IT in education: using assistive technology for people with sensorial and cognitive impairments

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«Использование информационно-коммуникационных технологий в обучении людей со специальными потребностями»

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Politecnico di Milano ARCSLAB

UNESCO IITE

Perm State University

Structure of the Presentation

- Goal of the presentation:
  - **Show ways to use currently available technology to assist impaired students during learning, and show prototypes created and results obtained in pilot experiments**
  - **Discuss lessons learned in the process**
- We will:
  - Describe some of the **impairments** that technology can address
  - Describe the basic working principles of the **technology** that can be used to develop assistive learning environments
  - Describe the main **experiments** carried and their **results**
  - Draw some **conclusions** and explain future possibilities

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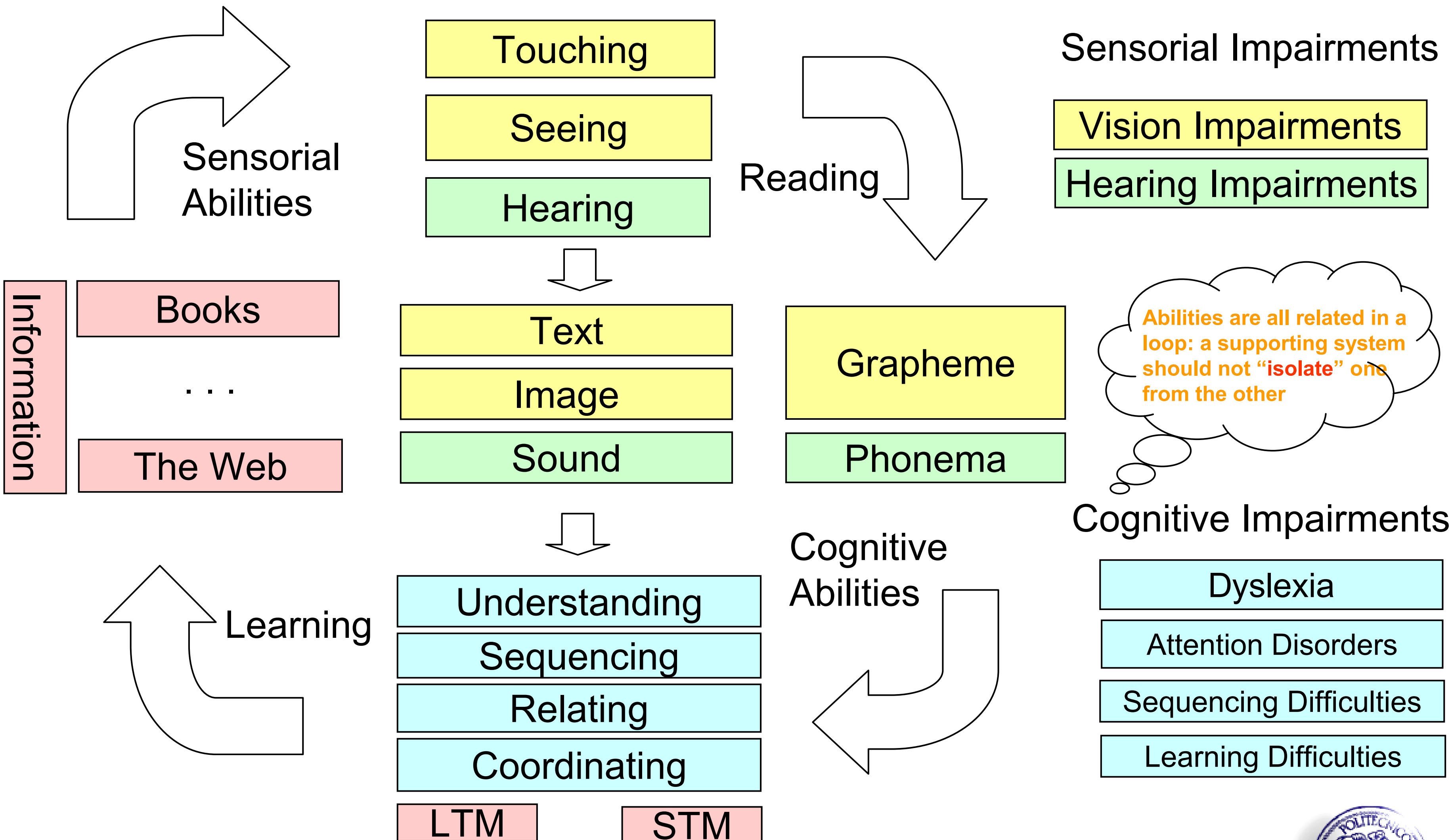
Impairments and Technologies

Sensorial and Cognitive Abilities



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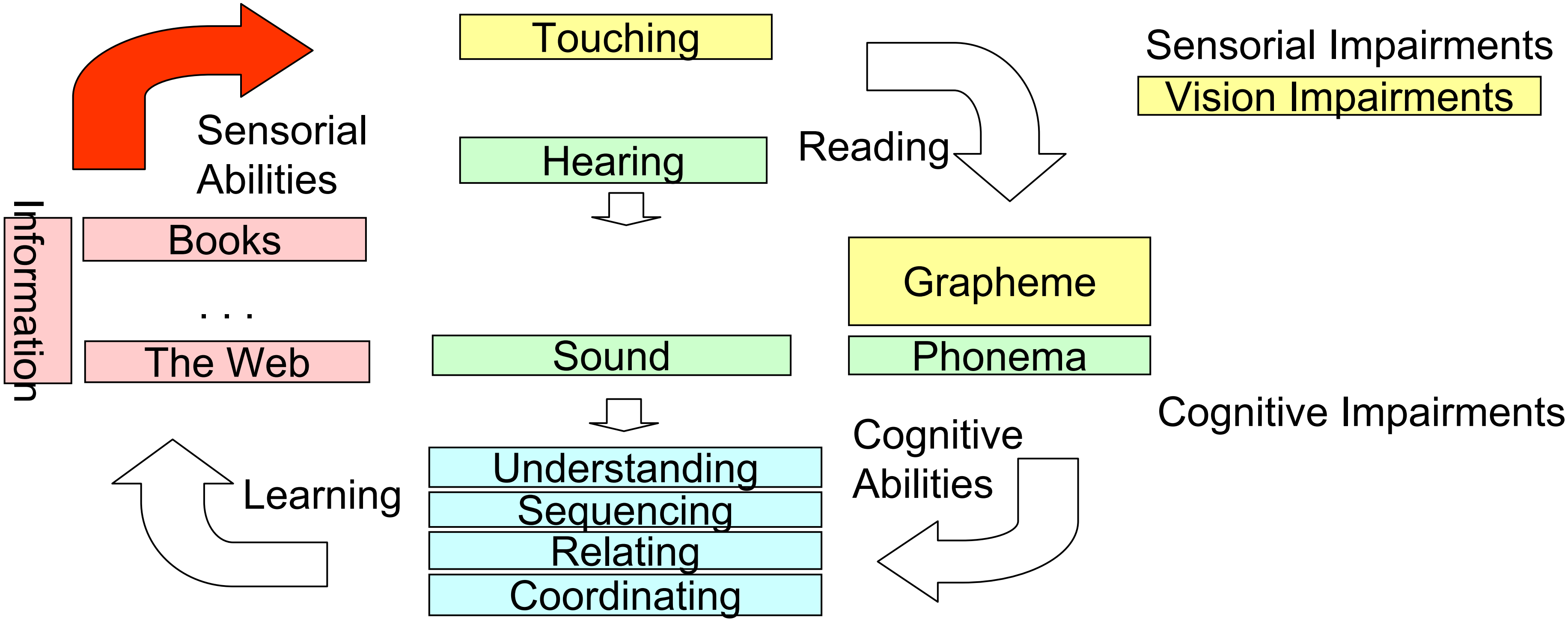
Sensorial Impairments



- In vision impairments, touching and hearing abilities are used to build the graphema / phonema relationship. Cognitive abilities are, in most cases, intact.
- The sense of touching is important to establish the cognition of the grapheme (examples: Braille, Optacon ™, Relief Exploration)
- In native hearing impairments, spoken communication is missing and this may lead to language difficulties, and understanding difficulties with complex written text.

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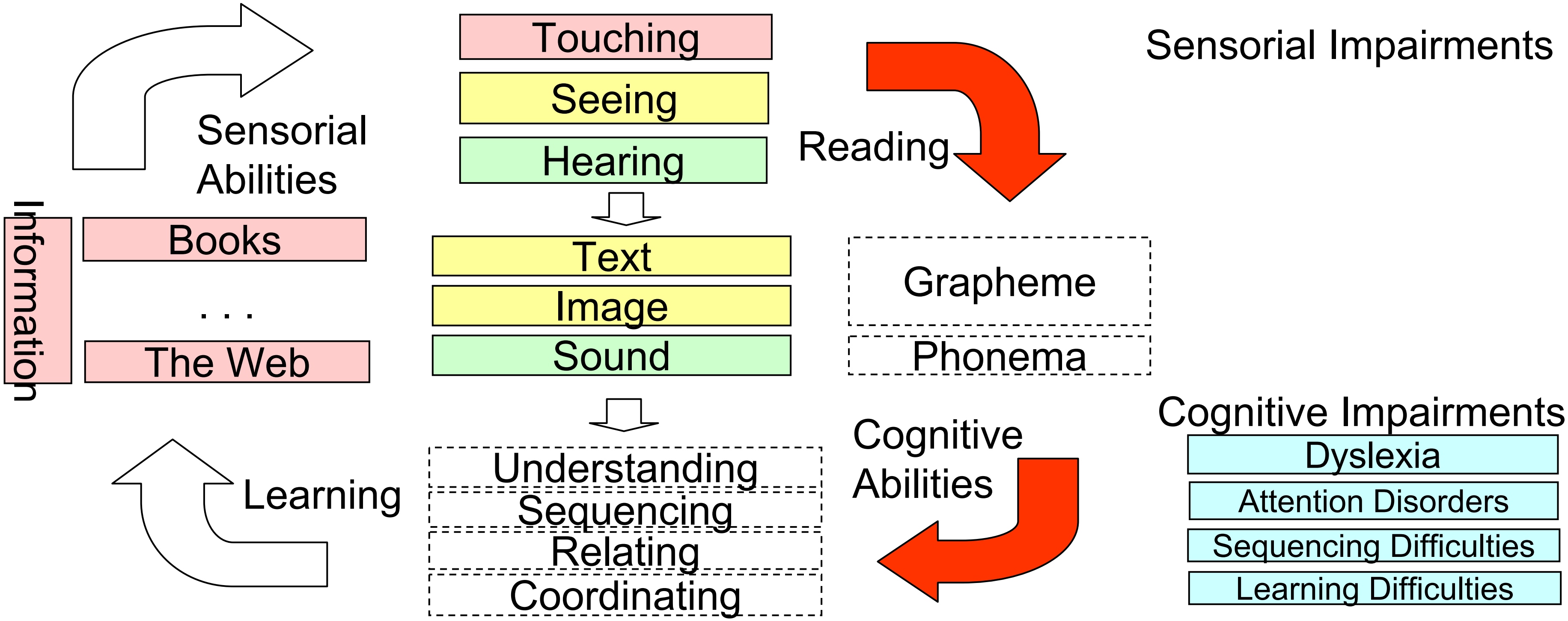
Cognitive Impairments



- **Dyslexia causes difficulties in learning to read, write and spell. Short-term memory, mathematics, concentration, personal organisation and sequencing may be affected. Dyslexia concerns difficulties in relating graphemes to phonema. Students with dyslexia develop specific strategies to perform grapheme-phonema correlation. This is why foreign languages represent an additional difficulty.**
- **Sequencing difficulties make it difficult to users to remember the sequence of operations made to reach a goal or an information. Short-term Memory (STM) is problematic.**
- **Attention disorders (ADHD - Attention Deficit Hyperactivity Disorder) make difficult to users to concentrate for long on a single subject. A high number of different images, options, buttons, as in most of today's websites, make it impossible for these users to reach the information they need.**

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Technologies: the Web

- The web is a world-wide collection of pages containing information. Pages can be loaded using an Internet connection.
- The information is reperesented with text, images, sound, animations.
- The visualization of the information is described with a simple universal language (HTML), which can be understood by different visualisation or sonification programs (Web Browsers, Screen Readers)
- To make web information readable to all programs, and different categories of users, some basic rules have to be followed (Accessibility Rules or “WCAG”)

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Technologies: Text To Speech

- TTS (Text To Speech) allows to create synthetic speech from the written text using a computer. There are realistic TTS voices for all the most common languages.
- The counterpart, ASR (Automatic Speech Recognition) allows a computer to derive text from a speech audio signal.
- This technology is based on the concept of formants, the basic sounds forming words and speech in a specific language. Formants are recurring patterns in the way sound energy is distributed over frequency and time
- TTS and ASR are technologies that can also be integrated into telephony networks.
- There is a convergence between Computer Networks and Telephony Networks. These two networks are being combined together. This makes possible to use telephones as means of input and output of information in a speech form, using TTS and ASR for converting voice into computer-readable data.

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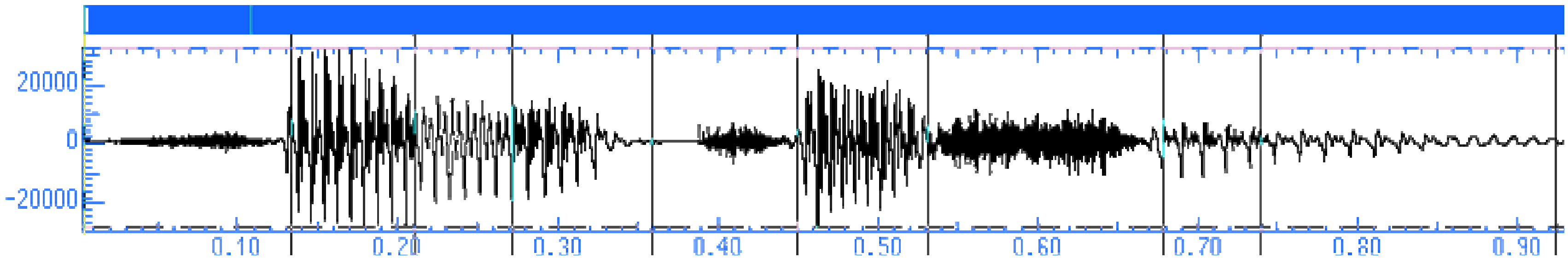
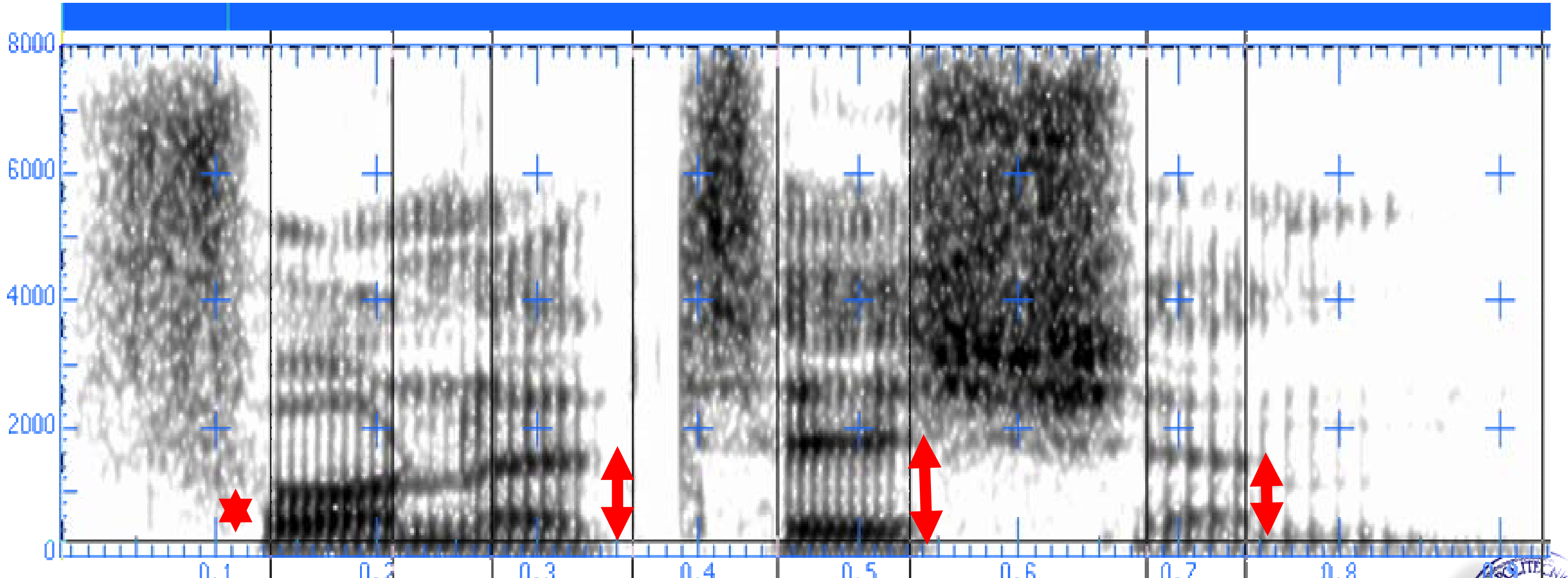
Wave Sampling and Sonograms: Formants



f o n e t i sh ia n



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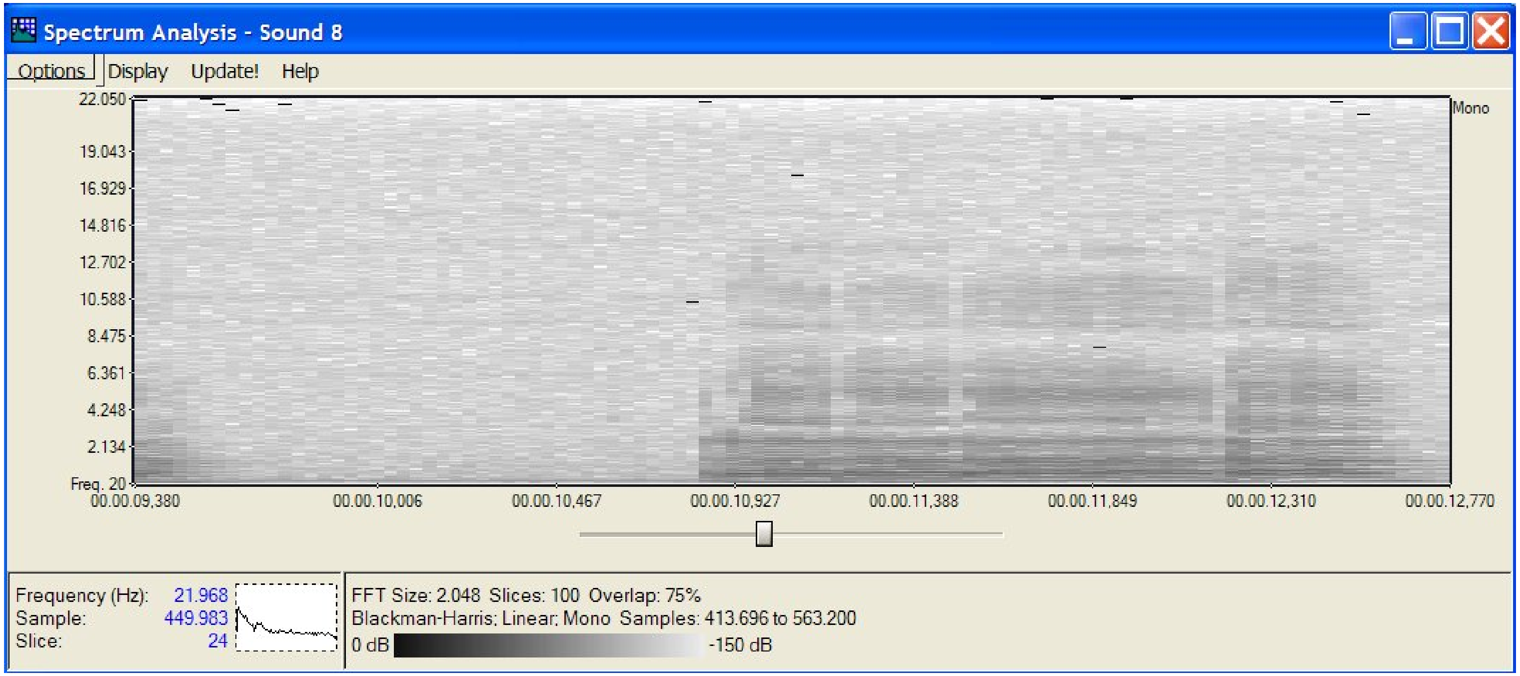
TTS Examples

Russian Voice: Katya

Italian Voice: Giulia



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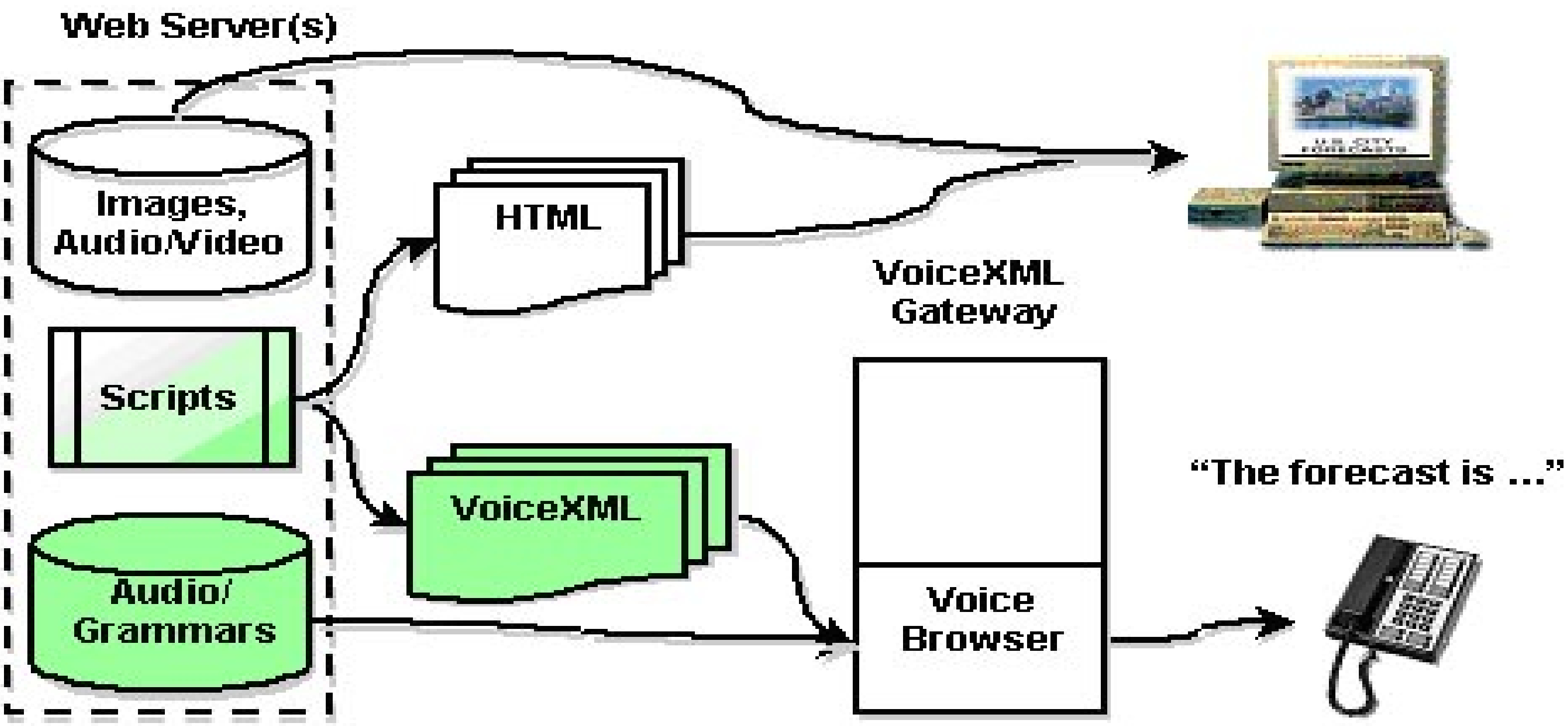
Integration of Telephone and the Internet



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Technologies: Natural Language Processing

- Natural Language Processing is a field of language and computer science whose goal is to extract automatically information and meaning from text written in natural language (not programming languages).
- NLP allows a computer to:
  - Decide what are the principal meanings of a text
  - Perform an automatic summarization of the text
  - Classify the parts of speech of a written text
  - Identify the words which carry the most significative meaning or play the most important role in a sentence / text
  - Evaluate the cognitive complexity of a text

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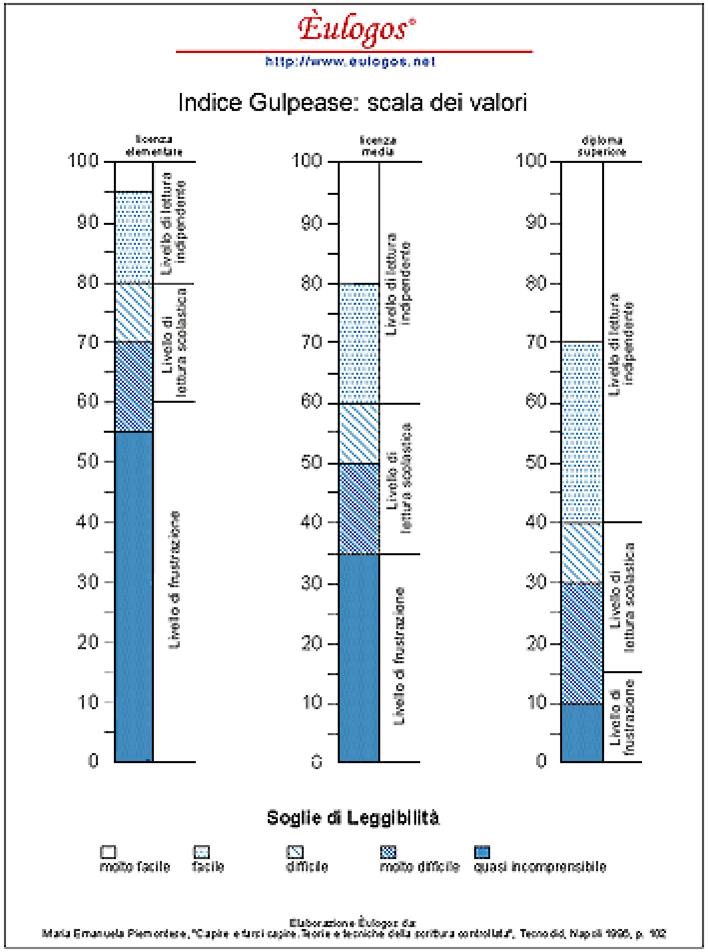
GulpEase Index

- The Gulpease Index is a number which expresses the easiness of readability of an italian text based on the text structure.
- Gulpease Index =
  89 - (Lp / 10) + (3 × Fr)
- where:
  - Lp = (100 × total letters) / total words
  - Fr = (100 × total sentences) / total words.
- The Gulpease Index ranges between 0 and 100, where 100 is highest readability and 0 not readable.
- The readability is related to the index empirically (with tests over students with different scholarity): e.g. Index 50 is unreadable for a student in first class, but easily readable for a student in high school



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Base Vocabulary

- A Base Vocabulary is a vocabulary that gathers the most used and understood words during oral communications for a certain language.
- The Italian Base Vocabulary was compiled by Tullio De Mauro in 1997 and contains 7000 words.
- The words in the BV are grouped into three levels:
  - Foundation Vocaboulary: 1.991 words which are the most frequent in the italian language;
  - Frequent Use Vocabulary: the next most used 2.750 words. They are frequently used, although less than foundational words;
  - High Availability Vocabulary: 2.337 words of different sources, mostly oral communication: these are words that are seldom present in written communication but often present during a conversation (eg: scissors, suntan, …).
- A text which mostly uses Base Vocabulary words is more understandable also to people which is less trained in reading complex texts. When a word not belonging to the BV has to be used, it can be used and subsequently explained with words of the BV.

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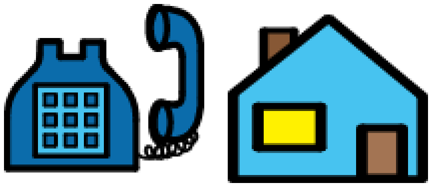
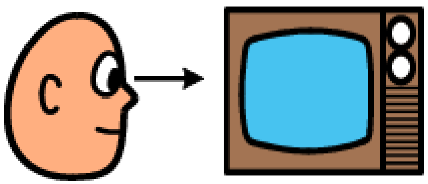
PCS

- **Picture Communication Symbols (PCS) (www.mayer-johnson.com) -** PCS originated in 1980 as a picture dictionary.



- There are approximately 3,000 symbols.
  PCS consist of simple drawings.
  There are no symbols for grammatical markers.
  There is an excellent selection of vocabulary for all ages.
- The PCS are designed to fill a need for a transparent (easy to learn) set of symbols for augmentative communication. The PCS are geared toward a younger population, but are used with older people as well.



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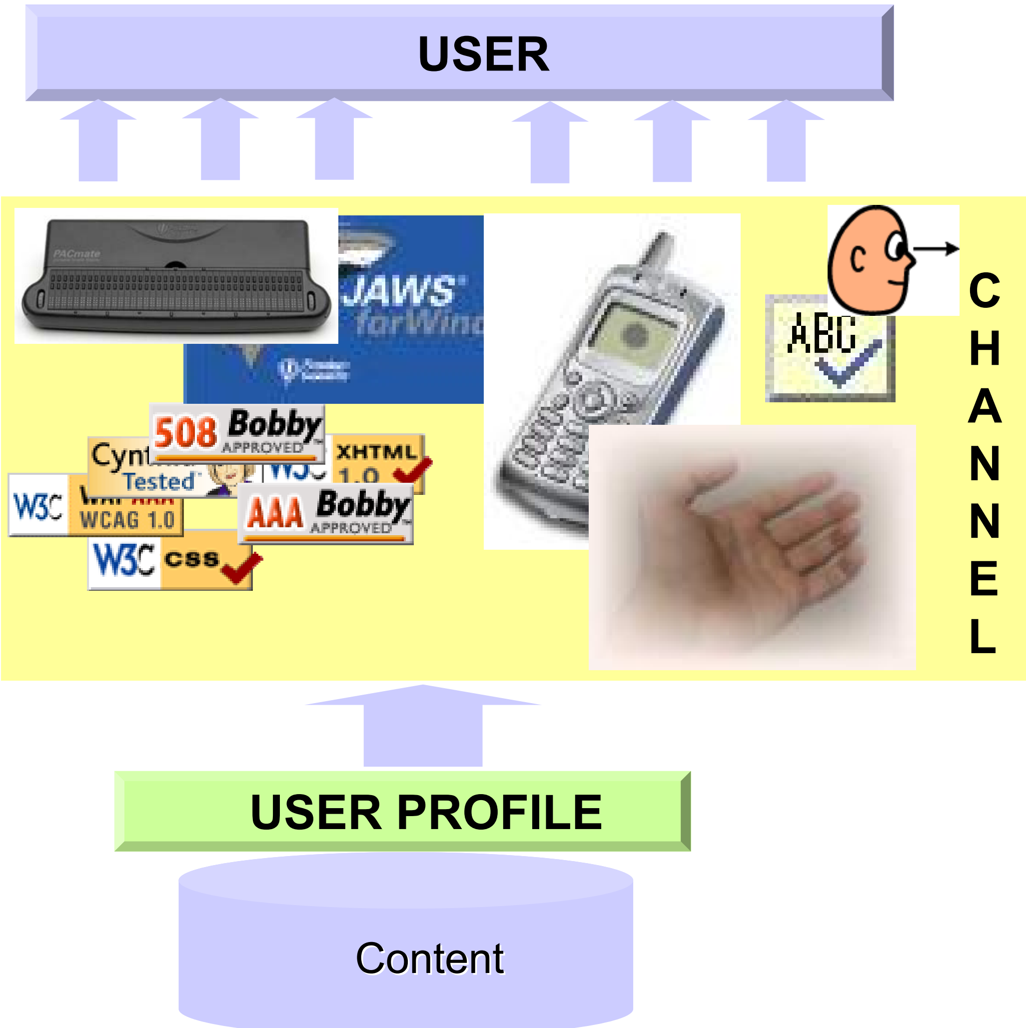
What is Content Accessibility?



- Content Accessibility is a range of technologies to allow users with different abilities to access content and understand its meaning.
- CA has to be modelled on a specific user profile and on the modality he/she prefers to navigate it/ use it
- A technological approach which allows to improve content accessibility is Multimodality, that is “providing more than one modality to access the same content”

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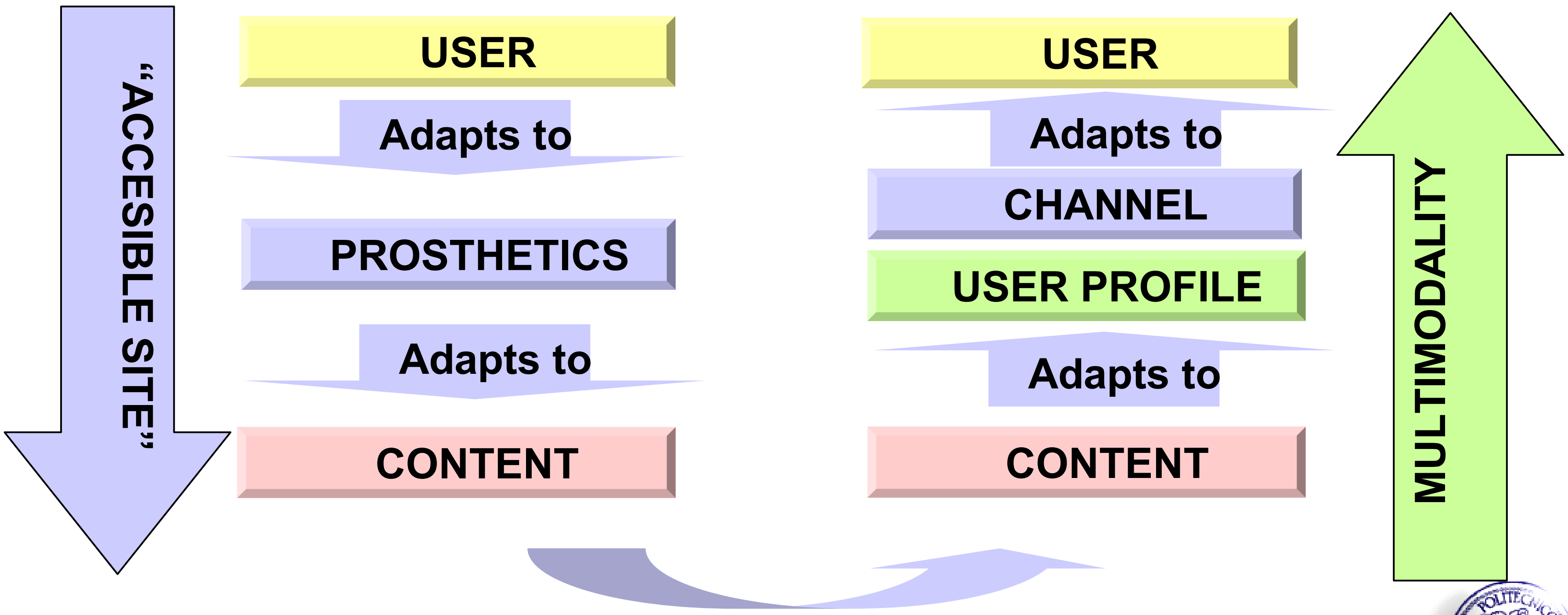
Multimodality for Content Accessibility

- Adapting a Web Site but not the content, forces users to adapt to prosthetics (Screen Reader…).
- Giving more modalities to access contents, we can adapt contents to the channel and modality chosen by the user (e.g. simplify text or provide a PCS representation, using a voice instead of text…)



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ARCSLAB at Politecnico di Milano

- In the following we are showing some prototypal experiments in which we are using different technologies to address the needs of users with different abilities.
- These prototypes are intented to give ideas on how to use technologies to assist impaired students, but they are not fully usable products (yet)
- The prototypes and the experiments were designed and realized at ARCSLAB (Adaptive, Relational and Cognitive Software Laboratory) at Politecnico di Milano.
  - Director: Licia Sbattella (sbattell@elet.polimi.it)
- The experiments were carried in collaboration with:
  - Milan's Institute of the Blind
  - The National Italian Association of People With Dyslexia
  - Region of Lombardy

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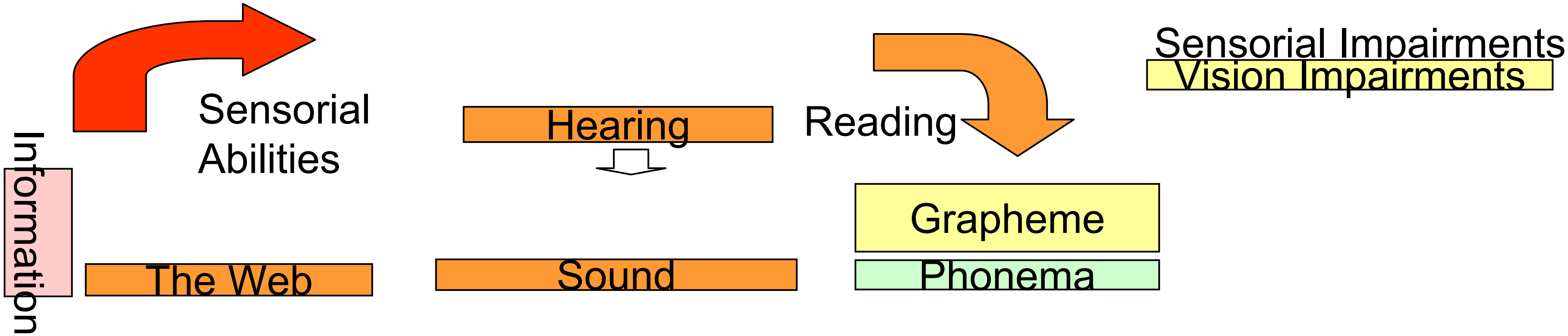
Prototypes and Results: Sensorial Impairments

MultiAbile: an accessible learning platform



- MultiAbile is a software which allows to publish course material for students on the web. The material is automatically presented in a way that it is easy to read it using screen readers, or Braille.
- It is also automatically accessible using TTS, by calling the system using a telephone.
- It also provides the possibility to subscribe to news channels on the web (a facility called RSS – Real Simple Syndication) and read these news using a Screen Reader, Braille or the Telephone.
- The interface is simple, in order not to distract the user.
- The text of the course is provided with different levels of readability
- Each user can choose the look of the interface, the level of text, etc.

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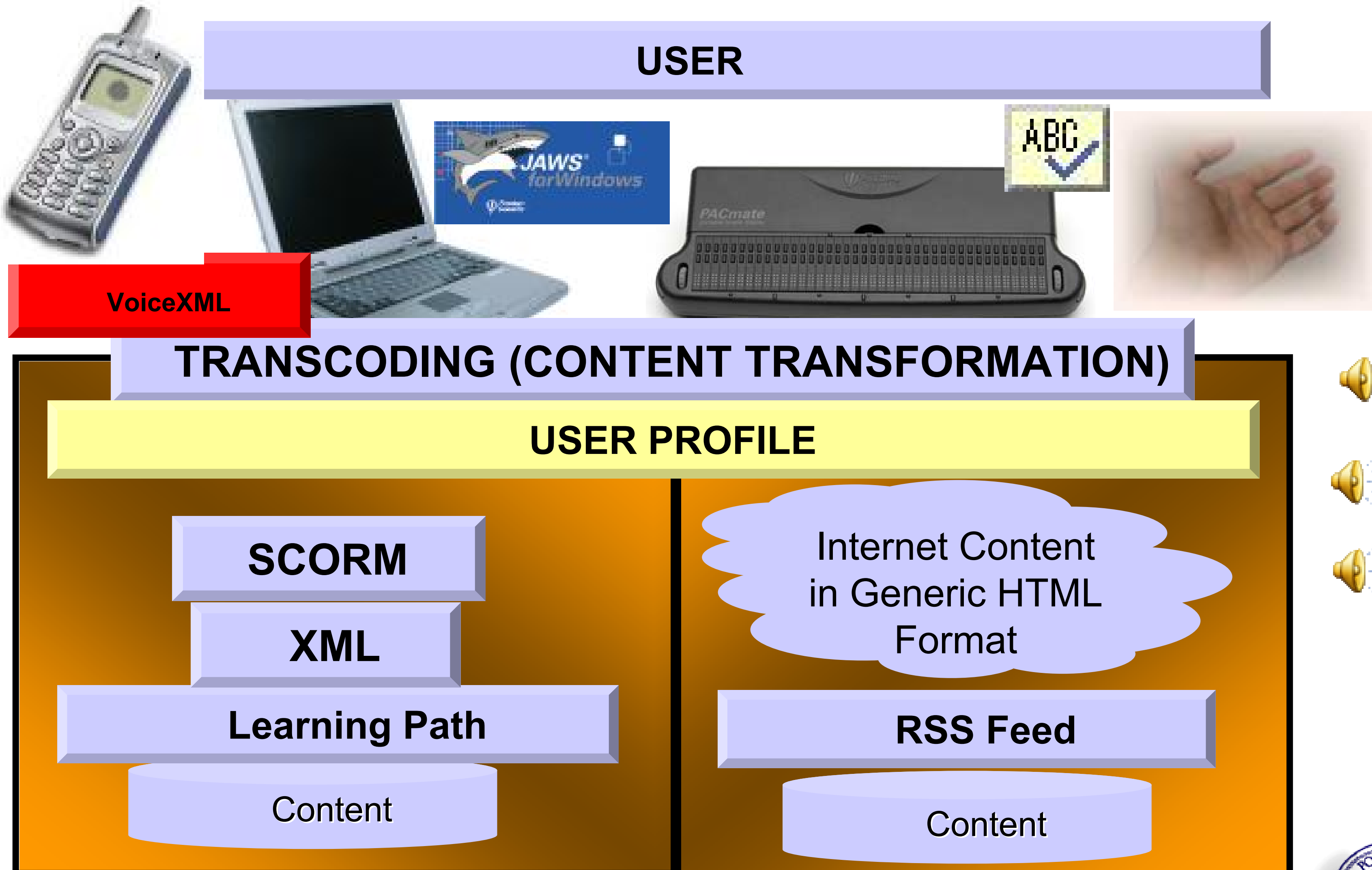
Content Transcoding



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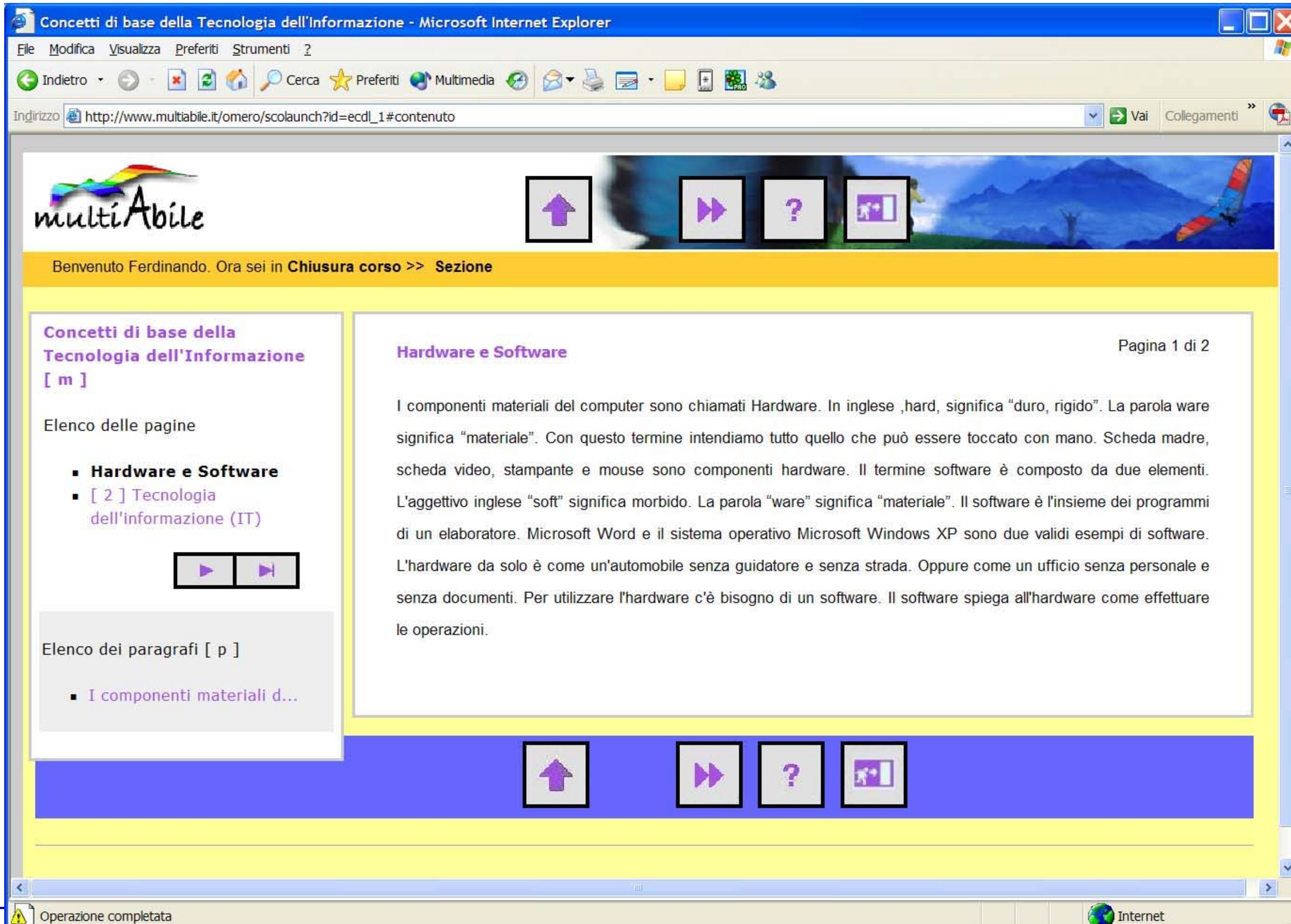
MultiAbile: Learning a Course on the Web



Contents and User Profile

- Content Transcoding is based on the user profile and the selected channel and allows to:
  - View content via web browser, using WCAG guidelines (reading with Jaws, Braille Display)
  - TTS via telephone in different modalities (“extended”, “short”, “slow reading”, “fast reading”), the user can choose the modality
  - Content can be read in different morphological-syntactical version (with different language complexity index)
  - Browse through structured content (Learning Path - SCORM, RSS Directory of information (news, info, blogs…)
  - Content can be:
    - A COURSE TO BE STUDIED
    - NEWS FROM A NEWS CHANNEL On the Web (Sport, Weather, Traffic, Literature, Events, etc.)

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MultiAbile: Testing

- The platform was tested using a course about “Basic Notions of Computer Technology”, used by 10 blind users, all already able to use accessible web sites using a Screen Reader and a Braille Bar. None of them had cognitive problems.
- The users were asked to:
  - Read some news in the news channel “Football”
  - Study some pages of the course
- The users were afterwards asked some questions about the news they heard and the part of the course they studied, to verify that they could learn information using the system.

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MultiAbile: Results

- The users gave correct answers after having used the system, with an average of **86% correct answers**.
- **100%** of the users claimed that they would **use the system to subscribe to news channels** and read them via the web or the telephone
- **67%** of the users claimed that they would use the web platform to learn a full course
- **33%** of the users claimed that they would use the telephone access to the system to learn a full course
  - However, these users were all fully educated in the use of the computer, screen reading software and braille bar.

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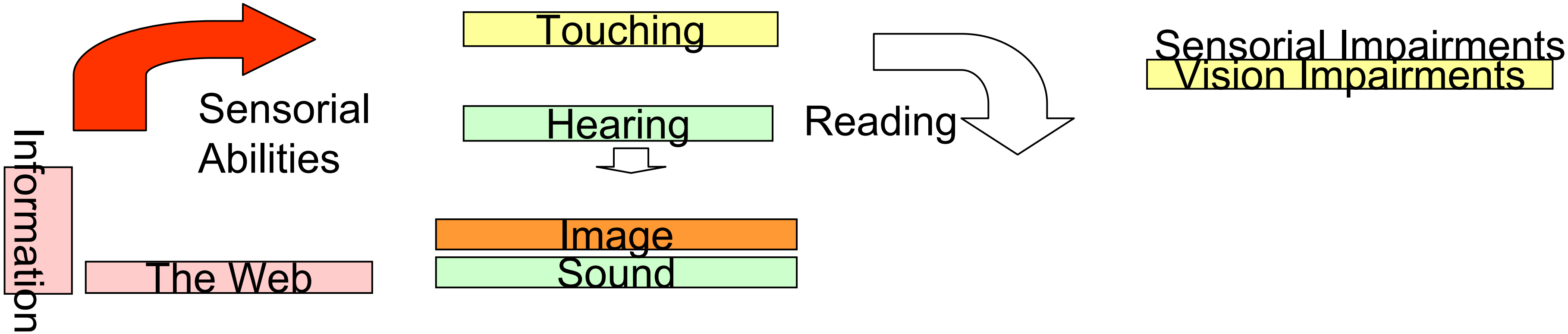
Accessing Images: AudioTact



- Screen Readers and TTS allow to read text and learn from written courses. However, in some cases images carry complex meaning, and it is not possible to render this meaning into text easily.
- For example, studying the geography of a region without seeing a map can prove difficult.
- AudioTact is a prototype of a system which allows in a simple way a blind user to explore bidimensional images (for example, geographical maps or geometric shapes) *taken from the web and autonomously* (without the need to build in advance a relief).

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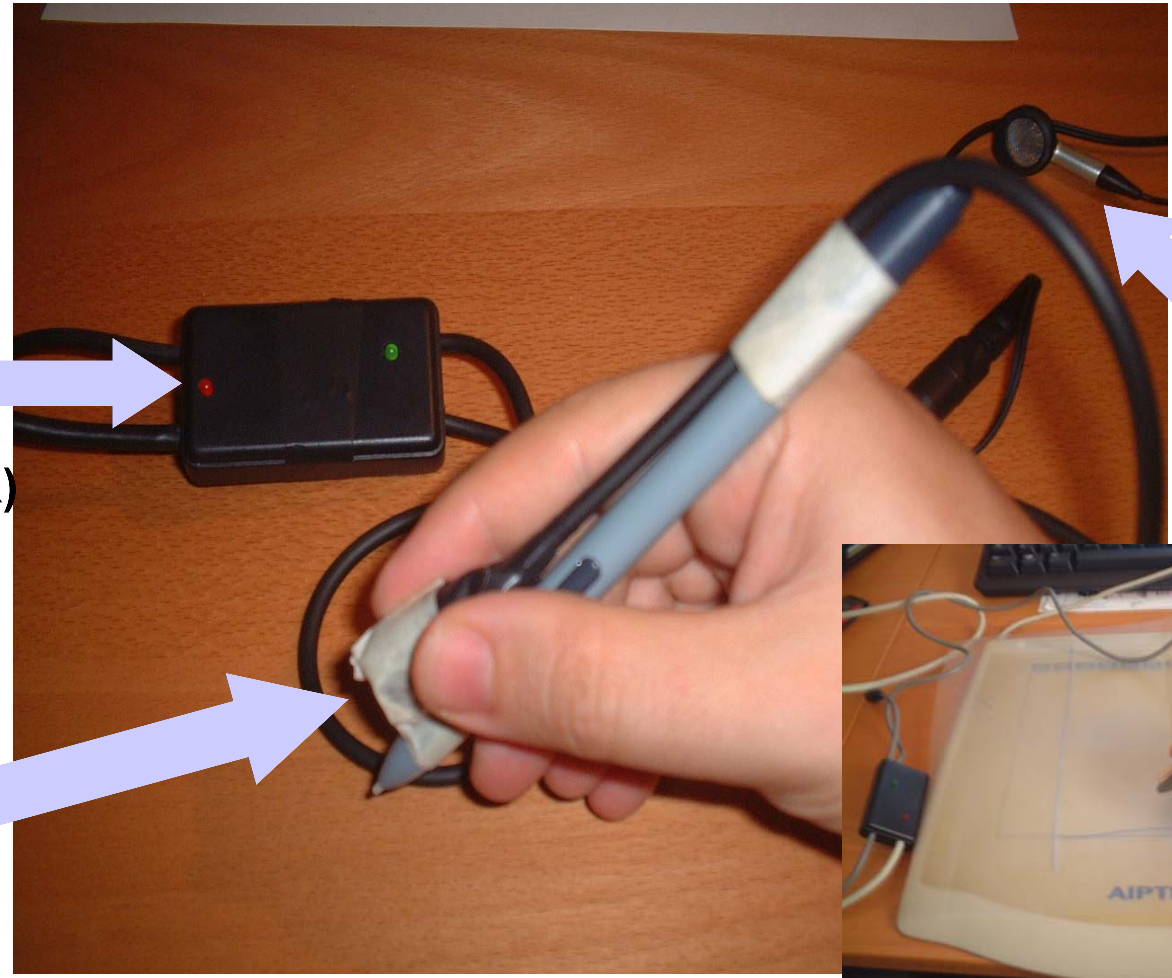
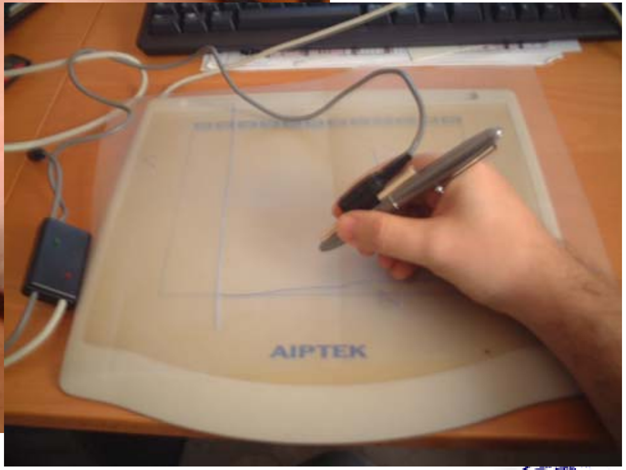
Pen for Vibrational and Audio Cues (prototype, Patented)

Channel Separator & Amplifier (IN: AUDIO L+R)



Audio Cues

Vibrational Transducer



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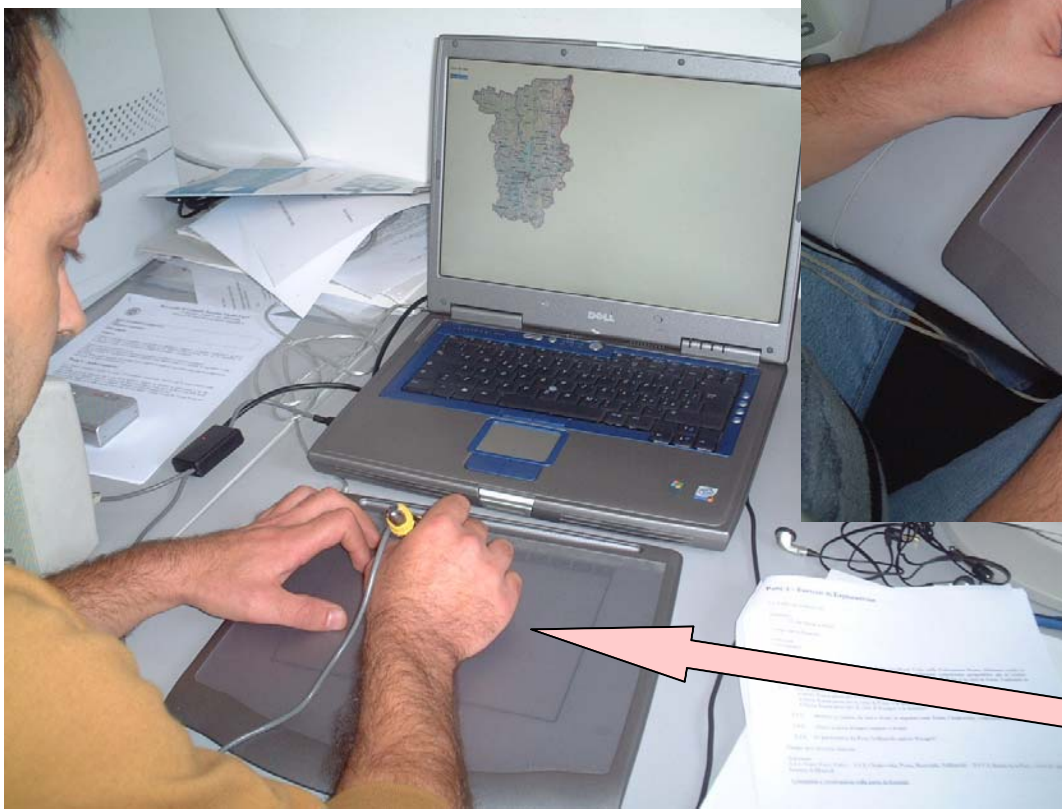
AudioTact

Studying Perm' Region



The student "holds Perm Region in his hand"

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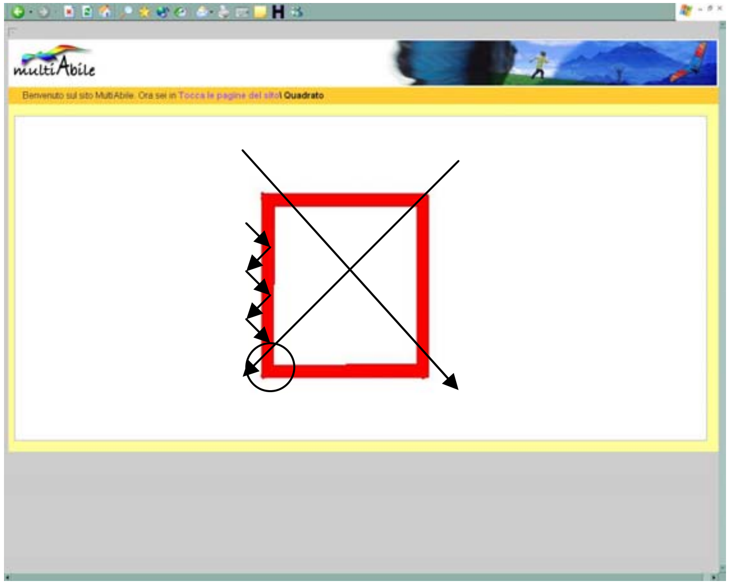
Using Vibrational and Audio Cues

- A device which uses the two stereo audio channels to offer a combination of audio and tactile stimula during exploration with a touch screen of an image downloaded via the web.
- The Web Image is pre-prepared in a way that it can generate sounds which are produced on the left channel by regular audio headphones and on the right channel by a vibrational transducer which has to be worn on the finger.
- Following a given exploration method, the visually impaired user can autonomously extract information from the features of the image.



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AudioTact: Testing

- This approach was tested in a case study which involved ten blind students of the Institute of the Blind in Milan. The test provided a training phase, in which the student could get confident with the method, and a second part in which it was required to use the system to extract new information from unknown images.
- During the traning stage, we explained to each student how the method worked, and we announced that he/she was going to explore a simple shape: a square; and a map of an area he/she knew: the region of Lombardy.
- At the end of the training session, we required the students to extract autonomously information from two images, a simple shape of a triangle and another geographical map, representing a region of which they did not have any previous knowledge (the map of the Region of Perm, in the Russian Federation).

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AudioTact: Testing

- During the experiment, we loaded the image of the triangle, and we asked the students to try to understand the shape by following its contours, and we took note of the time needed for the students to explore the shape and recognize it (or forfeit, declaring that they couldn’t understand).
- Subsequently, we explained that they were going to learn the geography of a region of the Russian Federation, and read in advance the questions that they should have answered:
  - Does the Kama River flow in the center of the region?
  - Does the Kama River flow across the city of Perm’?
  - Does the Kama River flow across the city of Kungur?
  - Place in order, from South to North, the following cities: Perm’, Chaikovskij, Solikamsk, Berezniki
  - Which city is farthest from Perm’, Solikamsk or Kungur?

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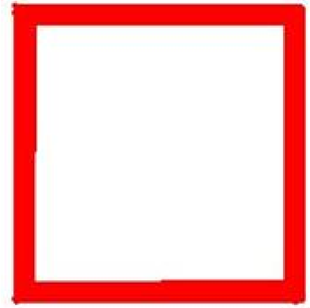
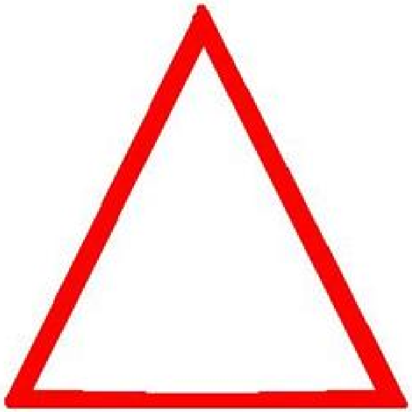
AudioTact: Images for Testing

- Training phase: a square and Lombardy Region



- Experimental phase: a triangle and Perm' Region



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AudioTact: Results

- After training and exploring the map, almost all users replied correctly about questions over a geographical region they didn't know before (they could tell the shape of the region and the position of the cities after having studied the map).
- In average it took 9 minutes to study the map to answer all 6 questions. For one student, it took 5 minutes.
- The method requires a high degree of concentration. Not all students proved capable to sustain it for all 6 questions.
- **Almost all students declared that they would like to use this system to study geography**

Test of Usage over 10 blind users				
	% Of users	Average Time (min)	Max Time (min)	Min Time (min)
Recognizes Square	90,00%	4,2	10	1
Avg % Correct Answers on Lombardia Region	83,33%	4,7	9	1
Recognizes Triangle	70,00%	4,2	8	1
Avg % Correct Answers on Perm Region	81,25%	9,0	12	5
Want to use for Geometry	60,00%			
Want to use for Geography	80,00%			

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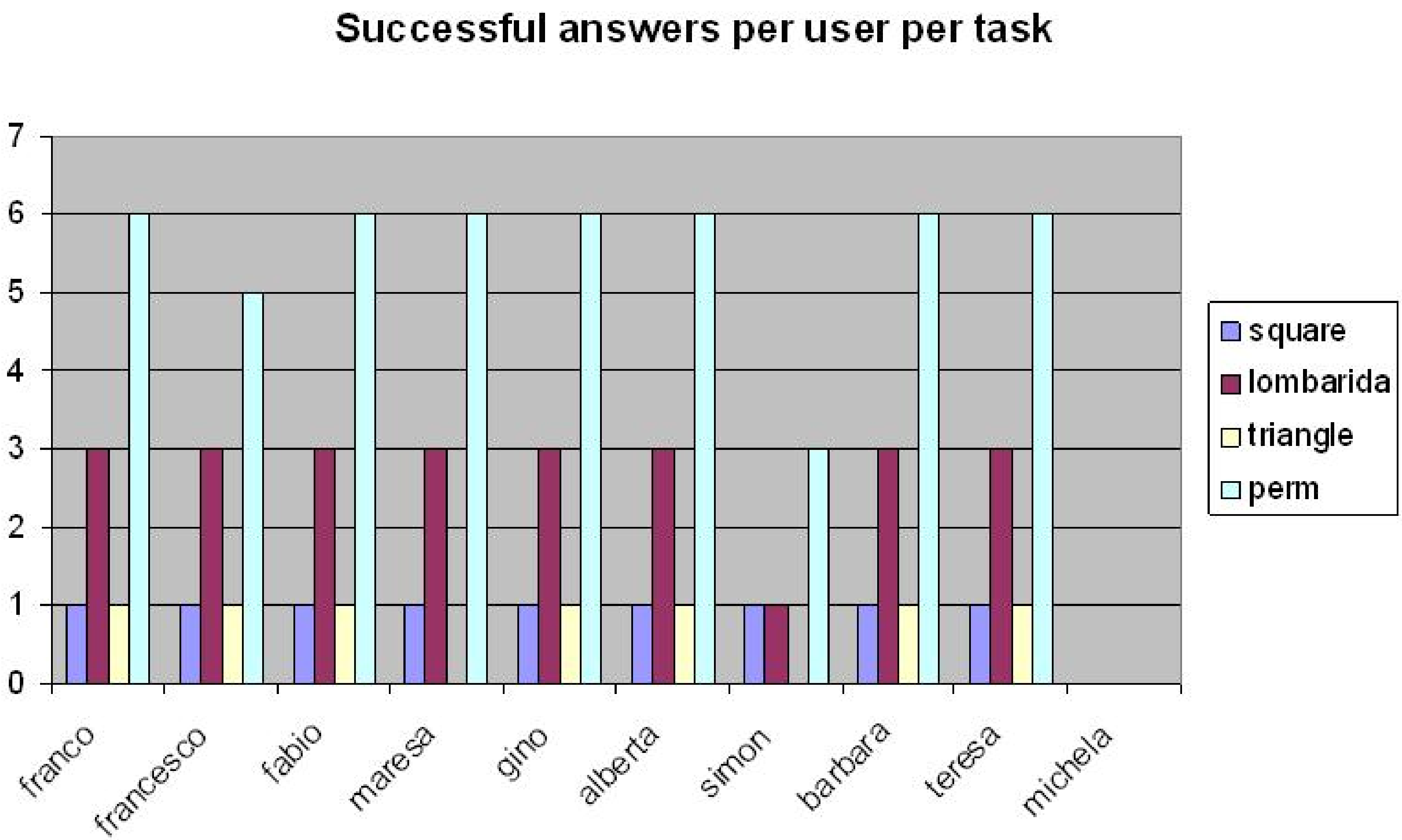
AudioTact: Results



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Prototypes and Results: Cognitive Impairments

Text Simplification

- In the MultiAbile platform, text is provided in at least two versions: full text and simplified text. Simplified text provides better access to people with problems understanding complex language structures, or people not fully trained in understanding TTS.
- The current version of the prototype requires a manual structural simplification, and uses a complexity index based on GULPEase, which takes into account phrase and word lengths, and uses in addition the results of a shallow parsing of the documents (syntactical analysis).
- Content writers were able to rewrite manually contents with a high accessibility index, at a rate of approx. 160 words per hour, starting from an already present original document.
- For manual simplification by a human content editor, we prepared the text of our courses requiring a minimum complexity index of 65 (the higher the index, the more readable the content).
- In our experiments, over a total of 30,000 words, content editors obtained easily an average readability GULPEase index of 70, leaving in the text 16% of words not belonging to the Base Vocabulary.

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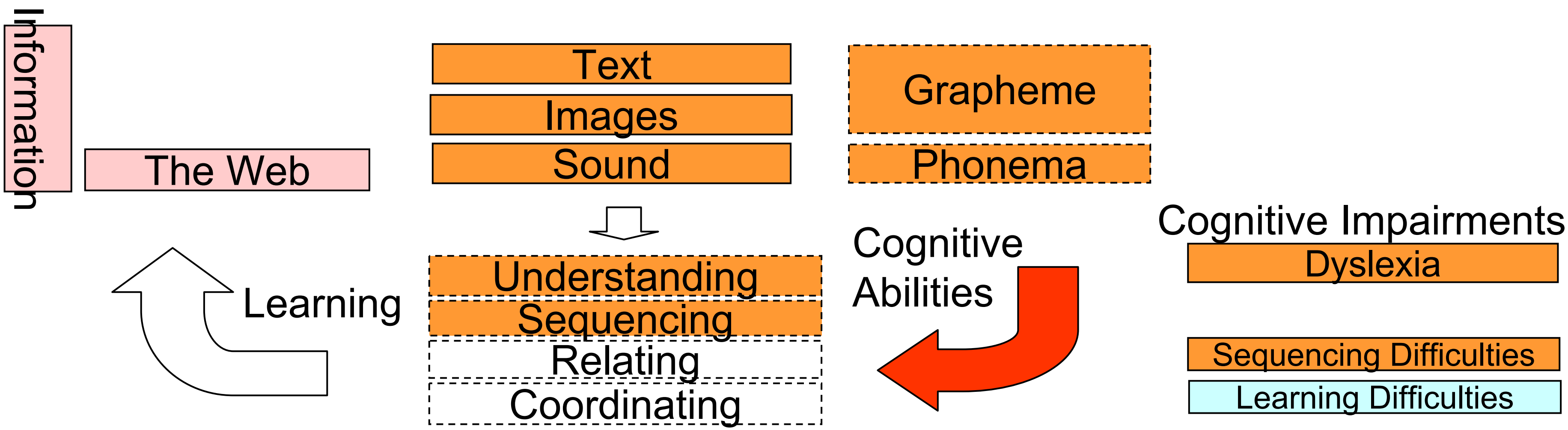
Cognitive Accessibility: AACLezi



- AACLezi is a subproject for the learning system which makes use of Alternative Augumentative Communication, associating to concepts in the text their iconic representation. This approach is mainly dedicated to young students (elementary schools).
- AACLezi uses PCS Symbols attached to Simplified Text. It has been tested to help young students with dyslexia to improve their ability to relate graphemes with phonema, with the aid of iconic concepts and TTS.

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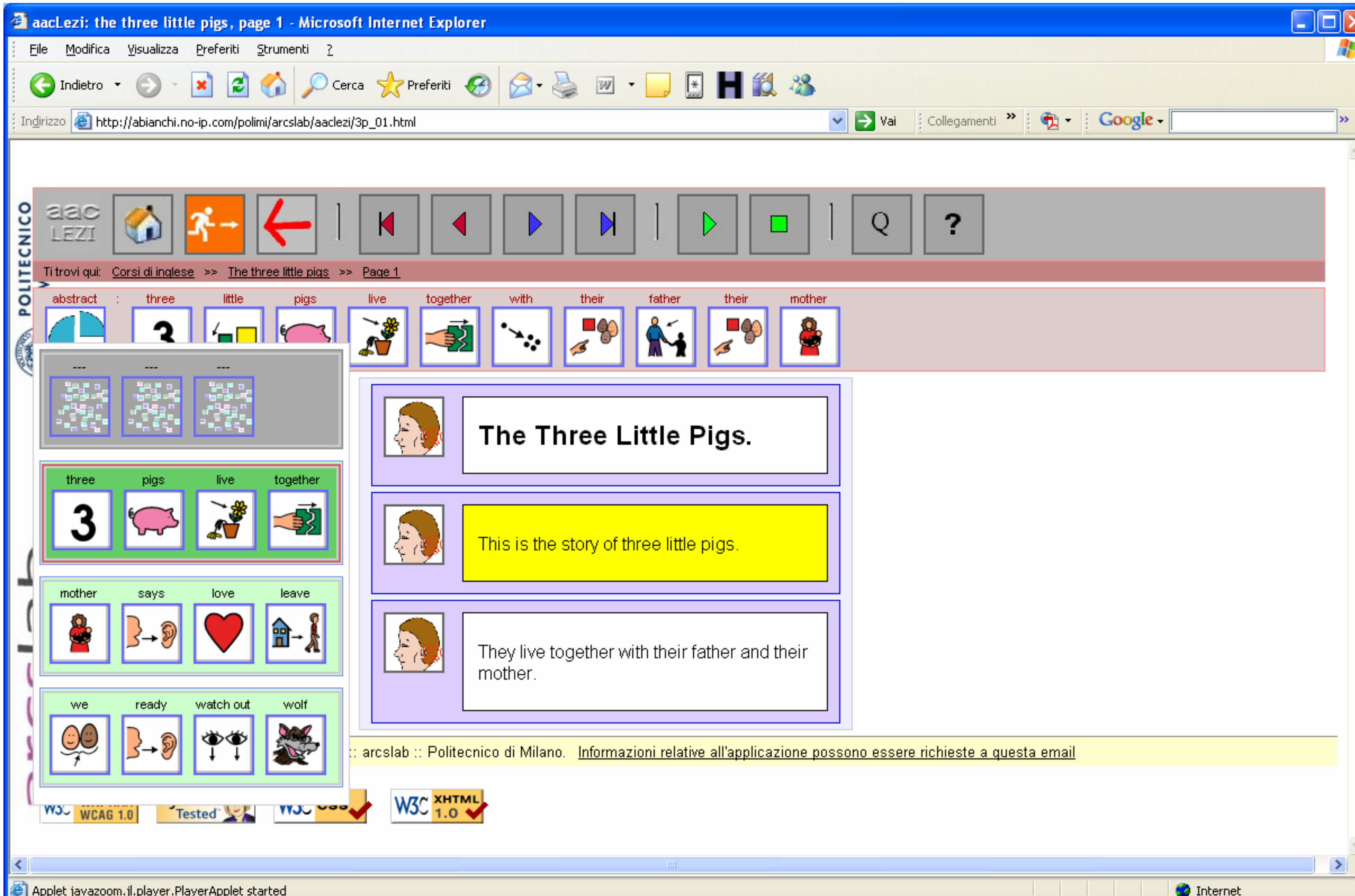
AACLezi: Video Demonstration



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AACLezi: Testing

- The system was tested in reading text from a school course, a book, some journal articles, and a story in foreign language. The test on foreign language is particularly interesting because it forces the students to uproot the phoneme/graphemes relationship they build with their written native language.
- **The tests were performed with 4 schoolchildren with dyslexia, studying at elementary school, and with 3 students with dyslexia in high school.**
- During tests, students showed good results in orienting themselves in the conceptual space, and perused effortlessly the visual and vocal strategies necessary to build complex sequences. Even with the difficulties of the english language, the level of attention was sustained and good in all subjects.
- In the test requiring to read questions and choose answers, the performance in understanding sequences degrades, while manual-visual coordination is good, as well as the ability to use sequential memory. The level of interaction with the program remains high, even with the added difficulty of the unclear grapheme/phoneme relationship of the english language.

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AACLezi: Evaluation Results

- The comments of the students on some features of the system were the following:
- The use of **keywords** summarizing in textual and iconic form the concepts in the page was considered:
  - **Excellent** (3 excellent, 1 good): elementary school
  - **Good** (2 good, 1 sufficient): high school
- Using **PCS** Symbols for representing keywords was considered:
  - **Excellent** (2 excellent, 1 good, 1 suff.): elementary school
  - **Unsatisfying** (2 suff, 1 unsatisfying): high school
- Using an **image to comment the text:**
  - 1 very useful, 3 useful: elementary school
  - 2 useful, 1 not useful: high school
- Paragraph Length:
  - All students preferred paragraphs which could be longer, but complete in their logical meaning, instead of shorter paragraphs, but with the meaning divided into more sentences.
- Modality of Interaction with the Page:
  - All students favored the choice to let them choose whether to activate or not the speech reading of the text (with a click).
- Highlighting of the text:
  - All students favored the way text being read gets highlighted as reading proceeds.

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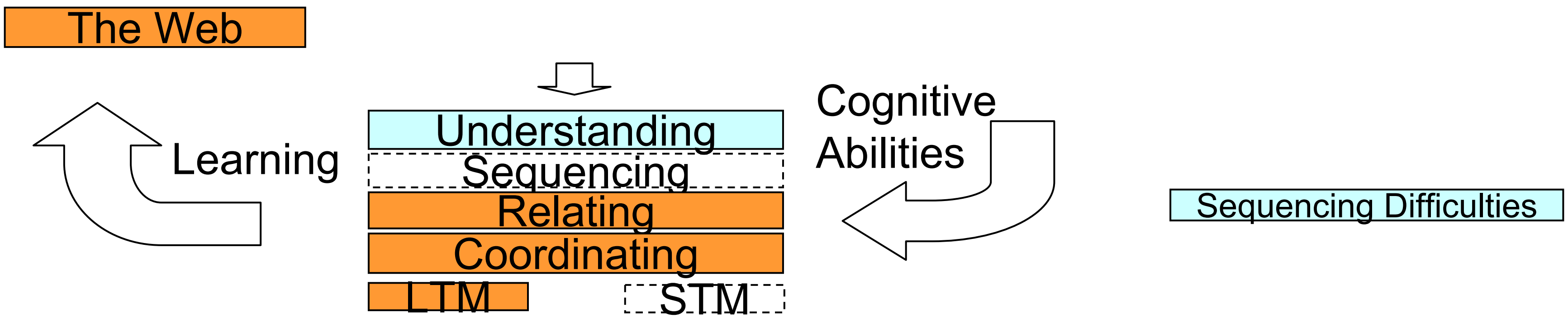
Sequencing Accessibility: Semantic Gestures



- Sequencing difficulties make it difficult to find out and remember the sequence of actions needed to find information (first click here… then click there… then go down.. then click again…). Even if the sequence is found once, difficulties with short-term memory do not help in remembering the correct sequence.
- The “Semantic Gestures” project is an attempt to *substitute sequencing in the short-term memory (STM) with gestural resources in the long-term memory (LTM)*, that is find information related to a single pair gesture-concept which has been learnt, instead of trying to build and remember in the short term a sequence of operations.

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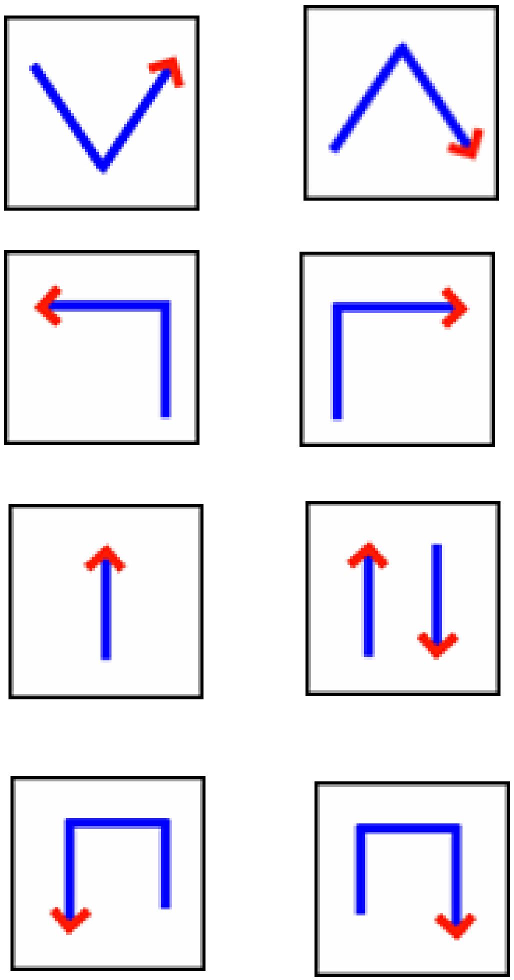
Pen Gestures



- In the Semantic Gestures project, gestures are made with a pen. There are 20 different gestures related to common concepts (e.g. find a name, a price, a time, …)
- A plug-in with a neural network recognizes the pen strokes and maps them to specific pages in a web site.
- The concepts in the web pages are now marked manually, but in future they will be discovered automatically using learning algorithms from Natural Language Processing

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Semantic Gestures: Sites used for Testing

- We asked 20 users (with different levels of sequencing abilities and different ages and computer skills) to find information from the following websites:
  - The web site of the bus shuttle service between Milan's Central Railway Station and Milan's International Airport
  - The web site of an italian company producing and selling software
  - The web site of a local soccer football team, featuring information on players, schedule of matches and results, open days for visitors during player's training session, etc.
  - A virtual museum gallery about Leonardo's life and works hosted at the National Science Museum web site
  - The web site of the National Science Museum, containing information about the location of the museum, working hours, ticket prices, etc.
  - The web site of a hotel in a location in Pisa, Tuscany

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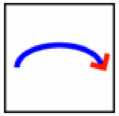
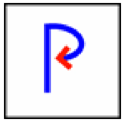
Semantic Gestures: Tasks

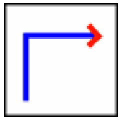
- *Instead of finding (and remembering in the short-term) which is the sequence of links to find an information, use these gestures from your long-term memory (hand/pen strokes):*



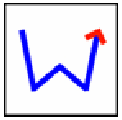
- Find address and telephone of people to contact



- Find prices of the services



- Find working hours / timetable



- Find name of person in charge or to contact

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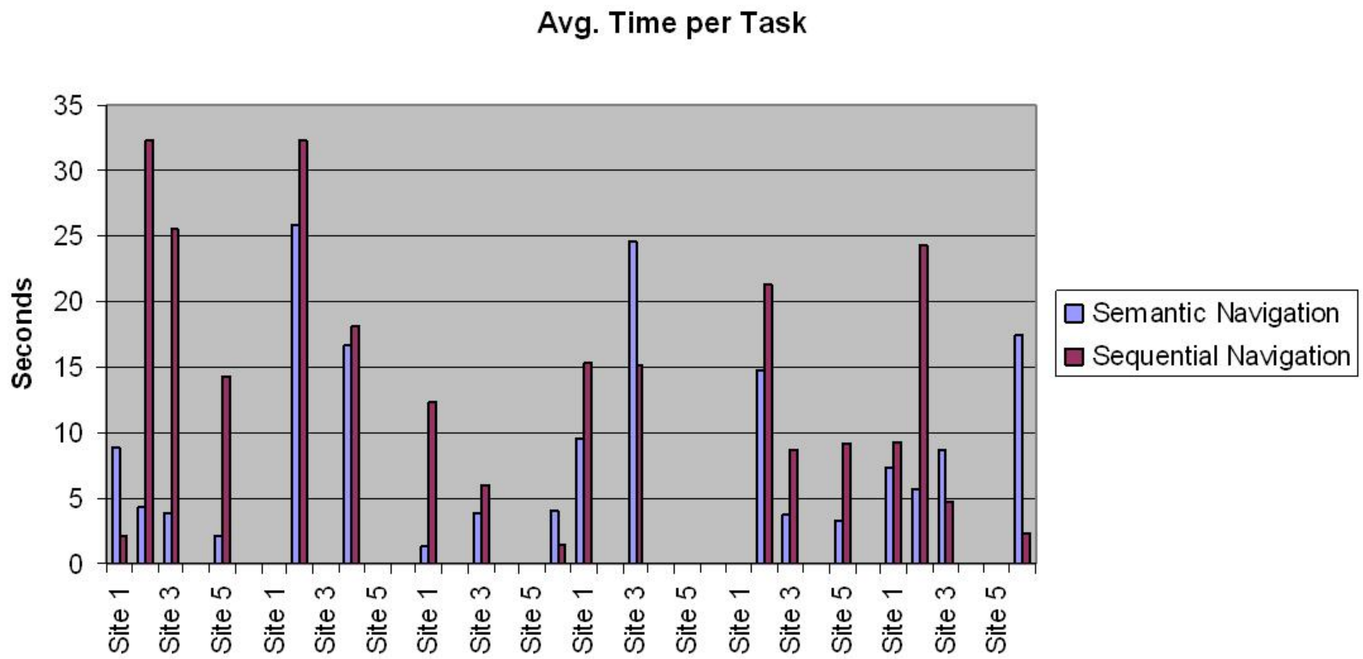
Semantic Gestures: Results



- Semantic gestures proved 65% faster (almost half time needed to find information)
- Semantic gestures proved 78% more efficient (almost one third less actions were needed by the user to find information)

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Conclusions

Conclusions

- Sensorial and Cognitive abilities form a virtual loop in the way we learn
- The web and related technologies provide excellent opportunities to distribute contents and provide different ways to provide content to students with different abilities
- A web system supporting students with special needs should consider the entire loop, because each student is peculiar in his/her own and can find his/her own way to access content and learn from it
- An assistive learning web system could, among other things:
  - Help students reading text they cannot read (e.g. MultiAbile)
  - Help students exploring images they can't see and learning from what they represent (e.g. AudioTact)
  - Help students understand text which is hard to read (e.g. AACLezi)
  - Help students to find information which is hard to reach (e.g. Semantic Gestures)

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- AACLezi: Licia Sbattella, Antonio Bianchi, Marco Ferra
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