INFORMATICS & TELEMATICS INSTITUTE

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An innovative user modelling methodology focusing on the elderly and disabled

Nikolaos Kaklanis

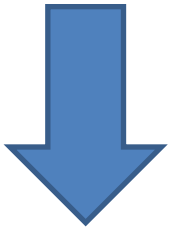
People with disabilities – Current situation

- People with disabilities are not just a tiny minority of the population.
- The lowest estimate, based on the currently defined disablement categories, estimates their total number at around 74 Million persons, in the European Union.
- With increasing life expectancy, visual and hearing impairments also increase, as well as neurological disorders such as Alzheimer's disease and dementia.
- The composition of the population is changing. Many people are surviving permanently disabling accidents and illness and even more are living longer.

- **It would seem logical that the spaces built to accommodate this population must, by necessity, change also.**

The Problem

Despite the rapid evolution of ICT over the last years and the increasing acknowledgment of the importance of accessibility, the developers of mainstream ICT and non-ICT based products still act and struggle under total absence of structured guidance and support for adjusting their products and services with their user's real-time accessibility needs.



A critical mass market, including that of accessible ICT and non-ICT based products and services targeting older people and people with disabilities, remains highly locked.

Proposed solution

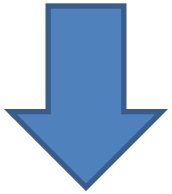
- The proposed solution aims to empower the accessibility of ICT and non-ICT technologies *by introducing an innovative user modelling methodology focusing on the elderly and disabled.*
- This new user modelling methodology aims to describe in detail
  - all the possible disabilities
  - the affected by the disabilities tasks
  - the physical
  - cognitive and
  - behavioural/psychological characteristics of any user

Proposed solution – Main objectives

- An extension of UsiXML language will be developed
  - Virtual User Models in a machine-readable format.
- Research will be conducted in order to determine how the values of various disability parameters vary over individuals and whether these values follow any common probability distribution (e.g.: Gaussian, etc.).
  - it will enable making realistic assumptions for different percentages of the disabled population.
    - e.g. if we know the mean value and the standard deviation of visual acuity for people with myopia and we also know that visual acuity follows the Gaussian probability distribution, we could find the value of visual acuity for the 80%, 90%, etc. of people with myopia.
- Tools for the creation/editing of the Virtual User Models will be developed.
- A Simulation Platform based on the ACT-R cognitive model will be also developed to simulate human behavior on specific tasks.
- Moreover, applications focusing on accessibility of the elderly and disabled will be developed or existing tools will be extended according to the proposed methodology, in order to put the proposed methodology into practice.

How a user modelling methodology could empower the accessibility of products and services?

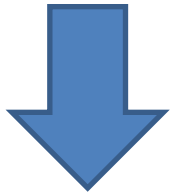
- If there was a methodology able to describe sufficiently:
  - User characteristics (including possible disabilities)
  - User tasks
  - Products/services to be tested
  - User-product interaction



- It could become the basis for the development of an innovative simulation framework that would perform accessibility testing of virtual environments with virtual users
- Additionally, it could be used in adaptive interfaces.

What is the great importance of such a framework?

- Instead of testing real prototypes with real users with disabilities
- it will enable the automatic accessibility evaluation of any environment for any user by testing its equivalent virtual environment for the corresponding virtual user



- Reduced costs
- Reduced development time
- More accessible products

Open issues on User Modelling

- There is not any unified User Modelling methodology that can sufficiently describe
  - the user (including elderly and disabled)
  - user tasks
- and provide these descriptions in a machine-readable format

User Modelling – existing approaches

- **Ontology-based models**
  - OntobUM
    - An ontology is used to store user characteristics (name, e-mail, level_of_activity, type_of_activity, etc.)
  - General User Model Ontology (GUMO)
    - An ontology is used to store user's emotional states, characteristics personality, etc.)
- **XML-based models**
  - UserML
    - User description in XML format.
    - Generic approach – not detailed user description
- **Cognitive User Models**
  - Goals, Operators, Methods and Selection Rules (GOMS)
    - Good for basic movement operations, but less rigid with cognitive actions.
  - ACT-R
    - ACT-R's most important assumption is that human knowledge can be divided into two irreducible kinds of representations: *declarative* (facts-primitive knowledge) and *procedural* (productions-how do we do things).
- **Personas**
  - Hypothetical archetypes of actual users.
  - Their primary goal is to make developers, designers, managers and other stakeholders develop empathy for their end-users.
  - Personas are one of the most widely known user models.

Relevant standards

Standard	Focus on accessibility	Tasks support	Workflows support	Description of user needs/ preferences	Description of device characteristics	Description of user characteristics (physical, cognitive, etc.)	Guidelines	Implementation details
ETSI TS 102 747							✓	
ETSI ES 202 746	✓			✓				✓
ISO/IEC 24751-1:2008	✓							✓
ISO/IEC 24751-2:2008	✓			✓				✓
W3C Delivery Context Ontology					✓			✓
W3C CC/PP				✓	✓			✓
IMS Access For All Personal Needs and Preferences Description	✓			✓				✓
ETSI EG 202 116	✓				✓	✓	✓	
ETSI TR 102 068	✓				✓	✓	✓	
ETSI EG 202 325	✓ (limited)						✓	
BS EN 1332-4:2007	✓			✓				✓
ISO 11228-2:2007						✓	✓	
ISO/DIS 24502						✓	✓	
BPMN		✓	✓					✓
XPDL		✓	✓					✓
WHO ICF	✓							

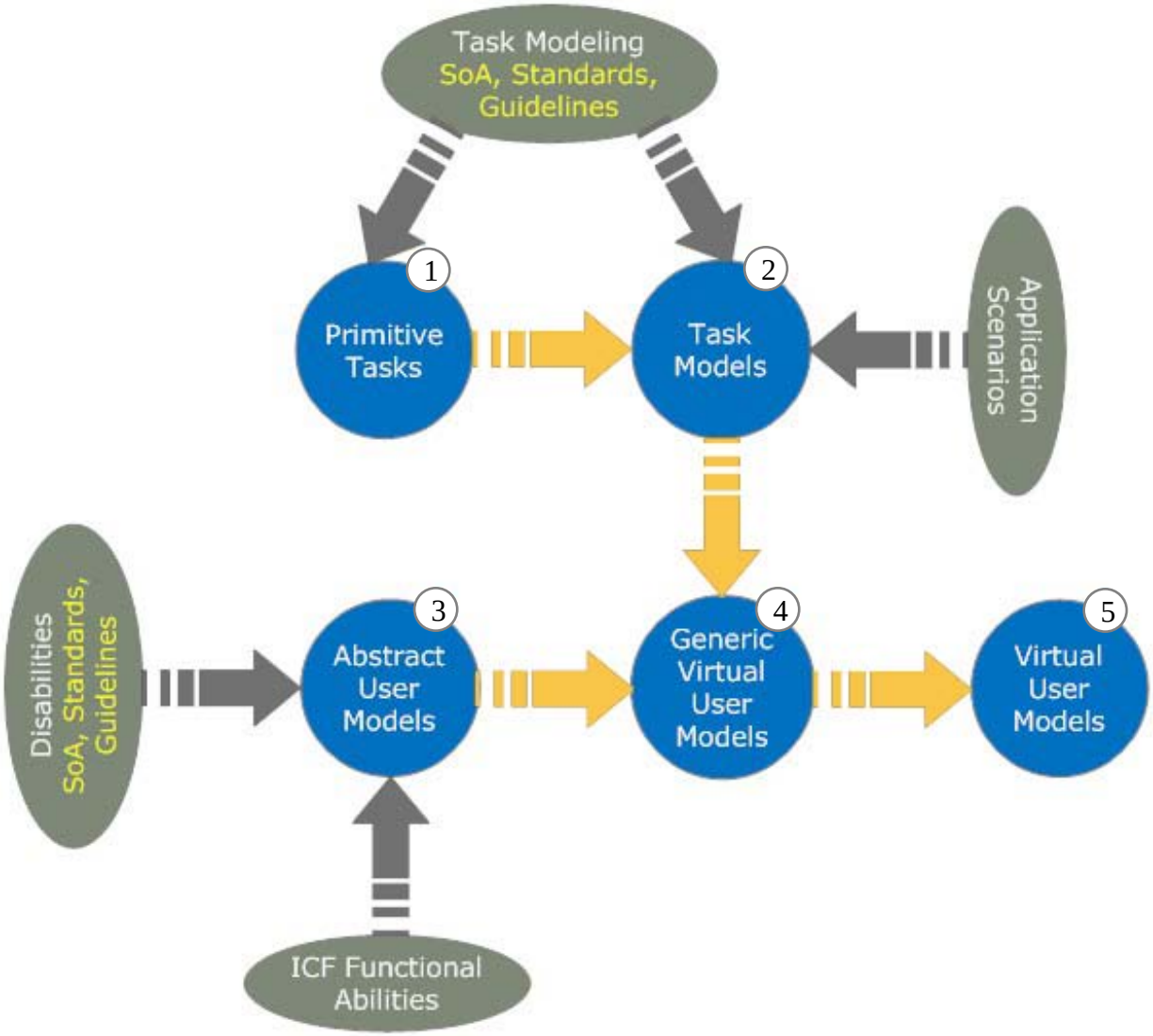
Relevant Task Modelling techniques

	AMBOSS	ANSI/CEA	CTT	Diane +	GOMS	GTA	HTA	TKS	TOOD	UsiXML	Relevance
Decomposition	Hierarchy	Hierarchy	Hierarchy	Hierarchy	Hierarchy	Hierarchy	Hierarchy	Hierarchy	Hierarchy	Hierarchy	Must
Sequence	Sequence	Ordered sequence, enabling with information passing	Enabling, enabling with information passing	Ordered sequence	Sequence	Sequence	Fixed sequence	Sequence	Sequence	Enabling, enabling with information passing	Must
Iteration	X	MinOccurs/ MaxOccurs	Iteration, finite iteration	Loop	Loop (If, then, else)	X	Stop rules	X	X	Iteration, finite iteration	Should
Choice	ALT	Precodition	Choice	Required choice, free choice	Or (If, then, else)	Or	Selective rule	Or	Choice	Deterministic choice, undeterministic choice, inclusive choice	Should
Optionality	Barrier	MinOccurs/ MaxOccurs	Optional	Optional	Optional (If, then, else)	Start condition	X	X	X	Optional	Should
Interruption	X	X	Suspend-resume, disabling	X	Interruption (If, then, else)	Stop condition	Stop rules	X	Interruption	Suspend- resume, disabling, disabling with information passing	Should
Concurrency	SER	Ordered	Concurrent, concurrent communicating tasks, independence	unordered sequence	Concurrency (If, then, else)	X	Selective rule	X	Concurrency	Independent concurrency, concurrency with information passing, order independence	Should
Cooperation	Precondition	X	Cooperative	X	X	Cooperation	Teamwork	Collaboration	Collaboration	Cooperation	Should

The proposed User Modelling methodology will be based on UsiXML. Why?

- UsiXML can describe the tasks sufficiently and it can offer a much more complete description of tasks compared with other task modelling techniques.
- As there is no widely accepted user modeling language that can adequately describe the elderly and disabled users, there could be an extension of UsiXML (that has already some primary support for the description of the user), in order to achieve the detailed description of the possible disabilities of the user as well as the affected by the disabilities tasks.

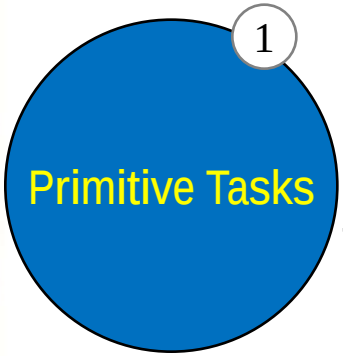
Proposed methodology - Overview



User and Task models - Overview

- **User Models**
  - **Abstract User Model**
    - Describes a disability
  - **Generic Virtual User Model**
    - Describes a set of users having a specific disability,
    - the affected primitive tasks and
    - the affected primitive tasks' parameters
      - Binary (ex. Abnormal step rhythm: Yes)
      - **Range of values** (ex. Gait cycle [1.12, 3.22] sec)
  - **Virtual User Model**
    - An instance of a virtual user
    - Describes user's disabilities,
    - the affected primitive tasks and
    - the affected primitive tasks' parameters for the specific user
      - Binary (ex. Abnormal step rhythm: Yes)
      - **Specific values** (ex. Gait cycle : 2.1 sec)
- **Task Model**
  - Describes how a complex task can be divided into primitive tasks.

Primitive Tasks - Definition



The primitive tasks define the *primitive human actions*.

Steps for defining a primitive task:

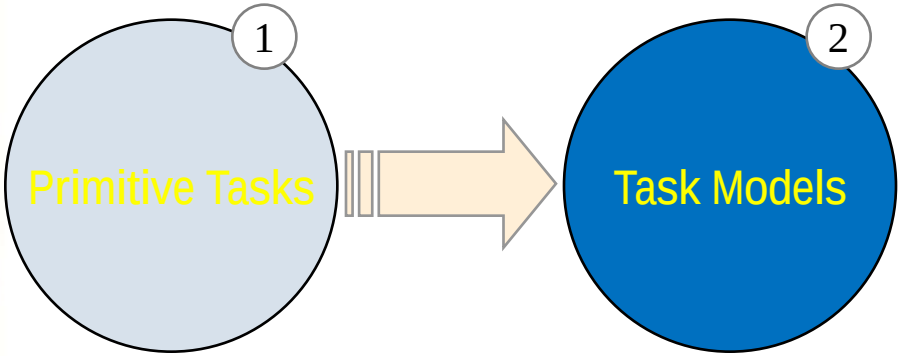
- Define primitive task's category
  - Motor
  - Cognitive
  - Perceptual
  - Visual
  - Hearing
  - Speech
  - etc.
- Define primitive task's name

Primitive Tasks - Examples

List of primitive tasks - Example

Primitive task's category	Primitive task
Physical	Push
Physical	Grasp
Physical	Pull
Physical	Walk
Physical	Sit
Cognitive	Select
Cognitive	Wait
Cognitive	Read
…	…

Task Models - Definition



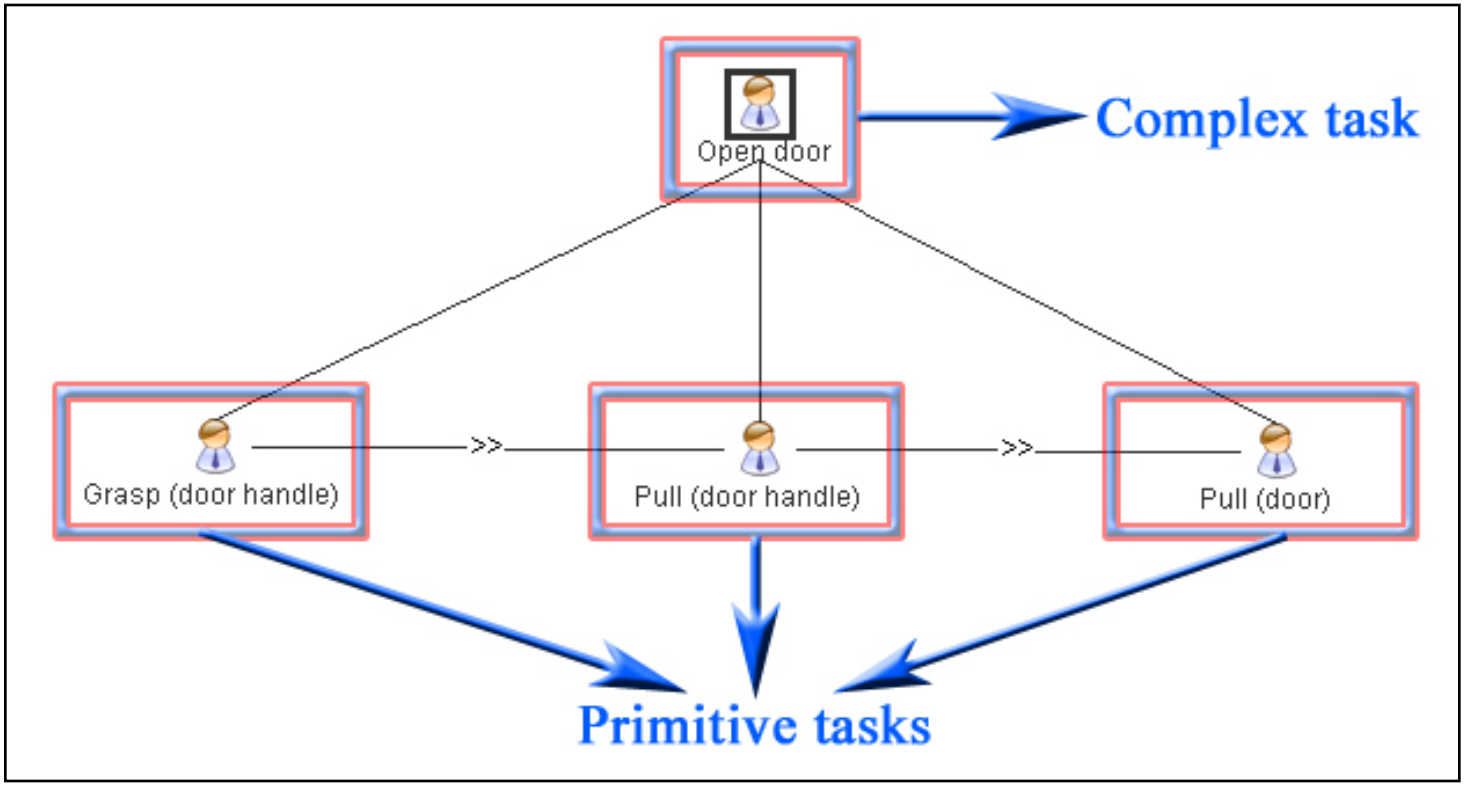
The Task Models describe how the complex tasks can be divided into primitive tasks.

Steps for defining a Task Model:

1. Define the sector where the complex application-oriented task (ex. driving) belongs (automotive, workplace, etc.)
2. Define the name of the complex task
3. Define the name of the complex subtasks (if any).
4. Define the primitive tasks that should be executed, in order to achieve successful execution of the complex task.
5. Define an object related to each primitive task (if any) (ex. Object: “Door handle” for primitive task “Grasp”)

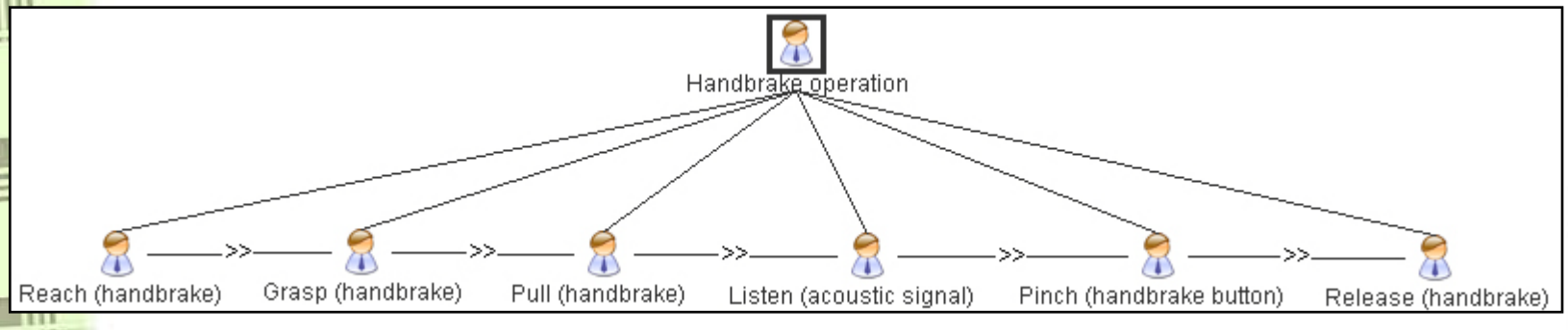
Task Model – Example (Open door)

Sector	Task	Subtask	Primitive tasks	Primitive task – Object
Automotive	Getting in a car	Open door	Grasp	Door handle
			Pull	Door handle
			Pull	Door

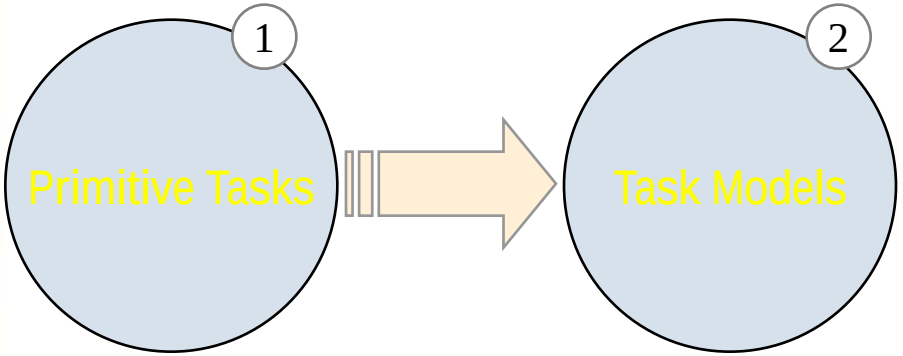


Task Models are expressed in UsiXML

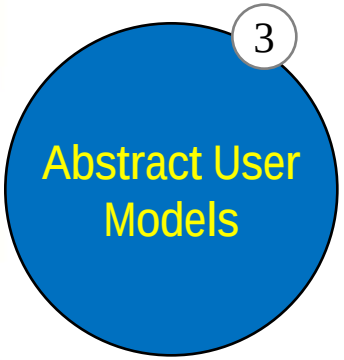
Task Model – Example (Handbrake operation)



Abstract User Models - Definition



The Abstract User Models describe the disabilities.



Steps for defining an Abstract User Model:

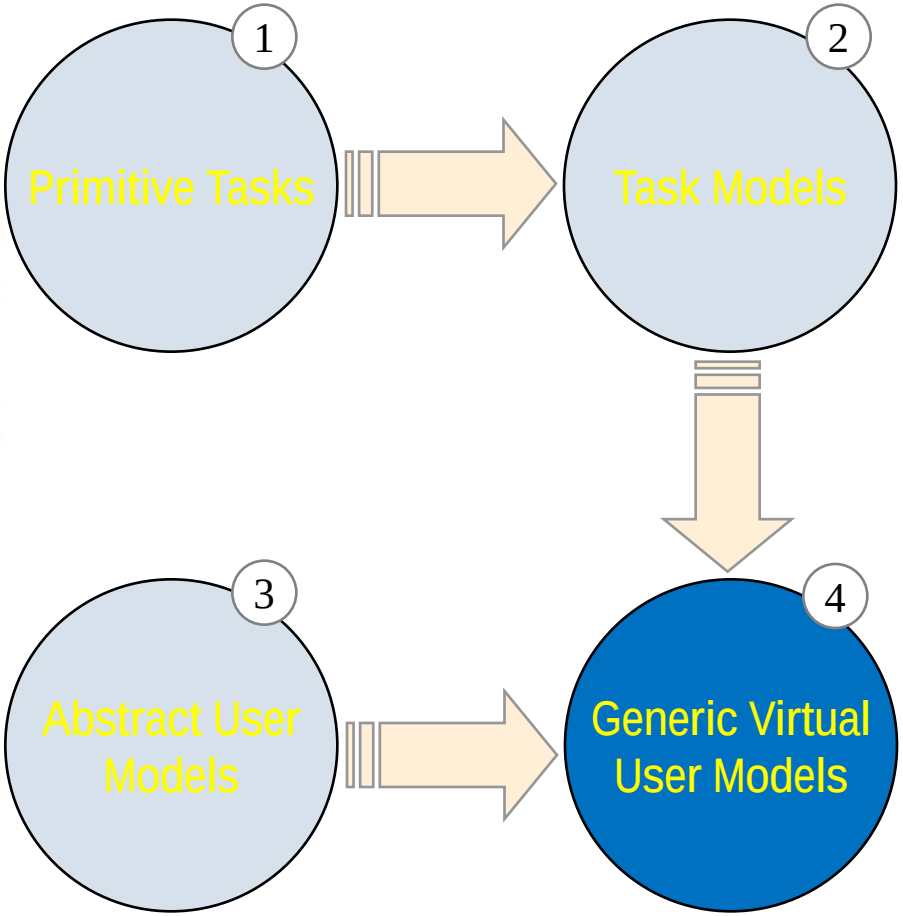
1. Define the disability category
2. Define the disability name
3. Add a short description of the disability
4. Find quantitative metrics
5. Identify the corresponding ICF functional limitations
6. Identify if the disability is age-related or not

Abstract User Model - Example

An Abstract User Model describes a disability.

Disability category	Disability	Short description	Quantitative disability metrics	Functional limitations *(ICF Classification)*	Age-related
Motor impairments	Spinal cord injuries (Thoracic injuries)	Spinal cord injuries cause myelopathy or damage to nerve roots or myelinated fiber tracts that carry signals to and from the brain. The nerves that control a man's ability to have a reflex erection are located in the sacral nerves (S2-S4) of the spinal cord and could be affected after a spinal cord injury. *American Spinal Injury Association Impairment Scale* o A=complete. No sensory or motor function is preserved in the sagral segments S4-S5. o B=incomplete. Sensory but not motor function is preserved below the neurological level and includes the sacral segments S4-S5 o C=incomplete. Motor function is preserved below the neurological level and more than half of key muscles below the neurological level have a muscle grade less than 3. o D=incomplete. Motor function is preserved below the neurological level, and at least half of key muscles below the neurological level have a muscle grade greater than or equal to 3. E=Normal. Sensory and motor function is normal. -Self-selected gait "The SF-36 Subscales and Descriptive Statistics for the SCI Group (n=320) in Comparison With Swedish Normative Data (n=8,930)". Muscle lengthening and shortening (velocity at the ankle, ANK d/dt) -A knee flexion contracture blocks progression during stance by inhibiting the advancement of the thigh. -Lower extremity muscle strength is an important determinant of functional walking performance. -Hip extensors are important for the ambulatory capacity. -Falling during activities. General affected tasks -Access to sports and work activities -Driving -Neurogenic bladder and bowel problems -Ability to concentrate -Memory function -Locomotor capacities	**1. Gait parameters[6]:** -Weight shift: inability to effectively transfer weight between legs -Step width: decreased step width -Step height: decreased step height -Step length: decreased step length -Step rhythm: abnormal step rhythm -Excessive plantar flexion during swing phase - Delayed heel rise achieved less peak knee flexion in swing **2. Temporal gait variables:** -Gait Cycle (sec):2.17 (1.05) -Cadence (steps/min): 65.0 (23.1) -Double support (%): 42.8 (10.2) -Stride (m): 0.48 (0.13) -Velocity ((m/sec)/height): 0.27 (0.13) **3. Kinematic variables:** -Hip excursion (°): 39.3 (9.0) -Knee excursion (°): 38.1 (13.2) -Ankle excursion (°): 25.0 (4.9) -Hip velocity (°/sec): 38.2 (17.5) -Knee velocity (flexion) (°/sec): 64.1 (41.8) -Knee velocity (extension) (°/sec): 83.8 (54.2) -Ankle velocity (°/sec): 48.1 (30.8)	• **S120** Spinal cord and related structures • **S1200** Structure of spinal cord • **S12000** Cervical spinal cord • **s12001** Thoracic spinal cord • **s12002** Lumbosacral spinal cord • **s12008** Structure of spinal cord, other specified • **s12009** Structure of spinal cord unspecified • **s1208** Spinal cord and related structures, other specified • **s1209** Spinal cord and related structures, unspecified	Could be

Generic Virtual User Models - Definition



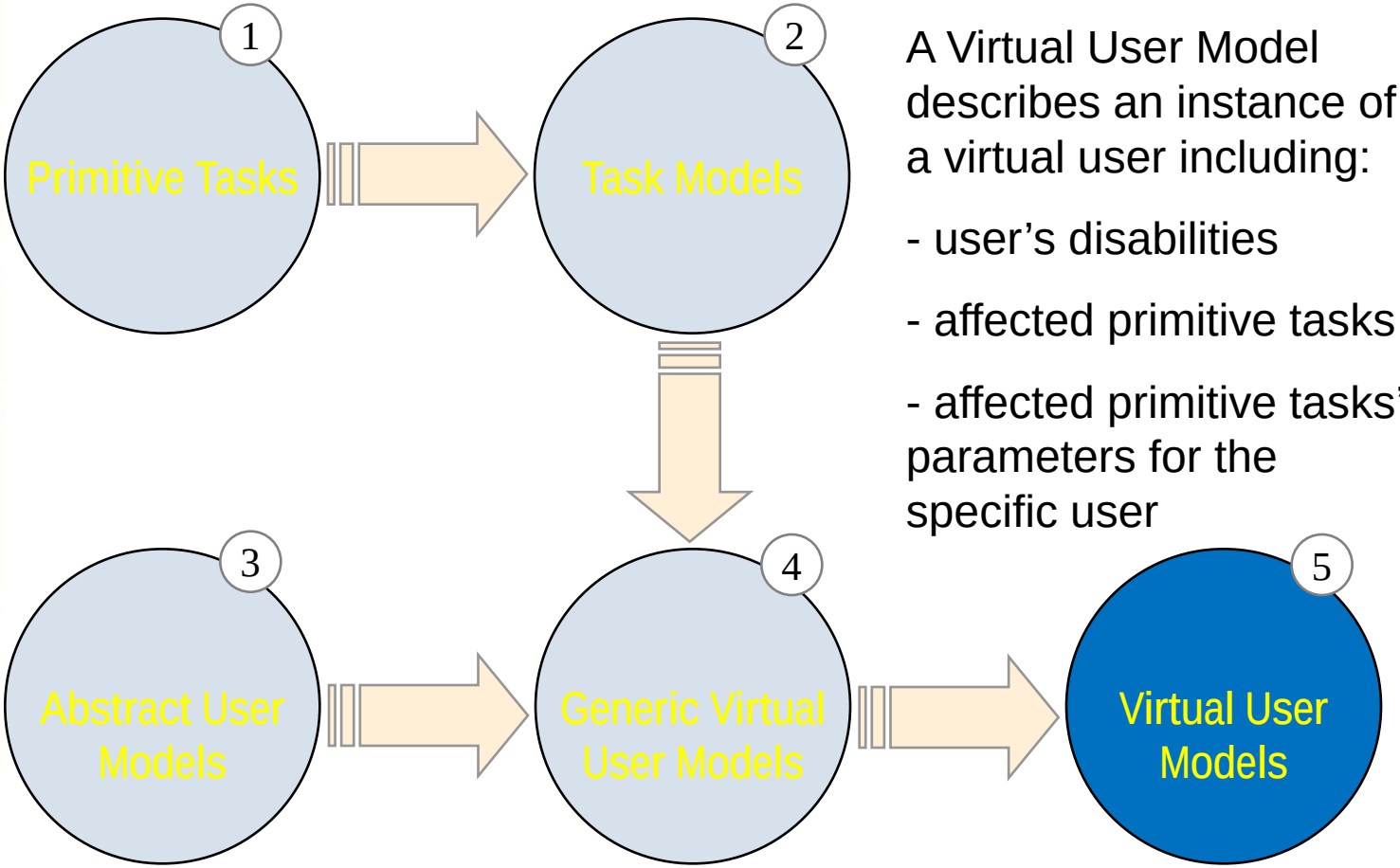
A Generic Virtual User Model describes the set of users having a specific disability, including:
- disability category
- disability name
- affected primitive tasks
- affected primitive tasks' parameters

Generic Virtual User Model - Example

Disability category	Disability	Affected primitive tasks (*)	Affected primitive tasks' parameters (*)
Motor	Hemiplegia	Grasp	The user is able to grasp objects, with size <= *3cm* x *3cm* x *3cm*
		Pull	The user can pull an object with max_Force: 5N
		Walk	Gait velocity ranges from 0.18 to 1.03 m/s
			Abnormal step rhythm

(*) The affected primitive tasks as well as the affected primitive tasks' parameters will result from the disability metrics defined in the Abstract User Models.

Virtual User Models - Definition



A Virtual User Model describes an instance of a virtual user including:

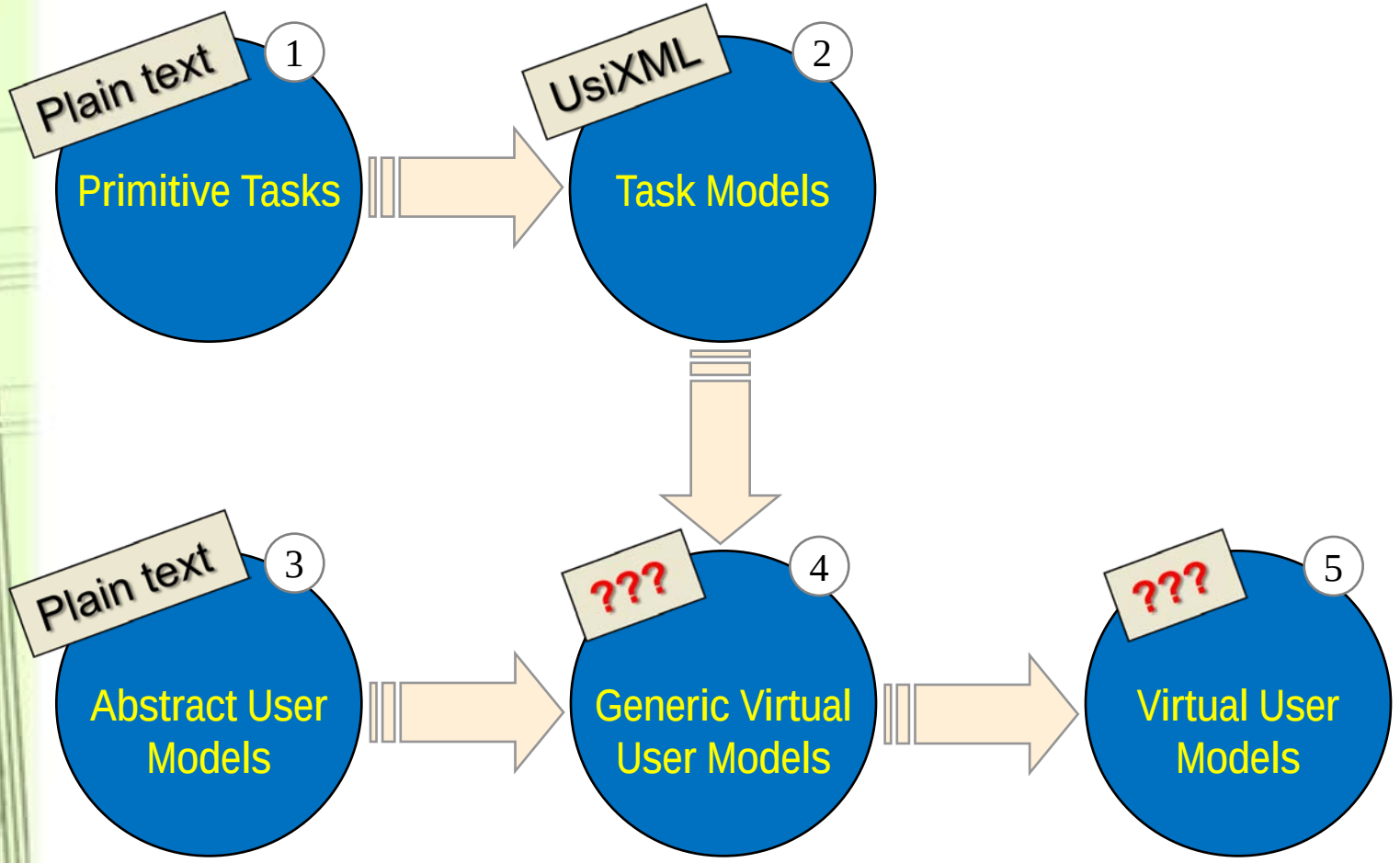
- user's disabilities
- affected primitive tasks
- affected primitive tasks' parameters for the specific user

Virtual User Model - Example

- A Virtual User Model describes an instance of a virtual user

User ID	Disability category	Disability	Affected primitive tasks	Affected primitive tasks' parameters (*)
User 1	Motor	Hemiplegia	Grasp	The user is able to grasp objects, with size <= *2.5cm* x *2.5cm* x *2.5cm*
			Pull	The user can pull an object with max_Force: 2N
			Walk	Gait velocity : 0.9 m/s
				Abnormal step rhythm

Proposed models and formats



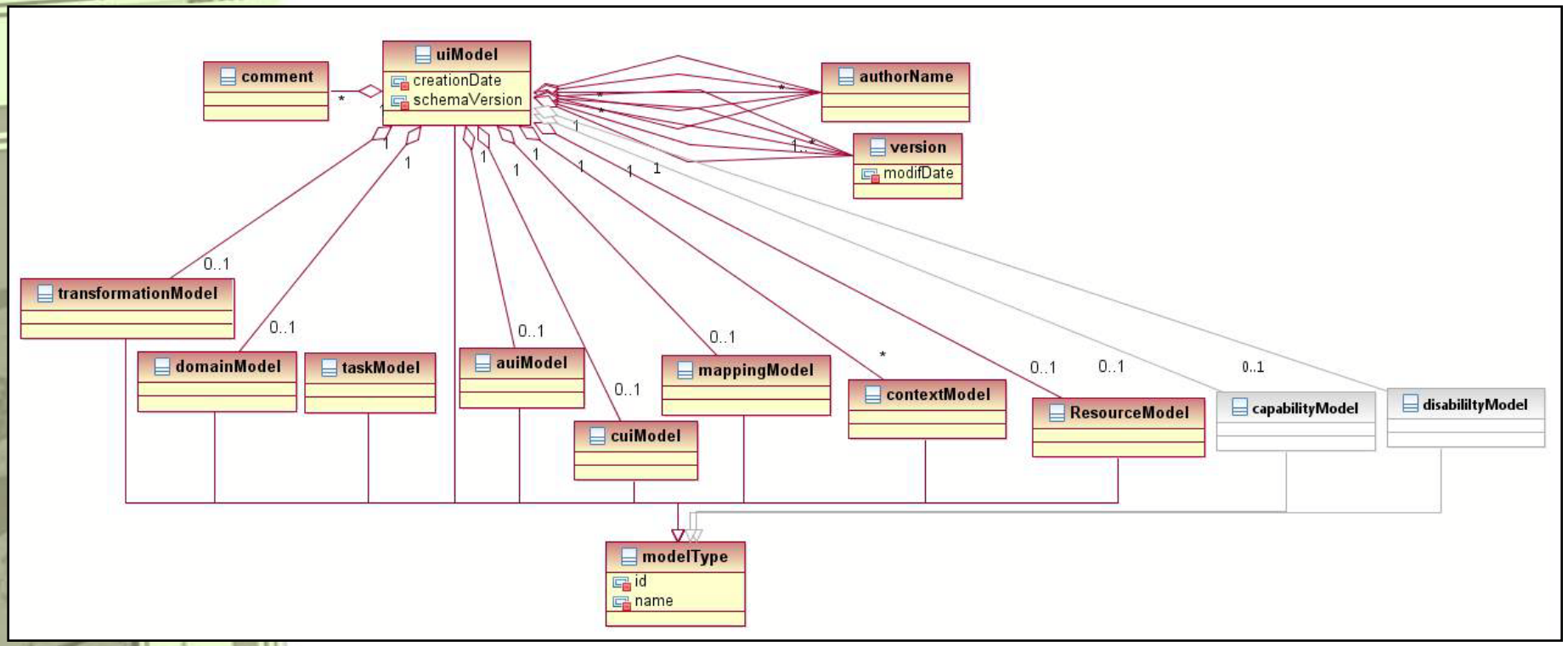
Generic Virtual User Models & Virtual User Models - UsiXML extension

- There is not any formal way to define users (including elderly and disabled)
- UsiXML has already some limited support for user description
- UsiXML is easily extensible, due to its XML nature

- An extension of UsiXML is proposed, in order to describe users in detail.

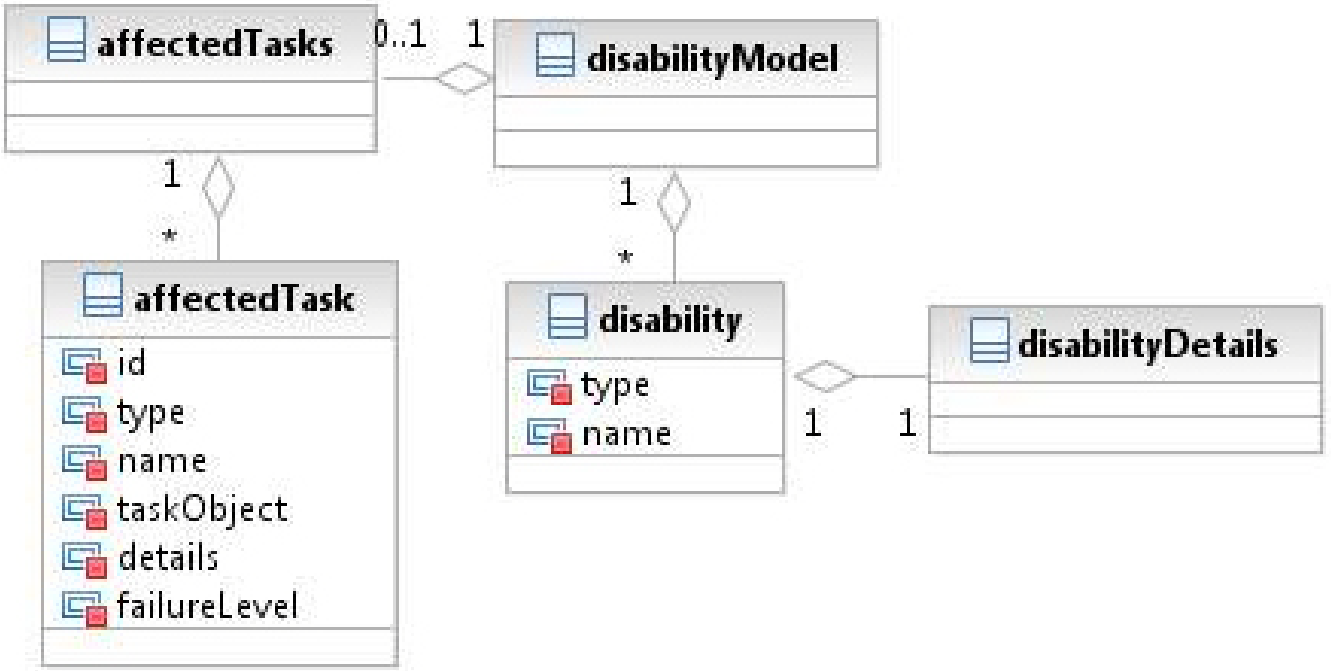
UsiXML extension

- Two new models are introduced:
  - disabilityModel
  - capabilityModel



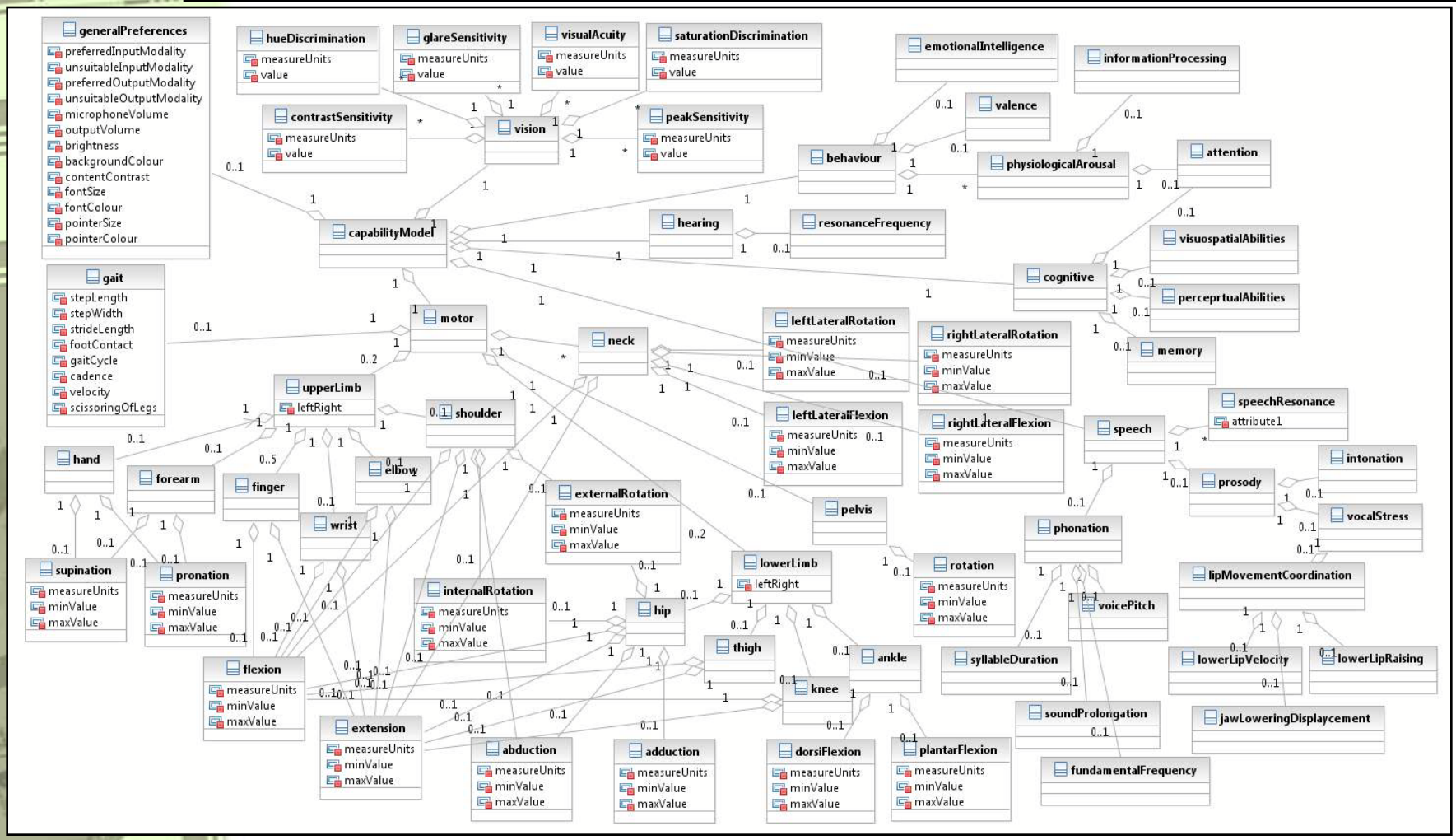
UsiXML extension - disabilityModel

- The *disabilityModel* describes all the possible disabilities of the user as well as the affected by the disabilities tasks.



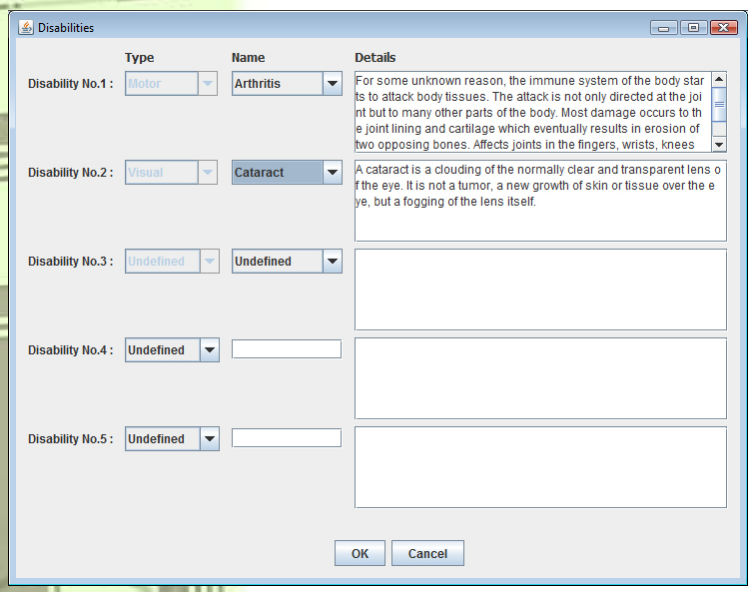
UsiXML extension - capabilityModel

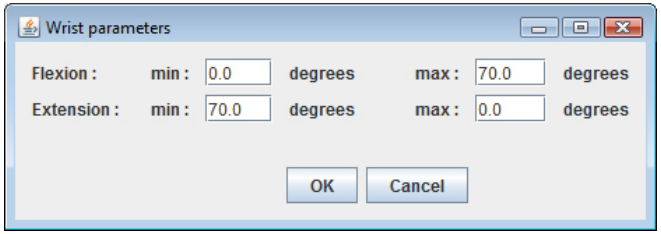
- The *capabilityModel* describes in detail the physical, cognitive and the behavioral/psychological user characteristics.

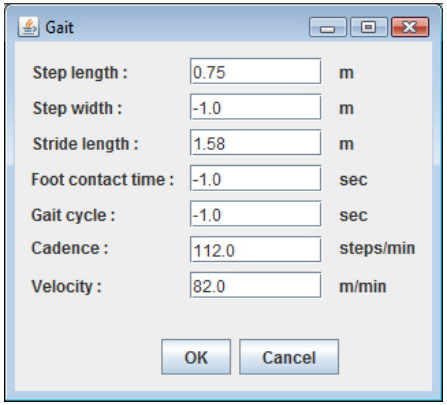


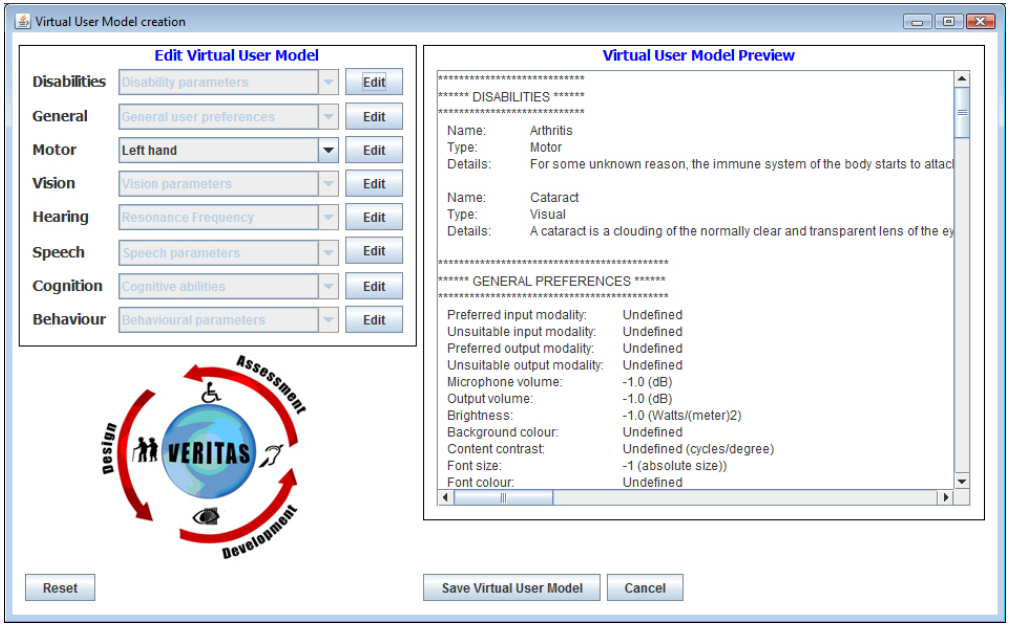
Virtual User Model Generator

- A Virtual User Model Generator has been developed, in order to easily extract a Virtual User Model in the proposed UsiXML format.









The proposed methodology in the context of existing standards

Standard/Methodology	Potential use in the proposed User Modelling methodology	Potential contribution of the proposed methodology
ETSI ES 202 746; Human Factors (HF); Personalization and User Profile Management; User Profile Preferences and Information	The proposed methodology may include the user preferences specified by the standard, especially those related to disabilities, to the structure of the Virtual User Models.	The proposed methodology could possibly extend the user preferences related to disabilities.
ISO/IEC 24751-2:2008 (Information technology - Individualized adaptability and accessibility in e-learning, education and training - Part 2: "Access for all" personal needs and preferences for digital delivery)	The proposed methodology may include a subset of the stated in the standard user needs and preferences related to disabilities to the structure of the Virtual User Models.	The proposed methodology could possibly extend the user preferences related to disabilities.
W3C Composite Capability/Preference Profiles (CC/PP)	The proposed methodology may use the user preferences specified by the standard, especially those related to disabilities, for the development of the Abstract and Virtual User Models.	The proposed methodology could possibly extend the user preferences related to disabilities.
IMS Access For All Personal Needs and Preferences Description for Digital Delivery Information Model	This standard provides a machine-readable method of stating user needs and preferences with respect to digitally based education or learning. Some of the stated user needs (that may also be used out of the scope of e-learning) may be used in the development of the Abstract and Virtual User Models.	The proposed methodology could possibly extend the definitions of user needs and link them with specific disabilities.

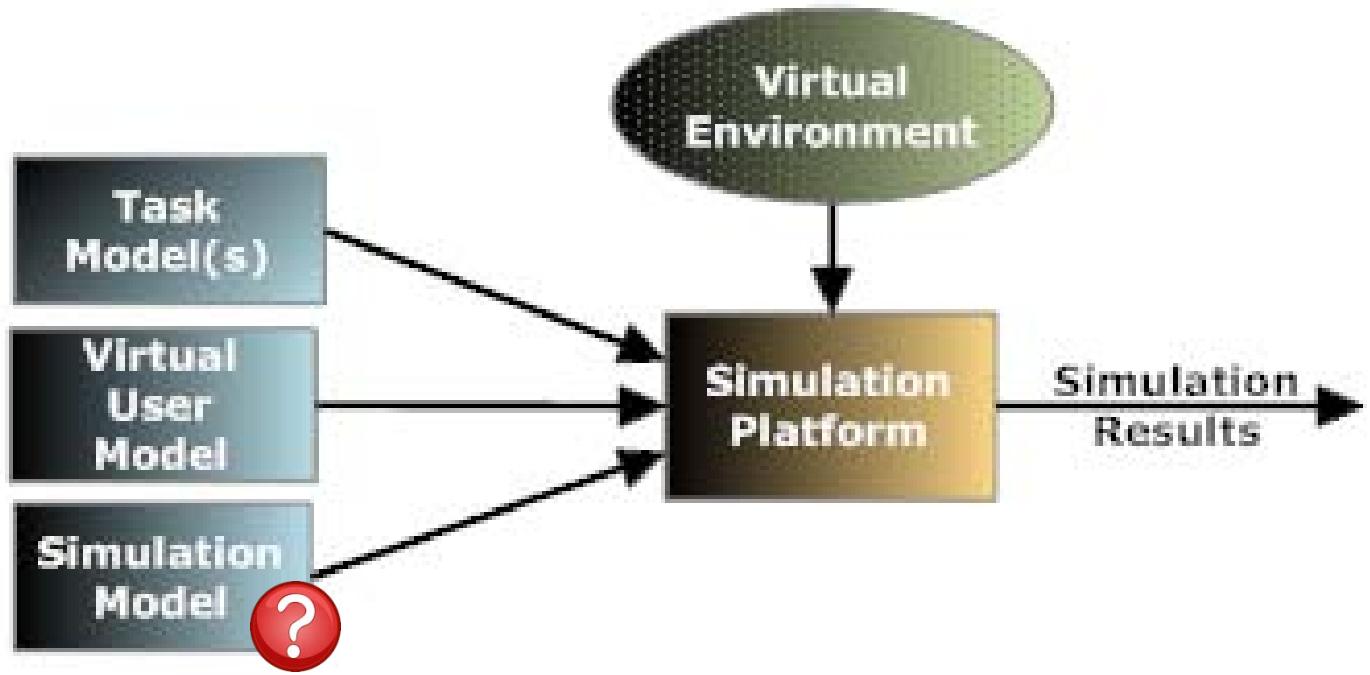
The proposed methodology in the context of existing standards

Standard/ Methodology	Potential use in the proposed User Modelling methodology	Potential contribution of the proposed methodology
ETSI EG 202 116; Human Factors (HF); Guidelines for ICT products and services; "Design for All"	ETSI EG 202 116 contains definitions of user characteristics, including sensory, physical and cognitive abilities. These definitions may be used in the development of the Abstract User Models, in order to express how the disabilities are connected with the sensory, physical and cognitive abilities of the user. Additionally, ETSI EG 202 116 describes how user abilities are changing over years. This information could be used in the development of the Generic Virtual User Models representing users of different age groups.	The proposed methodology could possibly extend the definitions of user characteristics and even create machine-readable formats (ex. XML-schemas) of these characteristics.
ETSI TR 102 068; Human Factors (HF); Requirements for assistive technology devices in ICT	ETSI TR 102 068 describes user sensory, physical and cognitive disabilities and correlates them with assistive devices. The proposed methodology may use this information in the development of the Abstract User Models, which describe the disabilities, in order to correlate the disabilities with assistive devices.	
BS EN 1332-4:2007 (Identification card systems. Man-machine interface. Coding of user requirements for people with special needs)	BS EN 1332-4:2007 provides a set of detailed definitions of user needs (such as preferred speech output rate, requirement for specific type of fonts, etc.), including people with special needs, for example the aged, minors, people with disabilities, those with learning difficulties, first time users, those not conversant with the local language. These user needs may be used in the Abstract User Models, presenting this way how user needs are connected with the disabilities.	The proposed methodology could possibly extend the list of requirements concerning the interaction of elderly and disabled people with a user interface.

Early results

How the proposed User Methodology could be used in a framework that performs automatic simulated accessibility testing of products and services?

A framework that performs simulated accessibility evaluation of ICT and non-ICT products and services



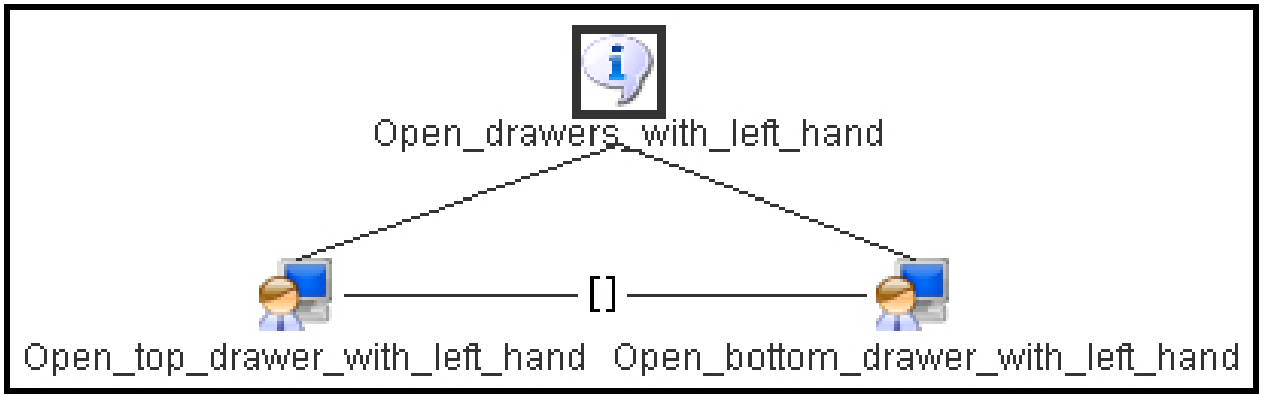
Simulation Models

- A simulation model refers to a sequence of actions that will be defined by the designers/developers, according to the functionality of the prototypes to be tested in terms of their accessibility.
- Simulation model = *Simulation scenario*
- Expressed in UsiXML

Virtual Environment

- The designer initially develops the virtual workspace prototype.

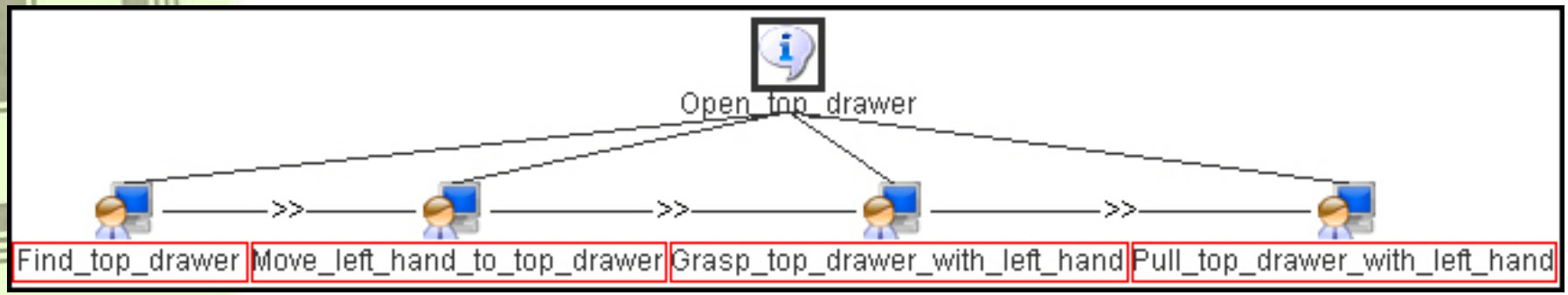
Simulation Model



UsiXML source code

```
<?xml version="1.0" encoding="UTF-8"?>
<taskmodel>
   <task id="st0task0" name="Open_drawers_with_left_hand" type="abstraction">
      <task id="st0task1" name="Open_top_drawer_with_left_hand" type="interaction"/>
      <task id="st0task2" name="Open_bottom_drawer_with_left_hand" type="interaction"/>
   </task>
   <deterministicChoice>
      <source sourceId="st0task1"/>
      <target targetId="st0task2"/>
    </deterministicChoice>
</taskmodel>
```

Task Model



UsiXML source code

```
<?xml version="1.0" encoding="UTF-8"?>
<taskmodel>
    <task id="st0task0" name="Open_top_drawer“ type="abstraction">
        <task id="st0task1" name="Find_top_drawer"  type="interaction"/>
        <task id="st0task2" name="Move_left_hand_to_top_drawer“ type="interaction"/>
        <task id="st0task3“ name="Grasp_top_drawer_with_left_hand“ type="interaction"/>
        <task id="st0task4" name="Pull_top_drawer_with_left_hand“ type="interaction"/>
    </task>
    <enabling>
        <source sourceId="st0task1"/>
        <target targetId="st0task2"/>
    </enabling>
    <enabling>
        <source sourceId="st0task2"/>
        <target targetId="st0task3"/>
    </enabling>
    <enabling>
        <source sourceId="st0task3"/>
        <target targetId="st0task4"/>
    </enabling>
</taskmodel>
```

Virtual User Models

- Using the Virtual User Model Generator, the designer generates five Virtual User Models, whose problematic physical parameters are presented in the table above.

Physical characteristics	**Normal values**	**Rheumatoid arthritis**	**Spinal cord injury**	**Adhesive shoulder capsulitis**	**Hemiparesis**	**Elderly man *75-79***
Wrist flexion (º)	0 - 60					0 - 62
Wrist extension (º)	0 - 60				0 – 67.48	0 - 53
Shoulder flexion (º)	0 - 180	0 - 10	0 – 118	0 – 20	0 – 53.39	
Shoulder abduction (º)	0 - 90	0 - 15	0 - 74	0 – 10		
Shoulder internal rotation (º)	0 - 90					
Shoulder external rotation (º)	0 - 50	0 – 15	0 - 31	0 - 10		
Forearm supination (º)	0 - 85					
Elbow flexion (º)	0 - 150				0 – 91.09	

Simulation Process

- During the simulation process, the simulation platform simulates the interaction of the virtual user (as it is defined in the Simulation Model) with the virtual environment.
- The specific disabled virtual user is the main “actor” of the physically-based simulation that aims to assess if the virtual user is able to accomplish all necessary actions described in the Simulation Model.

Simulation process - Results

	Task	Rheumatoid arthritis	Spinal cord injury	Adhesive shoulder capsulitis	Hemiparesis	Elderly
Drawers on desk	Open top drawer	 Simulation result: Failure – Shoulder joint limit	 Simulation result: Success	 Simulation result: Failure – Shoulder joint limit	 Simulation result: Success	 Simulation result: Success
	Open bottom drawer	 Simulation result: Failure – Shoulder joint limit	 Simulation result: Success	 Simulation result: Failure – Shoulder & Wrist joint limit	 Simulation result: Success	 Simulation result: Success
Drawers below desk	Open top drawer	 Simulation result: Failure – Shoulder joint limit	 Simulation result: Success	 Simulation result: Failure – Shoulder joint limit	 Simulation result: Success	 Simulation result: Success
	Open bottom drawer	 Simulation result: Failure – Shoulder & Elbow & Wrist joint limit	 Simulation result: Failure – Wrist joint limit	 Simulation result: Failure – Shoulder & Elbow joint limit	 Simulation result: Success	 Simulation result: Success


Thank you!