AsTeRICS

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Abstract. AsTeRICS - "The Assistive Technology Rapid Integration & Construction Set" is a construction set for assistive technologies which can be adapted to the motor abilities of end-users.

AsTeRICS allows access to different devices such as PCs, cell phones and smart home devices, with all of them integrated in a platform adapted as much as possible to each user.

People with motor disabilities in the upper limbs, with no cognitive impairment, no perceptual limitations (neither visual nor auditory) and with basic skills in using technologies such as PCs, cell phones, electronic agendas, etc. have available a flexible and adaptable technology which enables them to access the Human-Machine-Interfaces (HMI) on the standard desktop and beyond.

AsTeRICS provides graphical model design tools, a middleware and hardware support for the creation of tailored AT-solutions involving bioelectric signal acquisition, Brain-/Neural Computer Interfaces, Computer-Vision techniques and standardized actuator and device controls. Novel, end-user ready solutions can be created and adapted via a graphical editor without additional programming efforts. The AsTeRICS open-source framework provides resources for utilization and extension of the system to developers and researches.

AsTeRICS was developed by the AsTeRICS project [1] and was partially funded by EC.

Keywords. AsTeRICS, AT, Assistive Technologies, User driven AT, Ambient Assisted Living, Motor Disability, BCI, Brain-Computer Interface, Computer Vision, Model based design, Biosignal Acquistition.

Introduction

More than 2.6 million people in Europe have problems with their upper limbs and therefore many of them depend on Assistive Technologies (AT) [2]. As the potential of the individual user is very specific, adaptive, ICT-based solutions are needed to let this population group participate in modern society. Such solutions are rarely available on today's market.

AsTeRICS provides a flexible and affordable construction set (see Figure 1) for building assistive functionalities which can be highly adapted to individual user's needs. The scalable and extensible system allows integration of new functions without major changes. AsTeRICS opens access for people with severe motor disabilities to a standard desktop computer but also to embedded devices and mobile services, which have not offered highly specialised user interfaces before [3] .

Assistive Technologies (AT) for people with motor impairments must fit individual capabilities of the user to be efficient. Although objective classifications of the motor abilities in different stages of disabilities do exist [4], it is often a unique setup, hardware-/software combination or mounting option which makes a solution really useful for a particular person.

Figure 1: Flexible and affordable construction set

The vital research and development of accessible Information and Communication Technologies (ICT), foremost in the areas of Bioelectric Signal Processing and Computer Vision, led to a growing number of new input alternatives especially for people with severe motor conditions like late-stage Amyotrophic lateral sclerosis (ALS), muscular dystrophy, multiple sclerosis, quadriplegia or cerebral palsy. Such new solutions and their combination with traditional AT (switches, mouth-sticks or on-screen keyboards) bear the potential of highly efficient, tailored Human-Computer Interfaces (HCI) for barrier-free access to ICT and the embedded services of today's Smart Environments.

1. Technical Concept

The AsTeRICS platform implements a set of building blocks for the realization of assistive technology. The base of the concept is an embedded computing platform executing the AsTeRICS Runtime Environment with OSGi [5] plugins providing desired AT-functions. The platform can be connected to sensors and actuators which allow the system to interact with its environment (see Figure 2).

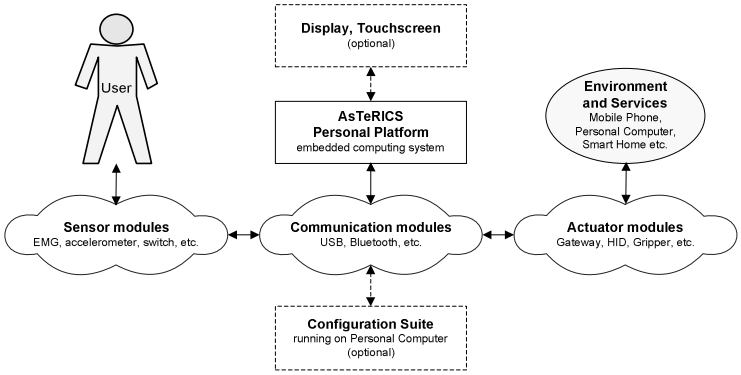


Figure 2: Schematic concept of AsTeRICS

2. Sensor Modules

The sensor modules make a basic classic solutions for AT available - e.g. switches, mini joysticks, accelerometers, strain gauges or sip/puff-switches. In addition to these off-the-shelf sensors, other multi-purpose input modules are integrated into the AsTeRICS system like Computer Vision and Brain Computer Interfaces (BCI), e.g. the Smart Vision Module, Enobio® wearable, modular and wireless electro-physiology sensor system for recording of EEG (electroencephalogram), EMG (electromyogram) and EOG (electrooculogram) or the Inertial Measurement Unit (IMU). Additionally, non-classical input devices like touchpad, MS Kinect or speech recognition are integrated to serve as AT-enabled sensors in the AsTeRICS construction set.

3. Communication Interface Modules

The Communication Interface Modules (CIMs) support the information transfer between the main system components: they link together the AsTeRICS Personal Platform, the sensor- and actuator modules and the Personal Computer for system configuration. The CIMs are put in place using mechanical sockets of the hardware platform. Furthermore, the CIMs can connect the AsTeRICS system to existing standardised solutions for environmental control, e.g. a home automation gateway.

4. Actuator Modules

The actuator modules provide the AsTeRICS system with an effective interface to the environment or to other ICT devices.

Actuators include simple switches and digital-to-analogue conversion but also more complex modules like keyboard-, mouse- or joystick emulation, generic infrared remote control, KNX [6] interface to existing building automation systems or mobile phone access. If desired, an On-Screen Keyboard displayed on an optional LCD-touchscreen provides selection or adjustment of system parameters via scanning, voice-feedback and touchscreen interaction. The system can be configured remotely using the ACS provides a graphical user interface to set up and tailor the components to the specific needs of the primary user.

5. Personal Platform

The core element of the AsTeRICS hardware is the AsTeRICS Personal Platform, an embedded computing system, which processes data from input modules and controls output to actuator modules - to put assistive functionalities in place.

The platform is based on a Kontron single board computer (COMe-mSP1) [7] which utilizes an Intel Atom Z530 processor [8]. This single-board computer provides a good compromise between mobility, low power consumption and high computation capabilities. The Personal Platform provides 6-port USB 2.0, DVI, built-in audio, microphone input and headphone output, 10/100/1000 Mbps LAN, optional 802.11 b/g/n WiFi interface and BlueTooth, with basic set of general purpose digital inputs

and outputs and analogue inputs, a mSATA 64 GB SSD, a control panel with graphical display and resistive touch panel and internal battery backup. The electronic is built in a robust aluminium case. This makes the Personal Platform a compact device, where the sensors and the actuators can be connected directly to and the Personal Platform can perform the basic assistive functionalities (see Figure 3).

Figure 3: Sensors connected to Personal Platform

Sensors and actuators are connected to the embedded computing platform by wire (USB, Ethernet) or wirelessly (WiFi, Bluetooth, ZigBee), directly or via Communication Interface Modules (CIMs). The CIMs can be connected to the platform directly via a USB cable or inserted to the optional attachable CIM container which can contain up to three CIMs to provide more compact and robust AsTeRICS system. Among others, the following modules are included:

- The optional LC-Display with touchscreen is a USB-connected and USB-powered off-the-shelf product by MIMO technologies [9] which can be easily integrated with the personal platform. The resistive touchscreen can be used with standard mouth- or head pointers.
- The GPI CIM is an extension module of the personal platform when additional digital inputs are needed. This module offers six General Purpose Inputs for switch-type sensors. This module has two interface variants – wired USB or wireless 802.15.4 interface.
- The GPO CIM is an extension module of the Personal platform when additional digital outputs are needed. It offers three open-collector (OC) General Purpose Outputs and two relay outputs. The module communicates via USB.
- The ADC CIM is an extension module of the Personal Platform when Analogue-to-Digital Conversion (ADC) is needed. This module offers 2-channel ADC Voltage and Resistive Inputs with programmable excitation current source (e.g. for strain gauge measurements). The module communicates via USB.
- The HID-actuator module is a USB dongle which enumerates standard mouse-keyboard- and joystick human interface devices (HID) on Windows-, Linux- and Mac operating systems without additional driver software. Thus, the HID actuator allows interfacing of the AsTeRICS system to any standard PC, by generating mouse movement and clicks, keyboard input or joystick control from signal features of other AsTeRICS sensors like BCI, Face-Tracker or

specialised AT input devices. The control communication between the dongle and the platform runs via USB cable or wirelessly via Bluetooth.

- The Accelerometer module contains tri-axial acceleration sensor with selectable g-ranges (1 to 16 g), 14 bit ADC operation. The module is in small plastic package with optional wrist strap. The module communicates via USB.
- The Inertial Measurement Unit (IMU) is a sensor module consisting of a 3-axis accelerometer, a 3-axis gyroscope and a 3-axis magnetometer. The firmware of the IMU module integrates these 9 degrees of freedom information into an Attitude and Heading Reference System (AHRS) which delivers orientation- and movement data to the AsTeRICS platform. The module can be easily attached to a desired location on the user's body by a Velcro strip. Combined with gesture recognition algorithms provided by software plugins of the AsTeRICS system, the IMU can support selection and control tasks of the user.
- The Smart Vision Module (SVM) represents a computer vision based tracking system using remote or head-mounted cameras. The head-mounted SVM will feature two camera modules for iris- and scene image acquisition. A data processing module sends the synchronized camera images via USB to the AsTeRICS Personal Platform, where algorithms for scene recognition and eye gaze tracking can be applied.
- The Enobio BNCI sensor is an EEG/ECG/EMG amplification- and signal acquisition system using dry electrodes and a low-power ZigBee wireless link. Enobio can deliver data for BCI applications and gesture detection (e.g. eye blink / double blink recognition). Enobio can deliver wireless data for about 8 hours running from rechargeable battery.
- The infrared remote control- and KNX-gateways. These actuators provide interfaces to commonly used home entertainment and home automation facilities like TV-/DVD-/HiFi center and lightning or HVAC control.

Configurations designed with the configuration suite (ACS) can be downloaded into the AsTeRICS personal platform to perform the desired functions. As individual users do not need the complete set of sensors and actuators, particular applications can only use appropriate modules. In this way, AsTeRICS provides cost-effective alternative AT-solutions which are highly customisable to the individual requirements of each person. The open source AsTeRICS software can be also downloaded to a netbook or desktop PC and with a single CIM connected it gives even cheaper replacement for certain basic use cases.

6. AsTeRICS Configuration Suite

The AsTeRICS Configuration Suite (ACS), open-source SW, provides an accessible graphical user interface to set up the system and tailor the components to specific needs of the primary user. Sensor and actuator modules are represented in the ACS by graphical symbols with input and output connectivity that can be connected to each other (see Figure 4). Module-parameters like threshold level, gain, sensitivity etc. define the mapping of sensor values and the responsiveness of the assistive

configuration. Users and caretakers are offered means to modify key parameters in a simplified version of the ACS.

An extensive set of signal processing components has been designed to implement a simple BNCI interface. Electrophysiological data is acquired via the Enobio wireless EEG/ECG/EMG sensor. Some components implement basic functionalities such as filtering, decimation, FFT, threshold comparison, dissimilarity, cross-correlation, epoch averaging, etc. that allow conditioning and processing the electrophysiological signals. Other components implement more complex algorithms like eye blink detection whose results might be directly used to drive an actuator.

One further component of the AsTeRICS software is the so-called BNCI Evaluation Suite. This is a MATLAB toolkit that integrates functionalities of already existent toolkits, e.g. BIOSIG and others [10]. The purpose of the BNCI Evaluation Suite is the off-line testing, comparison, and configuration of BNCI subsystems for a particular user. These subsystems are expected to include the most frequently used BNCI paradigms today, namely motor-imagery and P300 [11].

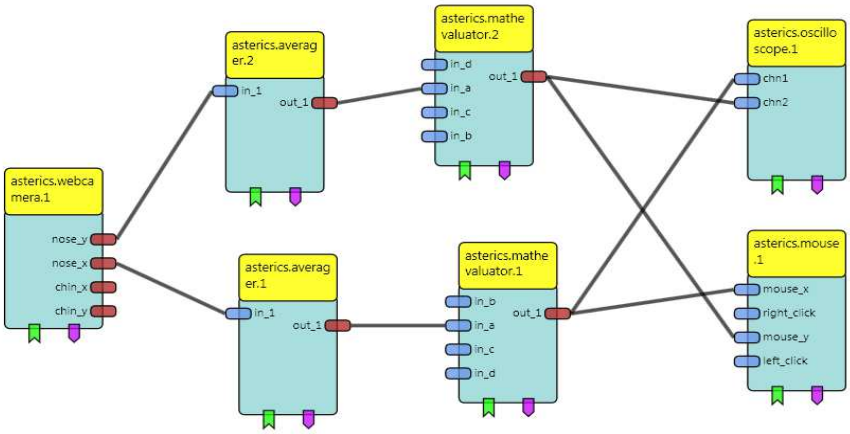


Figure 4: The AsTeRICS Configuration Suite with a simple Camera-Mouse design

7. AsTeRICS Runtime Environment

The AsTeRICS system comprises the following main software components:

- the AsTeRICS Runtime Environment (ARE), open-source SW
- Plugable Component Modules (PCOMs) for the ARE
- the AsTeRICS Configuration Suite (ACS) to set up and configure AT-designs
- the BNCI Evaluation Suite to investigate BCNI signal processing approaches
- Software libraries and APIs for AT software developers (mobile phone access, tremor reduction, 3D-mouse interface etc.)
- an On-Screen Keyboard with grid layout editor and acoustic feedback

The AsTeRICS Runtime Environment (ARE) is commonly deployed on an embedded device, running an appropriate operating system (OS), typically an embedded variant of Windows or Linux. On top of the OS, an appropriate Java Virtual

Machine (JVM) is used to host the OSGi component framework which provides support for modularity and dynamic loading/unloading of components [12][13]. All the core components of the framework are defined as OSGi modules. Certain components that need to access legacy code (e.g., written in C or C++) are also deployed on top of OSGi, and are interfaced to the native code using Java Native Interface (JNI) as needed.

Central to the ARE is the system model: an abstract representation of the actual software and hardware components currently available, and the actual bindings established between them. System models are graphically designed on the ACS and communicated to the runtime environment in a realizable format.

The main features of the AsTeRICS Runtime Environment are constituted as follows:

- Includes a mechanism that allows components to be deployed, resolved and activated dynamically, as defined by the system model;
- Provides methods for accessing and setting its running system model;
- Provides methods for accessing and setting certain properties of the running system;
- Provides methods for monitoring the computing load.

The main building blocks for any system design within AsTeRICS are called Pluggable Component Modules (PCOM). PCOMS can be *Sensors*, which produce data, *Processors* that process data or *Actuators* which are used to consume data towards a goal. Sensors are commonly coupled to underlying hardware sensors to generate their output data (e.g., a face tracking sensor which is coupled to a web-camera), but they can also be completely realized internally (e.g., a signal generator). Processors provide the foundation for forming applications. They can be either realized completely internally (e.g., an average which keeps track of the last n values of a scalar value and always outputs their average value) or they can be coupled to some external software library or even coupled to a hardware. Finally, the main role of actuators is to enable the desired functionality of the applications (KNX home automation, Infrared Remote Control, HID-actuator control for mouse/keyboard/joystick emulation, etc.)

The components communicate through *channels* which are used for representing the data flow between them. Channel edges are connected to component artifacts called *Ports.* Sensors have only output ports, actuators have only input ports while processors have both.

Furthermore, AsTeRICS incorporates a set of libraries intended for external developers. These libraries aim to help developers to build or adapt their application for people with motor disabilities. The libraries are delivered as native Microsoft Windows DLLs, and they work independently of ARE. Libraries already available are e.g.: Phone Library, Keyboard Library, Tremor Reduction Library and 3D Mouse Library.

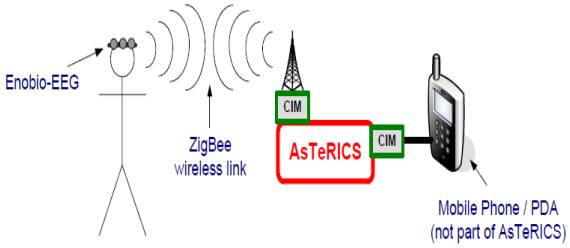
The Phone Library is designed to allow control of mobile phones. The library uses WiFi to connect to a special Phone Server application running on Android smartphone. The library interface allows the application to do such activities as making, receiving and dropping phone call, sending and receiving SMS. The Keyboard Library is designed for developers who need to adapt the computer keyboard for the specialized needs of motor disabled people. Developers using this library will be able to retrieve information about all system key events and send key events to other applications. The Tremor Reduction Library is designed to allow users suffering from conditions such as

Essential Tremor and Parkinson's Disease to use standard computer pointers like computer mice. The Library reduces the effect of the tremor using compensation algorithms. The 3D Mouse Library is designed to help in adapting 3Dconnexion 3D Mouse devices for people with motor disabilities.

8. Use cases

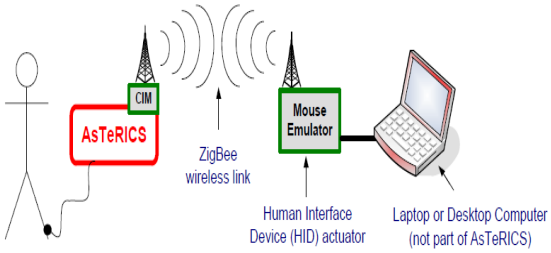
Use Case 1:

EEG (BCI) or EOG
+ Zigbee Transmission
to use a mobile phone



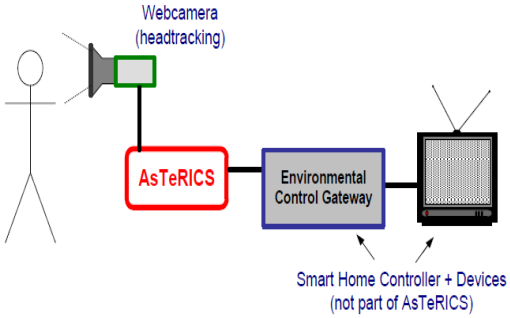
Use Case 2:

Acceleration Sensor
for Computer Mouse
Control



Use Case 3:

Head Movements detected by
Computer Vision Module to
control smart home functions



9. Summary

Key Characteristics of AsTeRICS:

- AsTeRICS is a platform fostered by EC as standardised kit for assistive devices
- Conceptually supports various products to be plugged in – simple and cheap solution
- Open source core gives opportunity to other AT developers to integrate new devices
- AsTeRICS addresses impaired society within AAL target population

Areas of use: Communication, Rehabilitation, Self-care, Work, Recreation

Users: Caregivers, Therapists, Family members and friends, Computer scientist AT

AsTeRICS allows to control: PC, Mobile phone, Home audio visual equipment, Intelligent home / smart home, Game console, Online tutorials, RC toys, etc.

Distributor: Harpo, IMA (only in the Czech Republic and Slovakia)

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