Motion Sensor Driven Gestrure Recognition for Future Internet Application Development

Kostas Stravoskoufos, Stelios Sotiriadis, Alexandros Preventis, Euripides G.M. Petrakis
Intelligent Systems Laboratory
Department of Electronic & Computer Engineering, Technical University of Crete (TUC)
Chania, Crete, GR-73100, Greece
(kgstravo, s.sotiriadis, apreventis, petrakis)@intelligence.tuc.gr

***Abstract*—The emerging Internet of Things landscape features billions of sensors that are connected to the Internet, monitoring our everyday life. Those sensors are able to communicate and share information and thus they have special requirements of storage, computation power and network. Cloud technology offers new services addressing the exponentially growing demands of IoT. We focus on innovation in developing Future Internet (FI) applications for motion sensor driven gesture recognition systems utilizing cloud technology and the FI-WARE core platform. We present a motion sensor cloud service (namely Interact project) that features a set of application enablers and cloud services to demonstrate the adaptation of new standards in FI-WARE in the area of motion sensors data collection, management and storage. The proposed solution interprets hand language and gesture signals by offering an open hand language and gesture database of motion sensor driven FI applications for third party developers. Also, it opens new opportunities for cloud providers, web entrepreneurs and SMEs to commercialize innovative products and services. This could impact various areas, like healthcare provision and bioinformatics cloud services for user monitoring, training and educating purposes as well as future market openings for social media.**

Keywords: Motion Sensor Gesture Systems, Future Internet Application Development, Iot, FI-WARE, Cloud based sensor Application Development

I. Introduction

This work focuses on Future Internet (FI) application development for motion sensor driven communication using cloud-based solutions [1]. These are cloud services that associate a person's surrounding motion sensor driven gesture recognition input devices that manifest a moving lucidness environment of Internet of Things (IoT) devices. The concept relates with users that express themselves using hands in order to communicate with a system. This could be particular useful and highlights new e-health and bioinformatics services for various users who live their lives in Smart Cities and can use next generation IoT devices (e.g. motion sensors) as part of their everyday activities. Thus, they could interact with applications for training, monitoring movements, rehabilitation actions as well as educating purposes. In this work we focus on motion devices and especially on the LEAP controller [10] in order to offer a cloud-based service and a motion sensor API for transforming specific hand language and gestures into system commands.

The system called Interact has been designed in the concept of FI-WARE [12]. The later is a leading cloud service provider that offers open specification for services available for utilization over the Internet. It offers cloud-based re-usable and modular components for cost-effective creation and delivery of FI applications and services, the so called Generic Enablers (GEs). GEs are considered as service modules hosted in clouds that offer various functionalities along with protocols and interfaces for operation and communication. GEs are implementations of open specifications of the most common functionalities that are provided by FI-WARE and are stored in a public catalogue, thus developers could easily browse and select the appropriate APIs to use.

This work develops the a cloud service for LEAP sensor to collect data, store and offer it as a service to prospect users (namely as "Interact" project). This promotes new opening sfor applications that integrate motion sensor applications. Today, various users (e.g. social networks) and special groups (e.g. for instance deaf mute people) could use this service. In particular we develop:

a) An end-user application for interpreting gestures and hand signals to text or voice, that eventually will be transformed to system actions and commands. The prototype is currently under development and identifies various hand motions including static and motion gestures.

b) An open cloud platform service to store hand language instructions and make a cloud platform service to act as an API for third party applications.

c) A FI-WARE based API for developers which they could use to develop applications allowing the interaction of users by using gestures. By this way others could access directly the proposed cloud service.

d) An end-user application for interpreting specific signals to various languages. The application offers the integrated business logic that uses proposed services and APIs.

The cloud services will be composed from a set of functional modules that integrate GEs such as the "identity management" and the "publish-subscribe context broker" GEs of FI-WARE. The prototype version supports a specific set of hand language gestures and instructions and offers translation services to preferred languages. The application offers high accessibility as developers are offered open APIs (by using the REST architectural style [2]). Based on this discussion, in Section II we present openings and innovation in developing Future Internet (FI) applications using motion sensors and cloud computing. Section III defines the architecture of the proposed system, Section IV the integration of the Interact project and Section V the modules (GEs) and third party software. Finally, the work concludes in Section VI,that presents potential impacts and future work actions.

II. Motion sensors and cloud services

Latest years, we witnessed the emergency of IoT devices and cloud. This expects to boost new markets for developers and entrepreneurs that integrate cloud applications, , especially those related with hand motion sensors. Many works have shown that nonverbal communication represents up to the two thirds of exchanged information and this is especially related with hand movements and gestures [4]. Also, people that have special communication needs are high in population (e.g., deaf mute people are approximately 70 million in the world [5]). This number represents also potential users of motion sensor technology and taking market potential into account, users of motion sensor driven gesture recognition systems utilizing cloud technology. In terms of market, a study [3] predicts that sales of motion recognition systems will shift into high gear. Also, smart-devices are expected to embed motion sensors as the next big step after the touchscreen monitor.

Thus, in this work we are motivated by the openings arising and the possibilities of applying next generation moving sensor settings in computing clouds. The proposed solution will demonstrate the adaptation of new standards in the concept of FI-WARE and will offer new opportunities for cloud providers, web entrepreneurs and SMEs to commercialize innovative products and services using hand motion sensor cloud services. This will benefit providers that will be able to improve their effectiveness and efficiency by developing special-purpose build instantiations (e.g., for healthcare applications), which will be based on GEs and APIs offered as a service.

III. Architecture Of Motion Sensor Cloud Service

In this Section we propose architecture for sensor driven FI applications. The architecture is based on software modules that operate on a cloud platform (e.g., FI WARE) and offer their functionality through REST APIs. The architecture is divided into 4 zones: the consumer zone, the front-end, the back-end and finally the application zone. The sensor operates on the consumer zone and communicates with the front-end zone. The front-end, which is responsible for sensor connectivity and sensor data collection, establishes a connection with the back-end and sends the collected sensor data. The back-end zone handles and processes sensor data and offers the results to authenticated applications thorough REST APIs. Finally, in the application zone, authorized developers and clients can access the APIs offered in order to use or create applications. In Figure 1 we present the architecture and below we describe each one of its functional blocks. Below we describe each of the architectures functional blocks:

- *IoT Connectivity – Protocol Adapter*: The IoT connectivity software module is responsible for connecting the sensor with the FI application components. For this task, the IoT connectivity module is using the Protocol Adapter module to adapt to the specific connectivity protocol that the sensor is using (e.g., Bluetooth).
- *Sensor Data Collector*: After the connection is established, the Sensor Data Collector is responsible for collecting the sensor data and then forward it to the cloud Back-End for processing. This module is also responsible for converting data into the correct form (e.g., JSON1) so it can be transferred to the back-end without causing interoperability problems.
- *Connectivity Service:* The Connectivity Service establishes a connection between the front-end and the back-end so the data from the Sensor Data Collector can be transferred to be processed by the Application Logic module.
- *Complex Event Proccessing*: The Complex Event Processing module is used for decision-making thorough the analysis of complex conditional events. The module processes custom event patterns and then, based on specific user defined conditions, decides the flow of the data.
- *Cloud Storage*: The Cloud Storage module is responsible for storing and retrieving data from a database. Its main functionalities are offered as a REST API because storing and retrieving data should be easily accessed (e.g., by developers).
- *Application Logic*: This module is application specific. It encapsulates the business logic of the FI application as it handles and processes sensor data. For decision making, the Application Logic is using the Complex Event Processing module and for storing and retrieving sensor data it uses the Cloud Storage module. results to the Publish/Subscribe broker.
- *Publish/Subscribe Context Broker*: The Publish/Subscribe Context Broker receives the results of the sensor data processing from the Application Logic in order to publish them. The role of the Context Broker is to publish context to subscribers. Consider for example a sensor that measures temperature and humidity. Some users are interested in getting updates on the current temperature while others only want to get updates on humidity.
- *Identity Management*: This module is used for user authentication and access authorization. This applies to both users and developers of applications who are based on or have access to services through REST APIs.

[1] http://www.json.org

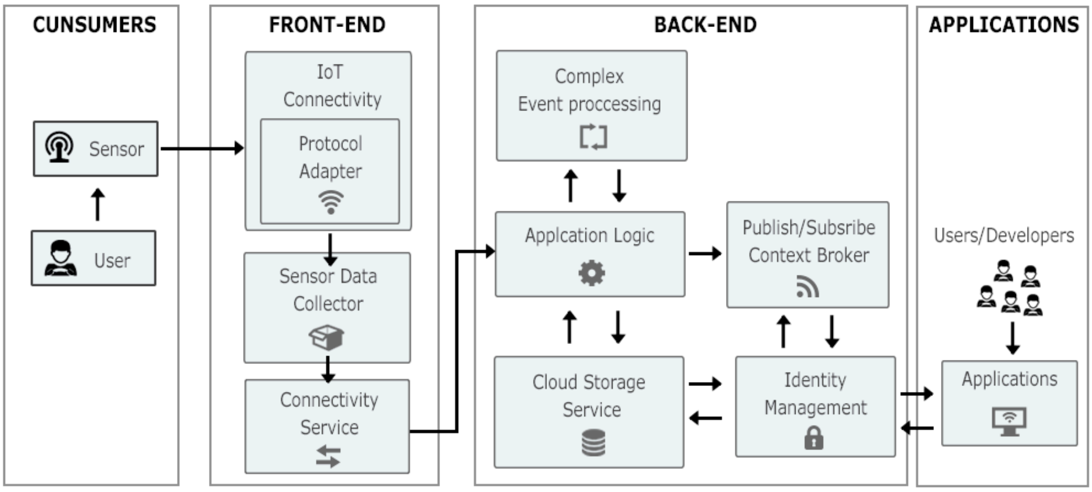

Fig. 1. The proposed architecture of the Motion Sensor for sensor driven FI applications

IV. THE 'INTERACT' PROJECT

Interact is a motion sensor driven FI application, based on the FI WARE core platform, offering its main functionalities as cloud services. The solution will promote the development of motion sensor-oriented applications by using the concept of FI-WARE core platform, and will offer interpretation of hand language signals that will be offered as an open API. For this, the study utilizes the LEAP motion sensor.

The main functionality of Interact is gesture recognition based on a gesture database where gestures are stored in the form of key-value pairs that represent features of the hands (e.g., number of fingers, rotation etc.). When a gesture is performed using the sensor, the system matches user input to gesture records in the database. The system features a public gesture collection, which can be accessed by anyone for matching gestures, but needs administrator privileges in order to insert new ones. Also, developers are allowed to create their own gesture collections with application specific gestures. The following scenario demonstrates the key step-by-step functions of the proposed multi-user application for a user that performs dedicated exercises in the concept of health-care provision.

- The user accesses the Front-End web application to perform validation in the concept of a healthcare provision cloud service. Users have a personal profile to define preferences (e.g., language). There are 3 types of users: a) Simple users who can access gesture collections for gesture matching, b) developers who can create new gesture collections and add new application specific gestures and c) Administrators who can insert new gestures in the public gesture collection.
- The user performs a hand language gesture. The hand features of the gesture are collected in the fronted and then a request is transferred to the cloud Back-End service to interpret the gesture.
- In the Back-End, where the application logic is implemented, a matching process is applied by accessing the database and results are posted back to the Front-End.

Fig. 2 illustrates the Interact interactions, which is a subset of the architecture proposed in Section III. Interact operations are separated into the Sensor Collector Application (part of the user experience site, Front-End), the Cloud Sensor Data Interpretation Application and API (cloud Back-End that offers implements the application logic) and the Cloud Storage service for storing data (cloud Back-End). A device (e.g., a notebook) collects gesture data from the LEAP motion sensor using the Sensor Collector Application that sends data to the cloud. The architecture aims to be flexible allowing integration of third-party applications.

A. *Sensor Collector Application*

The Sensor Collector Application implements Front-End interaction functionality, which is responsible for collecting hand data from the motion sensor. Data is forwarded to the cloud Back-End for processing and results are returned to the front end for viewing. The sensor collector application also has the task of user authentication.

B. *Cloud Storage*

The Cloud Storage module is responsible for storing hand gestures and their corresponding functionality (i.e., actions). It supports input of new gestures, as well as retrieval for actions matching an input hand gesture.

Each gesture that is stored is an array of features describing a snapshot of the user's hands at a specific time point (e.g., number of fingers, rotation etc.). When the user makes a hand gesture, the cloud storage module searches the database for gestures that match by using a matching function that is based on comparing hand feature arrays. After a gesture is matched the cloud storage module retrieves the corresponding action, for this gesture, to the front-end. Users can access the gesture data that are offered in the database through a REST API but for inserting new gestures special privileges are required.

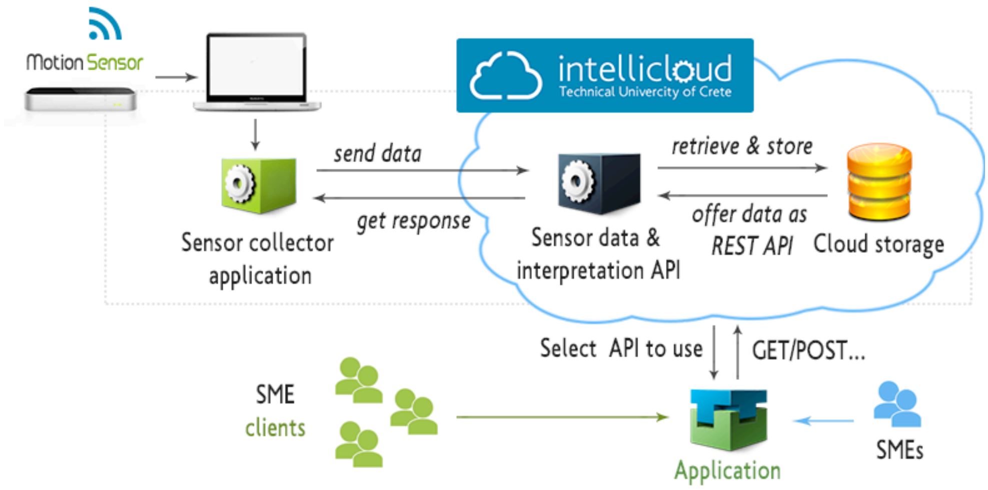

Fig. 2. Interact's high-level architecture

C. Cloud Sensor Data Interpretation Application & API

The Cloud Sensor Data Interpretation Application & API implements business logic of Interact. Requests from the Front-End (i.e., the Sensor Collector Application) are collected and are processed accordingly (match or store a gesture). All requests are handled as events by an event handling mechanism which decides the next action. Developers can make REST calls to the API and create FI applications based on gesture recognition. Recognized gestures can trigger actions in applications enhancing the user experience. Another key feature is that developers can support user subscription to specific gestures or gesture collections by taking advantage of the publish/subscribe broker that Interact uses. This way applications can be more personalized and user specific.

V. GENERIC ENABLERS

This section describes the draft mapping process of operational blocks identified in Section IV into FI-WARE Generic Enablers (GEs). Figure 5 shows the GEs as follows:

"Identity Management GE[2]" (GCP Implementation) applies an authentication mechanism to enable user authentication. It integrates authentication control into the web application Sensor Collector Application module. The identity management GE is implemented on FI-LAB[3], which is a FI-WARE platform testbed, and implements the following interfaces (illustrated in Fig. 3):

- An interface that secures communication among the various actors of the application. The interface is related with point-to-point authentication strategy between the end-user application and the cloud in addition to the communication to other GEs. It provides input for login authorization.
- An interface that will output an access token in order to validate users.

Fig. 3. The Identity management GE interfaces

The "Publish/Subscribe Context Broker GE", which is also implemented on the FI-LAB platform, offers publication of context information to context subscribers. This means that subscribers are notified whenever changes occur on the context they have subscribed to. This is very useful in case we want to trigger actions on specific events (e.g., do something when a specific gesture is made). We use the Orion Context Broker[4] implementation in the Cloud Sensor Data Interpretation Application & API. The Publish/Subscribe Context Broker implements the following interfaces as demonstrated in Figure 4:

- An interface for retrieving context data in a request/response or in a subscription mode from the Front-End application.
- An interface for querying data and/or registering data to the cloud data storage.

Fig. 4. The Publish/Subscribe Broker GE interfaces

The "Complex Event Processing (CEP) GE" offers real time event management and allows events to be produced based on various conditions.

[2] http://catalogue.fi-ware.org/enablers/identity-management-gcp
[3] lab.fi-ware.eu
[4] http://catalogue.fi-ware.org/enablers/publishsubscribe-context-broker-orion-context-broker

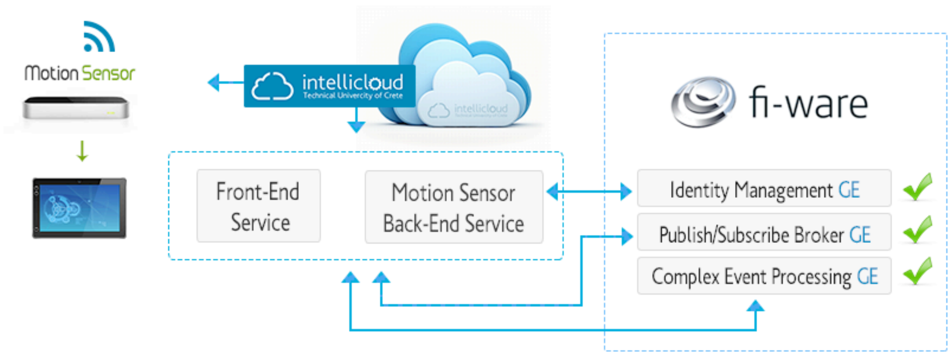

Fig. 5. Interact integrated GEs

This integrates the business logic of the Sensor Data Interpretation Application and an API for decision-making processes. In particular, the various events and their interactions are defined in the CEP GE, and the Cloud Sensor Data Interpretation Application and API can call it to get responses regarding information on the occurrence of events from event producers, to detect situations and act analogous (report the detected situations to external applications etc.). The CEP GE is implemented on FI-LAB and encapsulates the following interfaces as demonstrated in Fig. 6.

- An interface to add events.
- An interface to input relationships of how real-time events are linked and what are their conditions.
- An interface for forwarding updates with regards to events and changing conditions.
- An interface for output event based results according to their relationships.

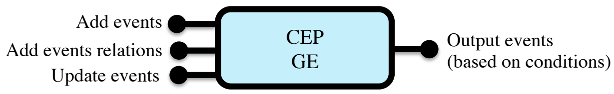

Fig. 6. The CEP GE interfaces

Fig. 5 shows the interactions of the above GEs. Data entry is achieved by using a Graphical User Interface (GUI) and then it is submitted to the cloud. Here, a new service (Motion Sensor Front-End and Back-End) applies sensor input (such functionality is not available through the catalogue). From GUI, communication is forwarded to the Back-End cloud service. The publish/subscribe context broker allows push/pull or message subscribing for alerts triggering. Also, the CEP GE offers the event processing business logic of the application. The Identity Management GE authenticates users, applications and GEs (part of functionality a, b and c using FI-WARE OAuth 2.0). The Motion Sensor Back-End service is currently implemented in the Intellicloud infrastructure. The storage service, in Fig. 7, is integrated by using the mongoDB[5] NoSQL database. This supports two interfaces: the data input to store a gesture, and data output to retrieve a gesture for matching.

Fig. 7. The Storage Service interfaces

The Motion Sensor Front-End is a web application developed on Apache[6] server. It receives sensor data as input and outputs an event along with data to be sent to the Back-End. Fig. 8 shows the interfaces of the Motion Sensor Front-End application service.

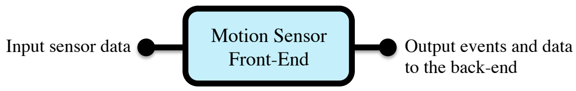

Fig. 8. The Motion Sensor Front-End interfaces

The Motion Sensor Back-End API makes data from motion sensors available as a REST API. It receives an input of events from the user (motion sensor Front-End) and outputs an event for the CEP GE and an interface to offer data as API using the REST protocol.

Fig. 9 shows the interfaces of the Motion Sensor Back-End service.

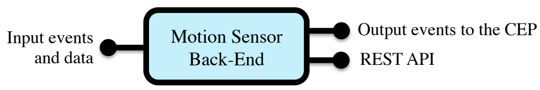

Fig. 9. The Motion Sensor Back-End interfaces

Fig. 10 shows the big picture of the GEs and their interfaces. CEP has two interfaces used from the administrator (e.g., add events and relationships during system configuration) while the cloud storage service is available to the end-user application as API using the Motion Sensor Back-End. Identity Management GE will be used for authentication among users and GEs. The project will use the LEAP API[7] and the Google translation API. In terms of hardware the application will use the IntelliCloud and FI-LAB infrastructure to create the services. It is expected that each service will be encapsulated in a virtual machine and will be easily accessed through the web via a REST API.

[5] https://www.mongodb.org/

[6] http://www.apache.org/

[7] LEAP Development API, https://developer.leapmotion.com

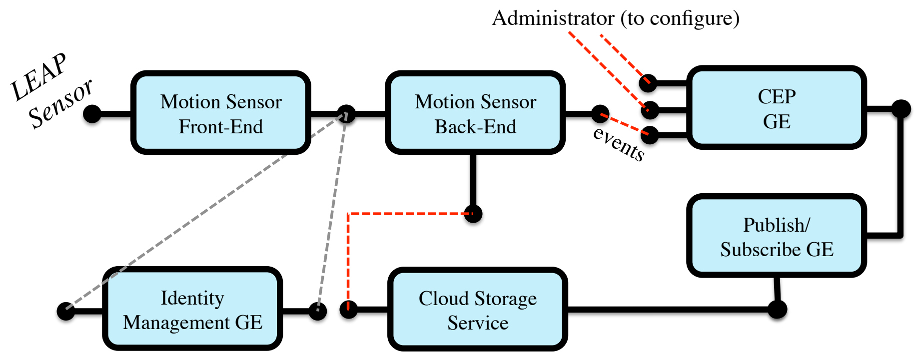

Fig. 10. The Motion Sensor Back-End interface

VI. CONCLUSIONS AND FUTURE WORK

This work proposes Motion Sensor SaaS for third party application developers of FI applications. The cloud services (e.g., the APIs) are designed to be reusable, for easy access, and to be browse-able for various users and developers. It has been designed to highlight new means of communication that could be in advantage to people with special needs (e.g., people with speaking disabilities) as it could make their interaction with FI applications much easier. In general the work put forward new market and business opportunities for SMEs that require developing FI applications using hand motion sensors to automate and enhance their services. Also, in the concept of healthcare sensitive domain cloud applications, could offer anew services for patient monitoring. The service has been designed to be flexible and portable in order to overcome the problem of medical data transferring in clouds [8].

In the Interact project the expectation is to attract customers that could use the motion sensor services without the need to redevelop the functionalities offered by the solution. Future developers for FI applications are able to develop their own solutions by utilizing the hand motion storage services that offers an open database. The application highlights utilizes FI-WARE GEs as the new cloud services that offer innovation in the European cloud sector. It could motivate new FI application clients to move to new standards.

The solution is hosted in the intellicloud [6] and offered as an instance. Intellicloud is an experimental cloud infrastructure for designing cloud-based Internet applications. It is an open testbed environment for researchers and developers that aim to design and deploy cloud based FI applications. The infrastructure is based on OpenStack (an open source cloud computing platform) [7] and offers infrastructural and platform services that include pre-configured FI-WARE GEs and deployment of Specific Enablers (SEs) for exploration, configuration and testing from the Future Internet Social and Technological Alignment Research (FI-STAR [9]) programme. In the future, we aim to develop additional APIs in order to allow incorporation of other motion sensors like the Microsoft Kinect [11] that senses up to 6 peoples and their movements in a space. Also, we aim to include communication with other IoT devices. For instance this could be proven to be valuable in the area of robotics, so by using the cloud service it will make feasible to control a robotic system remotely.

ACKNOWLEDGMENT

The research leading to these results has received funding from the European Unions Seventh Framework Programme (FP7/2007-2013) under grant agreement no 604691 (project FI-STAR).

REFERENCES

[1] L. Schubert, K. Jeffery, B. Neidecker-Lutz (2010) "The Future of Cloud Computing –Opportunities for European cloud computing beyond 2010", European Commission [Online]. Available: http://cordis.europa.eu/fp7/ict/ssai/docs/cloud-report-final.pdf.

[2] Roy T. Fielding and Richard N. Taylor. 2002. Principled design of the modern Web architecture. ACM Trans. Internet Technol. 2, 2 (May 2002), 115-150.

[3] "Motion sensors market, global forecast" *The Free Library* 11 April 2012

[4] Nonverbal Communication, Chapter 6: http://www.sagepub.com/upm-data/53604_Gamble_(IC)_Chapter_6.pdf

[5] DMH Facts: Top 10 Facts you may not have known abot deafness, Report provided by: Missouri Department of Menatl Health, http://dmh.mo.gov/deafsvcs/documents/DMHFacts-DeafServicesFacts.pdf

[6] Intellicloud of Technical University of Crete: http://www.inteligence.tuc.gr

[7] OpenStack, Open source software for bulind private and public clouds: https://www.openstack.org

[8] S. Sotiriadis , G.M. E. Petrakis, S., Covaci, P., Zampognaro, E., Georga, C., Thuemmler (2013) "An architecture for designing Future Internet (FI) applications in sensitive domains: Expressing the Software to data paradigm by utilizing hybrid cloud technology", 13th IEEE International Conference on BioInformatics and BioEngineering (BIBE 2013), November 10-13, Chania, Greece

[9] Future Internet Social and Technological Alignment Research (FI-STAR) http://www.fi-star.eu

[10] LEAP Motion Sensor: https://www.leapmotion.com

[11] Microsoft Kinect: http://www.microsoft.com/en-us/kinectforwindows/

[12] FI-WARE: http://www.fi-ware.org

[13] L. Richardson, S. Ruby (2007) RESTFul Web Services: Web Services for the Real World, O'Reilly Media.