Empath2: A Flexible Web and Cloud-based Home Health Care Monitoring System

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Introduction

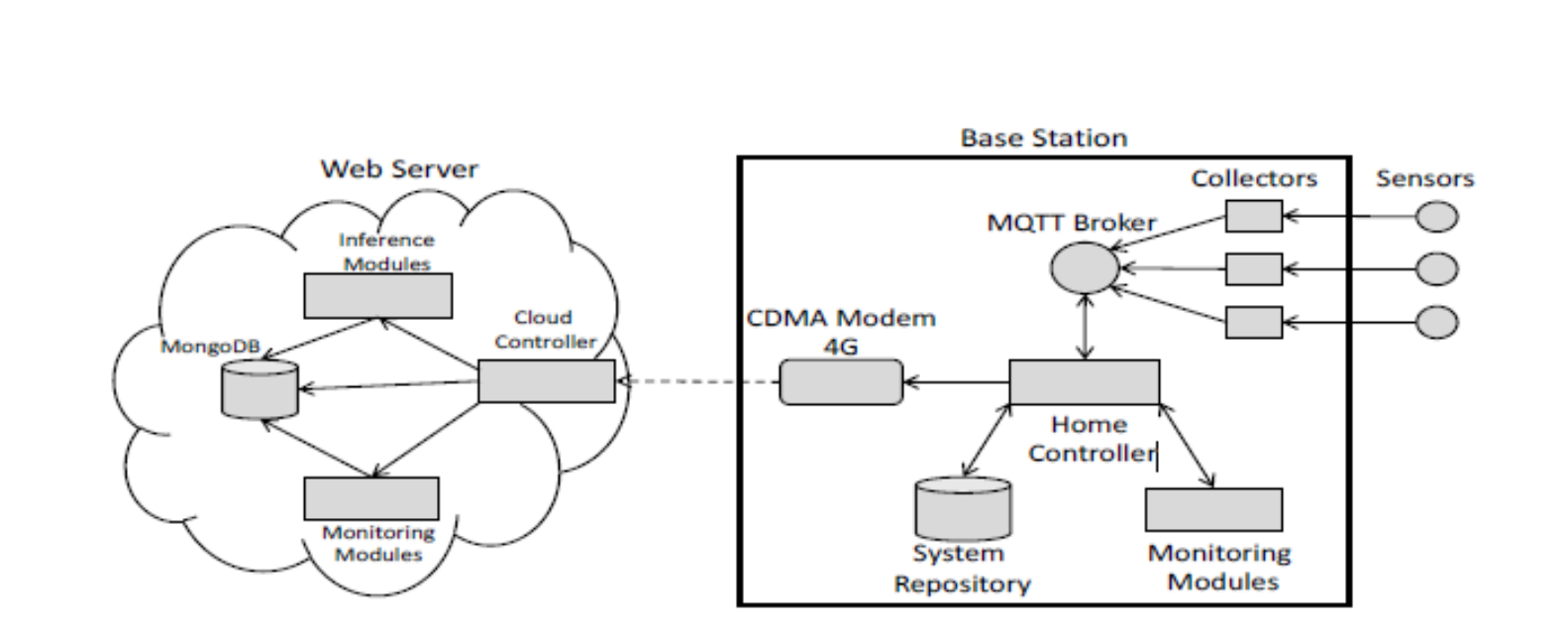
- Many of the current sensing systems are not flexible enough to easily handle the different applications from different vendors.
- EMPATH2 uses the Cloud technology and is easily interoperable among different home health care applications.
- EMPATH2 aims at short deployment times, short software development times, and effectiveness for the applications.

Motivation

- According to the U.S. Census Bureau the population of people aged 65 and above will almost double by 2050.
- To provide an independent and hassle free living environment for the elderly.
- In Assisted living facilities and even in their own homes an increasing number of technologies are being developed and researched upon to be deployed on small as well as large scales.

EMPATH2 Design

- Sensing layer
- Basestation
- Cloudbased web server



Sensing Layer

- Wired and wireless sensors can be installed for both continuous and event – based data.
- A **communication radio adaptor** at the basestation allows sensing devices with different communication protocols to be integrated.
- **Reducers** are used to convert high data rate or highly multidimensional data to lower data rate and fewer dimensions.
- Supports adding new sensors to the architecture.
- **Data collection class** is created to read the raw sensor data and publish it to the MQTT broker.

Basestation

- The basestation temporarily stores the incoming epoch for syncing to the web service.
- The basestation runs the Message broker which listens for incoming connections.
- The Message broker uses the **MQTT** protocol which implements a publish/subscribe message pattern to decouple the modules from one another.
- When a message arrives the message is stored in the database and later synced with the Cloud.
- Data is deleted from the database after syncing.

The Cloud Layer

- Implemented by a Java web application that can be installed into any Java servlet container. (Spring3 framework)
- Users are given roles such as Patient, Clinician etc. to determine the level of access to resources.
- Communication is achieved through a HTTPS protocol.
- StreamFeed, an abstraction mechanism similar to HTML which can be accessed by an URL following RESTful principle for sensor streams. (http://www.XYZ.com/stream/{UUID})
- The feeds can be fused, processed and filtered to create new StreamFeeds repeatedly to generate an inference tree.

Types of Streams & database

- Persistent Streams – Streams that are stored in a database.
- Memory Streams – Streams that are generated upon request to produce information to the accessing user.
- Web Streams – These streams are not stored on the Empath2 system, but on another webserver on the Internet.

- Document-based database – Since the data rarely changes the need for consistency is much less.

Operation of the Cloud layer

- After deployment processors are created and streams wired to the input and output ports of the processors.
- **Example with a Questionnaire:**

1. PHQ9Evaluator processor is created.
2. Input port PHQ-9 Responses is wired to a persistent stream A which holds the item responses.
3. A memory stream B is wired to the output port PHQ-9 score.
4. The evaluate() function queries persistent Stream A for epochs in that time range and the score is added to Stream B.
5. This process is repeated to produce an inference chain.
6. Cycles are not recommended to avoid infinite evaluation.

Device Failure

- Monitoring modules in the base station checks the memory consumption, Internet connectivity status, battery level of the machine and for any inconsistent data that might mean a corrupted sensor.
- The status is automatically delivered to a monitoring team.
- Logs are also automatically uploaded in the cloud.

Instantiation Time

- Depends on the time it takes to implement the inference and sensing modules.
- **Inference modules** are application-dependent and vary with the complexity application.
- The **sensing modules** also varies depending on the complexity of the application.
- **Test Results (Inference logic) :**
  1. Incontinence – 7 days
  2. Depression – 15 days
  3. Epilepsy – 2 days

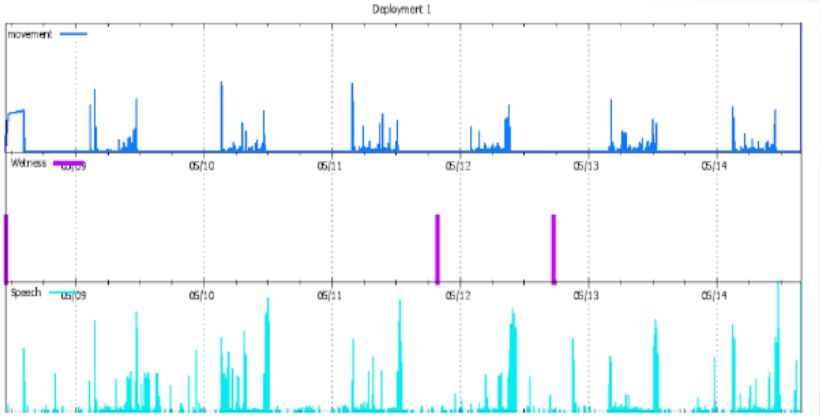
Incontinence and Dementia

Sensors used:

- Accelerometer-based sleep monitoring module
- Activity monitoring module (wetness sensor, acoustic based speech module.)
- **DryBuddy** a lightweight wireless sensor to determine if wetness has occurred.
- A **microphone** for speech outbursts.

For Instantiation :

- Sensing – Few hours
- Inference logic – 7 da



Depression

Conditions Tested :

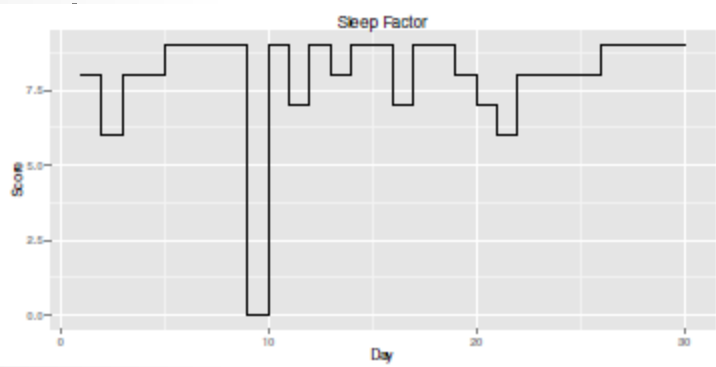
- Sleeping patterns
- Changes in behaviors
- Weight gain or loss
- Social interaction
- Feedback via PHQ-9 (medically approved questionnaire)

Sensors used:

- Accelerometer-based sleep monitoring module
- Activity monitoring module (with X10 sensors)
- Acoustic based speech module
- Weight monitoring module
- Subjective mood scoring module

Depression

- The sleep quality score calculated from the bed sensor readings for each night on a scale of 0 to 9, where a higher score represents a better quality of

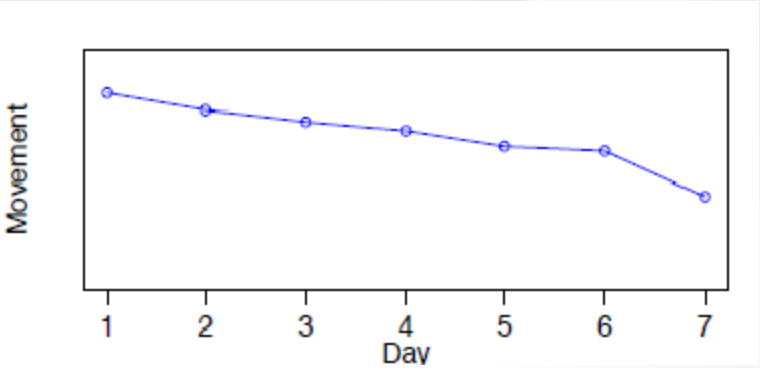


- The subject's report of sleep quality correlate with the sleep quality score.

Epilepsy and Stress

Conditions Tested:

- Stress
- Sleep quality



Sensors used:

- 2 tri-axis accelerometers

Method :

Internal qigong an ancient Chinese healing art was used which is intended to reduce stress, and thus improve the sleep quality.

Lessons learned

- Deployment time must be short.
- Must be capable to quickly discover the sensors.
- Must be installable by non-technical experts.
- Must support frequent monitoring of the correct operation of the system.
- System must be resilient to the behavior of patients and caregivers.

Conclusion

In contrast to other Home Health Sensing systems the EMPATH2 is actually easier to be installed and deployed in home health care for a wide range of purposes. EMPATH2 has been deployed and tested in 17 homes to date over 3 instances. Two of which were with actual ill patients. These deployments demonstrate that EMPATH2 can be implemented over multimodal, passive behavioral monitoring systems that are useful to caregivers and medical professionals.