraith DG, Guang-Zhong Y (2009)).**

**Bio-chemical sensors are also increasing due to increase in micro and nano fabrication technologies (Microsensor integration into systems-on-chip, Brand O (2006)). For example Dudde et al. (Computer aided continuous drug infusion: setup and test of a mobile closed-loop system for the continuous automated infusion of insulin, Dudde R, Thomas V, Piechotta G, Histsche R (2006)) developed a minimally invasive wearable closed-loop quasi-continuous drug infusion system that measures blood glucose levels and infuses insulin automatically. The device also has an integrate Bluetooth communication capability for displaying and logging data and receiving commands from a PDA device.**

**An array of bio-chemical sensors has been developed as part of BIOTEX project, supported by European Commission. The BIOTEX project deals with the integration of bio-chemical sensors into textiles for monitoring body fluids. A textile based fluid collecting system and sensors were developed for in-vitro and in-vivo testing of the wearable system. Researchers have shown that the system can be used for a real-time analysis of sweat during physical activity (Wearable technology for bio-chemical analysis of body fluids during exercise: Morris D, Schazmann B… Diamond D (2008), BIOTEX – Biosensing textiles for personalized healthcare management, Coyle S, King-Tong L, Moyna N…. DeRossi DE et al. (2010)).   
As a part of the same project called PROeTEX, Curone et al. (Smart garments for emergency operators: the ProeTEX project, Curone D, Secco EL…… Magenes G (2010)) developed a wearable sensorized garment for firefighters which integrates CO2 sensor with sensors to measure movement, environment and body temperature, position, blood oxygen saturation, heart rate and respiration rate. This system can inform the firefighters of a potentially dangerous environment and also provide information about their well being to control center.**

**Another technology called System-on-chip (SOC) developed by Wang et al.(A wireless biomedical signal interface system-on-chip, Wang L, Yang G-Z….Cumming DRS (2010)) integrates pH and temperature sensor for remote monitoring applications.**

**Similarly, Ahn et al. (Disposable smart lab on a chip for point-of-care clinical diagnostics, Ahn CH, Jin-Woo C,… Lee JY, (2004)) developed a low cost disposable plastic lab-on-a-chip device for biochemical detection of parameters such as blood gas concentration and glucose. The biochip contains an integrated biosensor array for detecting multiple parameters and uses a passive microfluidic manipulation system instead of active microfluidic pumps.**

**In rehabilitation applications using wearable sensors, there is a huge reliance on inertial sensors for movement detection and tracking. These inertial sensors include accelerometers and gyroscopes. These sensors are often used in conjunction with magnetometers which helps to improve motion tracking.**

**2. Ambient sensors**

**One advantage of using ambient sensors over wearable sensors is that it helps to avoid problems related to misplacing or damaging sensors through continuous use and wear and tear.**

**AAL(Ambient Assisted Living) refers to intelligent systems of health assistance in the individual’s living environment (Wireless sensor networks in ambient intelligence, Fernandez L, BLasco JM, Hernandez JF (2009)). AAL technologies are embedded in appliances, furnitures and are personalized, adaptive and anticipatory. Sensors embedded in electrical devices and in doors and windows may be integrated into an easy-to-use house-control system that also provides improved personal safety and security (Pervasive or ubiquitous healthcare, Arnrich B, Mayora O, Bardram J (2010)).**

**Different smart home projects are going on such as:**

**1. TRIL – Techology Research for Independent Living in Ireland (Tril Center,** [**http://www.trilcenter.org**](http://www.trilcenter.org)**)**

**2. TigerPlace – In Missouri (**[**http://eldertech.missouri.edu/overview.htm**](http://eldertech.missouri.edu/overview.htm)**)**

**3. The Oregon Center for Aging and Technology (ORCATECH) – In Oregon (**[**http://www.orcatech.org**](http://www.orcatech.org)**)**

**4. University of Rochester Center for Future Health – (**[**http://www.urmc.rochester.edu/future-health/validation/smart-home.cfm**](http://www.urmc.rochester.edu/future-health/validation/smart-home.cfm)**)**

**5. Georgia Institute of Technology Aware Home – (**[**http://awarehome.imtc.gatech.edu/**](http://awarehome.imtc.gatech.edu/)**)**

**6. University of Florida Gator-Tech Smart House – (**[**http://www.icta.ufl.edu/gt.htm**](http://www.icta.ufl.edu/gt.htm)**)**

**7. Massachusetts Institute of Technology PlaceLab – (**[**http://architecture.mit.edu/house\_n/**](http://architecture.mit.edu/house_n/)**)**

**10. The smart house for older persons and persons with physical disabilities: Structure , Technology, Arrangements and Perspectives.**

**Smart houses differ in 5 groups depending on the types and arrangements of installed devices:**

**1. Smart house for people with movement disabilities (Information strategies in achieving an integrated home care environment: S. Brownsell, G. Williams(1999), Smart house automation system for older persons and persons with physical disabilities: M.Chan, C. Hariton, P. Ringeard and E.Campo (1995), Communication and motor control aids for people with motor disabilities, G Bourhis, P. Pino, A . Leal-Olmeada (2001)).**

**--- Installation of devices used for assisting in mobility and manipulation**

**2. Smart house for older persons (Smart house automation system for older persons and persons with physical disabilities – 15)**

**--- Consideration of changes in some of the organic functions of older persons**

**3. Smart house for people with low vision (16)**

**--- Installation of special equipments and interfaces for communication and home navigation.**

**4. Smart house for hearing impaired persons**

**--- Installation of special equipments and interfaces for communication and home navigation.**

**5. Smart house for cognitively impaired people**

**--- Installation of devices that provide support in structuring their daily activities in the home**

**According to the function of devices, the installed devices can be classified into 5 groups:**

**1. Devices for automation and control of home environment**

**2. Assistive devices**

**3. Devices for health monitoring of important vital parameters**

**4. Devices for information exchange**

**5. Leisure devices**

**Posture monitoring system developed by Intelligent Cooperative Systems Laboratory , Mechano-Informatics Department, School of Engineering, The University of Tokyo. The methodology is based on pressure sensor arrays mounted on the bed or chair that deliver information about the body weight allocation. The user’s posture recognition is based on the analysis of the pressure distribution image.**

**There are various devices to help access and exchange of information. A variety of devices have been developed to facilitate the verbal communication between nondisabled people and those with speech or hearing impairments. These devices can be of two types:**

**i. devices that convert normal speech to alphabetic symbols or sign language**

**ii. devices that convert sign language gestures into voice-synthesis speech, computer text or electronic signals**

**Examples are:**

**1. SYUWAN translates Japanese into Japanese sign language (JSL) and outputs video images and computer graphics that correspond to JSL.**

**2. RALPH (Robotic ALPHabet) project developed “Spelling Hand” which converts text to sign language.**

**3. DIST( University of Genoa, Italy) developed a multimedia telephone for hard-of-hearing persons which converts normal speech into lip-movement image.**

**4. MIT, Media laboratory consists of a cap-mounted color camera which tracks the wearer’s hand and a wearable computer that performs real time recognition and interpretation.**

**5. KAIST translates Korean language into Korean Sign Language by detecting hand posture using sensing gloves and hand motion was detected by Polhemus System.**

**M3S (Multiple Master Multiple Slave) is a communication strategy especially designed for functional integration of home-installed rehabilitation devices. This M3S specification started a TIDE project (Rehabilitation Robotics in Europe: J. Dallaway, R. Jackson, P. Timmers (1995), M3S A general-purpose integrated and modular architecture for the rehabilitation environment: M.Nelisse (1995) )**

**ICAN (Integrated Control of All Needs) project has further developed the idea of functional integration of the home-installed devices(ICAN integrated communication and control for all needs; assistive technology on the threshold of the new millennium, C.Willems (1999)). The user can control all the home-installed devices by a single device, such as a joystick or switch input. A portable device named function carrier, will distribute the commands of a single interface device to various output devices. The function carrier will be a portable computer such as a palmtop or handheld device.**

**Virtual reality systems can entertain the inhabitant by such options as communication with virtual objects or game play. Such computer programs can generate a screen image of a virtual interloculator whose face, behavior and voice are similar to those whom the user likes and thus a natural dialog with the user can be simulated. This virtual interloculator can be based on the current emotional status of the user which can be detected by the image analysis of the user’s face.**

**RITY is a virtual creature, developed at KAIST which demonstrates a novel architecture and interactive learning method for an artificial creature implemented in the 3-D virtual world. The artificial creature can decide its behavior by itself based on its own motivation, homeostasis, emotion and external sensor information. A behavior is selected by two methods:**

**I. Probabilistic method**

**ii. Deterministic method**

**Probabilistic method uses mathematically modeled internal states and external sensor information.**

**Deterministic method which imitates the animal’s instinct uses only external sensor information.**

**A user can teach the creature to do a particular behavior by an interactive training method. Behavior learning is carried out with a reward and penalty signal. The learning algorithm includes the emotional parameter by which the training efficiency is affected. The data architecture is separated into two parts:**

**I. Algorithm part**

**ii. Data part**

**Panasonic has developed an electronic home interface and memory jogger designed as cuddly toys ---- Tama, the robocat and ---- Kuma, the robot bear. A speech synthesis device can reproduce a number of phrases as a voice response to particular user voice-activated inputs. It can remind users to take medications and failure to respond can activate a call to the care-giving staff.**

**BECKY is an interactive robot developed at KAIST which demonstrates different behaviors in accordance to the status of the user’s emotions. It can recognize the current emotions of the user by observing the user’s response to its actions and considering the environmental information that can affect the user’s emotional status. It can also adapt to the user’s preferences by a learning mechanism based on neural networks. In addition, it can also play music according to the human emotion.**

**Several European nations have conducted several demonstration projects where hundreds of smart houses were developed (A smart model house as research and demonstration tool for telematics development, A . van Berlo).**

**Model house in Eindhoven, The Netherlands(149)**

**Zwijndrecht project in Belgium**

**Eight care flats for people with dementia in Tonsberg, Norway**

**SmartBo is a two room ground floor apartment in a five story building situated in Stockholm, Sweden(150)**

**Gloucester Smart House in UK(151)**

**15 Welfare Techno houses built in Japan.**

**Intelligent Robotic House (IRH)**

**There are four key issues which must be considered while constructing an Intelligent Robotic House model :**

**1. Intelligent sensing and monitoring: Facial expressions and gestures are indicative of human intention and emotion. 93% of messages in the face-to-face communication situation are transmitted via facial expressions, gestures and voice tone, while only 7% are via linguistic language.**

**2. Intelligent human machine interface: It is interesting to note that human affinity for convenient and comfortable interaction with home appliances has changed continuously. The new generation of interface will be more natural and autonomous and simply “intelligent”. The biggest challenges of current human machine interactions are: understanding the human intention, learning to use complex appliances and presence an individual dependent operation mode. These problems can be solved by soft-computing technique –based autonomous operation along with recognition of human intention and learning capabilities.**

**3. Interactive Service Robots:**

**In future homes will have service robots catering to various needs of elderly as well as those with various disabilities.**

**4. Wireless Data Exchange:**

**Wearable sensors can transmit their information via LAN and 4G networks.**

**11.A survey of socially interactive robots**

**According to Design perspective, there are 2 primary ways to develop interactive robots:**

**i. Biologically inspired**

**ii. Functionally designed**

**i. Biologically inspired:**

**Robots are developed with this approach for two reasons:**

**1. Nature is the best model for “life-like” activity**

**2. It allows us to directly examine, test and refine scientific theories upon which the design is based(1).**

**Some of the theories commonly used in biologically inspired design are:**

**a. Ethology: Observational study of animals in their natural setting(95).**

**b. Structure of interaction: Analysis of interactional structure can help focus design of perception and cognition systems by identifying key interaction patterns(162).**

**c. Theory of mind: It refers to those social skills that allow humans to correctly attribute beliefs, goals, perceptions, feelings and desires to themselves and others (163).**

**d. Development psychology: Kismet’s “synthetic nervous system” particularly the perception and behavioral aspects is heavily inspired by the social development of human infants” (18).**

**ii. Functionally designed:**

**With the functionally designed approach, the objective is to design a robot that outwardly looks to be socially intelligent even if the internal design does not have a basis in science or nature. Here the design of the robot is done purely for functional use so it is not necessary to understand the human aspects.**

**Artificial emotions:**

**They are used in social robots for several reasons. Arkin et al. (4) discuss how ethological and componential emotion models are incorporated into Sony’s entertainment robots. Canamero and Fredslund (30) describe an affective activation model that regulates emotions through stimulation levels. Nourbaksh et al. (117) detail a fuzzy state machine based system, which was developed through a series of formative evaluation and design cycles. Schulte et al. (143) summarize the design of a simple state machine that produce four basic “moods”.**

**Emotions as control mechanisms:**

**Emotion can be used to determine control precedence between different behavior modes, to coordinate planning, and to trigger learning and adaptation, particularly when the environment is unknown or difficult to predict. Breazeal (18) discusses how emotions influence the operation of Kismet’s motivational system and how this affects its interaction with humans. Nourbakhsh et al. (117) discusses how mood changes can trigger different behavior in Sage, a museum tour robot.**

**Speech:**

**Primary parameters that govern the emotional content of speech are loudness, pitch (level, range, variation) and prosody. Murray and Arnott (111) contend that the vocal effects caused by particular emotions are consistent between speakers with only minor differences. The quality of synthesized speech is significantly poorer than synthesized facial expression and body language (9). In spite of this shortcoming, it has proved possible to generate emotional speech. Cahn (28) describes a system for mapping emotional quality onto speech synthesizer settings, including articulation, pitch and voice quality.**

**Facial Expressions:**

**The expressive behavior of robotic faces is generally not life-like. Vikia, is 3D rendered facial expressions which can be useful (26) since it is graphically generated and many degrees of freedom are available for generating expressions.**

**Body Language:**

**Besides facial expressions, a lot of non-verbal communication is done using gestures and body movement (9). Over 90% of gestures occur during speech and provide redundant information (86,105).**

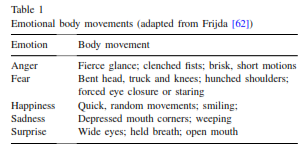
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Figure : Image 1 - Extracted from: Recognition of emotion, Advances in Experimental Social Psychology 4 (1969) N. Frijda (Survey of Socially interactive Robots)

Breazeal and Fitzpatrick (21) state that humans perceive all motor actions to be semantically rich, whether or not they were intended to be. For example, gaze and body direction is generally interpreted as indicating locus of attention. Mizoguchi et al. (110) discuss the use of gestures and movements, similar to ballet poses, to show emotion through movement. Scheeff et al. (142) describe the design of smooth, natural motions for Sparky. Lim et al. (93) describe how walking motions can be used to convey emotions.

12. Artificial Intelligence in Medical Diagnosis

Studies on fuzzy expert systems vary in various aspects such as:

1. Need
2. Importance
3. Potential
4. Approaches (3), (4), (10, (13)

Computer assisted applications for patient’s diagnosis and treatment is gaining momentum (2), (5), (18)

Fuzzy expert system has significant in the medical diagnosis for quantitative analysis and qualitative evaluation of medical data, consequently achieving the correctness of results.

The commercially available expert system shells are rigorously used to write the application specific rule-bases. It has been found that the frameworks are developed for generation of fuzzy expert systems with respect to specific diseases, general purpose diagnostic systems as well as for counseling of personal health (7), (16), (17).

The object oriented frameworks to be used for construction of FES are proposed. (12), (14)

13. Computer Assisted Diagnoses for Red Eye (CADRE)

CADRE’s knowledge base design:

1. CADRE is developed on “Shell” based approach.
2. It is a rule based expert system that assists in red-eye diagnosis and treatment
3. In this approach, Knowledge acquisition subsystem, inference engine, explanation facility, interface subsystem and knowledge management system are integrated into one component called shell.
4. PDC’s expert system shell, ESTA is easy to use and great stand-alone environment for constructing advisory and decision support system.

14.mHealth for mental health: Integrating smartphone technology in behavioral healthcare

1. eMoods Bipolar Mood Tracker app (Gigaram Technologies, 2011) enables users to input and keep track of subjective mood ratings in an electronic mood journal. It also keeps track of hours of sleep, anxiety levels, and medication use as well as generates reports that can be sent to a family member, caregiver or clinician.
2. Biofeedback apps are being introduced into smartphones, which can be used for a range of behavioral health purposes, for management of stress and related health and health problems, such as headaches (Nestoriuc, Martin, Rief, & Andrasik, 2008),insomnia (Taylor & Roane, 2010), chronic pain (Palermo, Eccleston, Lewandowski, de C. Williams, & Morley, 2010), and hypertension (Linden, & Moseley, 2006).
3. PLx xWave is a portable sensor that can track gamma, delta, theta, alpha and beta brain waves to provide neurofeedback.
4. Smartphones (Android and Apple) have been enabled with capabilities to monitor physiological signals such as heart-rates through sensors which can detect user’s cardiac activity and cardiac electrical signals.

15.Smart Phone, Smart Science: How the Use of Smartphones Can Revolutionize Research in Cognitive Science

1. Investigation of human cognitive faculties such as language, attention and memory are most often dependent on the testing of small and homogeneous groups of volunteers who participate in behavioral experiments.

2. This limitation can be overcome by using smartphone technology to collect data in cognitive science experiments from thousands of subjects through mass coordinated use of smartphones.

3. This project was a multilingual international collaboration in December 2010 collecting data from 4157 participants

4. It consisted of 7 languages in Roman alphabets (English, Basque, Catalan, Dutch, French, Malay, Spanish), this could however, include other languages with different scripts and alphabets.

5. Participants were asked to select one of the three proposed session durations:

(50, 100 or 140 stimuli). Sessions consisted of an equal amount of words and non-words randomly drawn from the database. Stimuli were displayed in black (Courier New Bold, 24 points) in the middle of a white background screen. The screen also showed two buttons YES and NO. If the response time extended beyond 1.7 seconds the sentence “Please, answer more quickly” was displayed.

At the end of each session, participants were asked to indicate their gender, age-category, handedness and native language.

6. The result displayed the mean accuracy and response time of the session. Participants could then send their recorded data via email.

16. Using smart phones for context aware prompting in smart environments

1. The system consists of an Android smart phone as a prompting interface for the context aware prompting system

2. Previous Context awareness consists of temporal and environmental parameters for identifying a useful context. In this system, subject behavioral information is included by performing real-time recognition of basic activities involving ambulatory movement such as standing, walking, climbing stairs. This is done by building machine learning models on training data gathered from a tri-axial accelerometer in the phone.

3. Although the system is targeted for older people, experiments were done using younger adults.

4. The study examined perceived prompt usefulness, appropriateness, timing and realism.

5. Movement based activity recognition

6. 5 activities were recorded: Sitting, standing, walking, running and climbing stairs

7. These activities were performed by a lab member with the mobile phone in the pants pocket for a period of 4 mins.

8. Four machine learning techniques are found to be suitable for real time activity recognition on the phone.

a. Naïve Bayes: It is a simple probabilistic classifier that assumes each feature of a class to be unrelated to any other features. It applies Bayes theorem to learn a mapping from the features to a classification label.

b. Decision Tree: It uses a statistical property that measures how well a given attribute separates the training examples according to their target classification, to create a classification model.

c. Support Vector Machine: It is a training algorithm for data classification which maximizes the classification margin between the training examples and the class boundary

d. K-Nearest Neighbor: It is an instance based learning method in which algorithm assigns a class label to data point that represents the most common value among the k training examples which are nearest to the data point.

17. How to build a baby that can read minds: Cognitive mechanisms in mindreading

Four cognitive mechanisms:

1. ID

ID stands for Intentionality Detector. Applying the 6 criteria for modularity to ID, what do we find?

1.1 Domain specificity:

1.2 Obligatory firing

1.3 Rapid speed

1.4 Characteristic ontogenesis

1.5 Dedicated neural architecture

1.6 Characteristic pattern of breakdown

2. EDD:

Eye Direction Detector.

**18. Harnessing context sensing to develop a mobile intervention for depression.**

1. Two broad classes of treatment components can be delivered via mobile phones.

a. Platforms which offer opportunity to deliver interactive tools to patients in their environment. These tools are also called **ecological momentary intervention (13),** which can prompt patients to input information about their situation or internal states and provide in the moment responses personalized to a patient’s immediate needs.

b. Mobile systems also have the potential to apply machine learning techniques that can monitor and learn to recognize patient’s circumstances and state. Smartphones contain numerous sensors that could provide clues to patient states and contexts. Smartphones also have the ability to conduct ecological momentary assessment and allow patients to report or “label” their current states. Machine learning and data mining techniques can be used to automatically learn the relationship between these two sources of data. This relationship is captured in what is known as a “learner” that can then be used to develop individualized predictions of patient states solely from low-level sensor data. Once trained using ecological momentary assessment data, the learner could potentially identify patient states continuously and passively.

Examples of Context aware systems:

a. Intel mobile heart health prototype

b. CenceMe

c. e-Sense

In this study a mobile-based system called “Mobilyze” is discussed. This system is targeted for those suffering from depression, which delivered ecological momentary intervention. The authors also developed a context aware system to identify participant’s location, activity, social context, mood, emotions and cognitive states. The system was supported by a website which allowed access to lessons, tools and graphical feedbacks on participant’s states.

**System Design:**

The context aware system consisted of an architecture containing 3 phases:

1. Phase 1: The sensors on the mobile device gathered observations about participants and their environment. These observations were transmitted to a secure server hosting a learner.

2. Phase 2: The learner used an algorithm to inductively “learn” the relationship between data and participant’s reported social context, activity, location, and internal states.

3. Phase 3: The learner could then predict participant states based on sensor data and these predictions were passed to the action components. The action components provided mechanisms for relaying predictions to other external outreach applications. In current context, the action component consisted of the phone application itself, which displayed predicted states to the participant. The architecture however can be extended in the future to trigger outreach events based on the predictions.

These components communicated using extensible messaging and presence protocol (XMPP) which added scalability and extensibility.

In Phase 1: data collection of contextual data was done from 38 sensors or more depending on the proximal Bluetooth devices and open applications on the mobile phone. Some of these data were directly collected from phone sensors such as GPS, Wi-Fi, Bluetooth detection of other wireless devices, accelerometer, and ambient light. Other contextual data were inferred by the phone application from information available on the phone such as time, day, activities of phone’s operating system such as recent calls, active phone applications.

The sensor data was encrypted and sent to secure backend server via XMPP interface protocol. The backend server logged the information by inserting it into a database. The backend also sent the sensor data to the server housing the learners, again using XMPP to lend the backend greater extensibility.

Phase 2: Sensor data acquired were paired with simultaneously labeled stated data. From the labeled data, individualized prediction models were generated to identify specific user states from sensor values, including location, activity, social environment and internal states. For every state, a machine learning algorithm generated a participant-specific model to predict that state from sensed data in the future.

Phase 3: Every 5 minutes the mobile phone application sent current, unlabeled sensor values to backend. The learner used these sensor readings to make predictions and infer the participant’s state without input from the participant. Because we rely on a service oriented architecture, predicted states could be used to implement context aware functionality through multiple devices.

When participants view the state entry ecological momentary assessment forms on the mobile phone, the predictions according their current states were shown.

**Discussion and future scope:**

“Mobilyze” is the first ecological momentary intervention system. It has shown great promise as the first context-sensing system for depression.

Problems related to battery drainage and connectivity was caused by the use of XMPP which required continuous connection to backend server. Therefore, a new underlying protocol must be used in future such as binary SMS messages. However, this solution is not available for all mobile devices so a better solution would be to use a better battery management solution. Reliability issues regarding connectivity are discovered which must be solved as well.

20. Use of artificial intelligence in the design of an intelligent cognitive orthosis for people with dementia

21. Adaptive interfaces for home health

Find out more about gestures and body posture and their relation to our system.

22. Emotion Representation, Analysis and Synthesis in Continuous Space: A survey

1. According to Psychological research, there are 3 main approaches to affect modeling:

**1. Categorical:** Small number of emotions that are hard wired, basic and universally understandable.

**2. Dimensional:** Different states of emotions are connected to each other in a systematic manner. Most widely used dimensional model is Circumplex of Affect. Circumplex of Affect is based on the hypothesis that each basic emotion consists of bipolar entity being a part of the same emotional continuum such as Arousal(Relaxed vs. Aroused), Valence(Pleasant vs. Unpleasant).

**3. Appraisal-based:** Emotions are generated through continuous and recursive subjective evaluations of our internal state as well as the outside world.

Emotional state of people can be measured from inner expressions such as BioSignals, subjective experiences (How the person feels) and the outward expressions(Audio/Visual signals).

**a. BioSignals**Signals from central and autonomic nervous systems. Some biosignals that are tracked are:

i. Galvanic skin response

ii. Electromyography(Frequency of muscle tension)

iii. Heart rate

iv. Respiration rate

v. Amygdala response

**b. Audio Signals**

i. Pitch of a sound can be an index of arousal.

ii. Mean of fundamental frequency(F0) , mean intensity, speech rate, pitch range, blaring timbre and high-frequency energy are positively correlated with arousal dimension.

iii. Shorter pauses and inter breath stretches are indicative of higher activation.

iv. Less evidence is discovered for relationship between certain acoustic parameters and dimensions such as valence and power.

**c. Visual Signals:**

i. Facial expressions

ii. Body postures

iii. Head nods and shakes

**Discussion:**

1. Interpretation of various expressions and physiological responses is challenging in terms of accuracy.

2. Visual signals help to interpret valence

3. Audio signals help to interpret arousal

4. Speech is less affected by power dimension than arousal dimension.

5. Different emotional dimensions such as valence, arousal, power are correlated.

6. A research is required to understand and analyze such correlations and investigate them further.

7. When multimodal approach is used to express emotions such as combined perception of human facial and bodily expressions, human detection of emotion signs in different modalities such as speech, facial expressions or gestures, they appear to be blended together Therefore, there needs to be a greater research to understand how such blending of expression affect recognition systems.

8.There is no particular framework used by researchers for a universally agreement of various findings from signals. There is still debate over interpretation of emotions and inter observer agreement over such interpretations especially in dimensional approach.

9. Real time affect prediction requires a small window size to be used for analysis while to obtain a reliable prediction accuracy longer time monitoring is required.

10. Baseline problem is a major challenge for BioSignals as there is a lack of a standard to compare. For Audio, this is done by segmenting the recordings into turns and processing each turn separately.

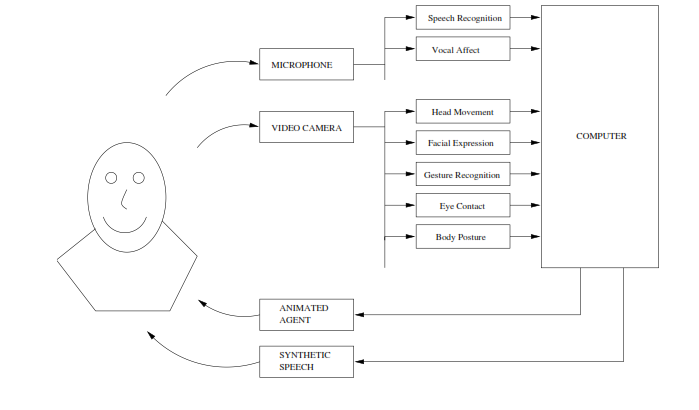
11. For visual signals, the video is divided into frames and the frame without any expression is extracted which acts as a standard and other expressions of face, body, pose and motion are tested against the standard.

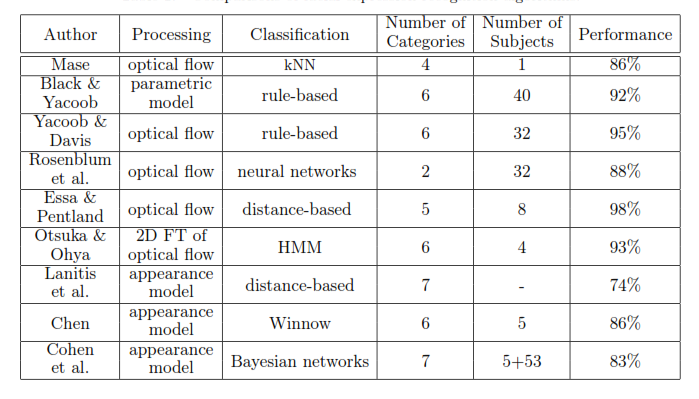
12. Classification schemes used for dimensional and continuous affect measurement are SVM, RVM and long short-term memory recurrent networks

13. Classification schemes used for quantized dimensional affect recognition tasks are Linear Discriminant Analysis, Conditional Random Fields and Support Vector Machines.

14.

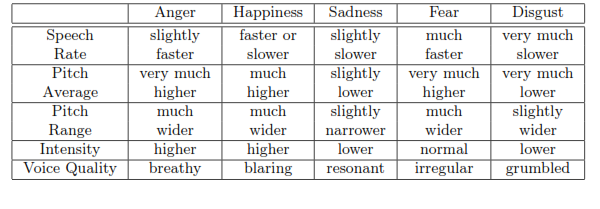
23. Multimodal emotion recognition





**Multimodal means of Human Computer Interaction.**

**Retrieved from: Multimodal emotion recognition, Nicu Sebe, Ira Cohen and Thomas S. Huang on 29-09-2016**

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**1. Probabilistic graphical models such as hidden Markov Models, Bayesian networks and Dynamic Bayesian networks are well suited for fusing multimodal information from multiples sources such as audio and visual sources.**

**2. These models can handle noisy features, temporal information and missing values of features all by using probabilisitic inferences.**

**3. Dynamic Bayesia networks and Hidden Markov Models variants have been found useful to fuse information from multimodal sources especially visual and audio sources.**

**24. String based audio visual fusion of behavior events for the assessment of dimensional affect**

**1. Behavioral events:**

**Non verbal visual events such as Head Gestures and Action Units (AUs) were included in the string based approach.**

**4 particular head gestures were used:**

**a. Head nods**

**b. Head shakes**

**c. head tilts to left**

**d. head tilts to right**

**Face detection through Viola and Jones face detector.**

**Head movement divided into 4 codes such as “Rightward, upward , leftward and downward” motions respectively and one for “no movement”.**

**The codes generated by the visual feature are fed into Hidden Markov model for training a nodHMM and a shakeHMM**