

**Algorithm to Automatically generate multi-modal
interfaces for hand held devices based on user
preferences and abilities.**

Thesis Dissertation
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2005

Introduction

- Thesis Overview
 - Universal Remote Consoles (URC)
 - URCs for Medical Devices
 - Multimodal Interfaces
 - Customized Interfaces
 - Automatic Interface Generation
 - Algorithm
 - Testing
 - Results and Discussion
 - Conclusion

Universal Remote Controls (URCs)

Advantages

- Control multiple devices
- Reduce clutter
- 'Learning remotes'
- One user interface per device
- Less memorizing of buttons
- Touch Screen/ Tactile buttons
- Programmable, up-gradable firmware

Disadvantages

- Complicated, too many buttons
- Programming required
- Firmware needs regular up-grades
- UI can be programmed, but complicated
- Entertainment purposes only
- No support for Medical devices
- No Accessibility Support



Photo: www.remotecentral.com

Photo: www.tomshardware.com



The future : Universal Remote Controls (URCs)

- **Hand held devices as URCs**
 - Mobile Phones, PDAs, Wrist Watches
- **Advantages**
 - Computing Power (300-500Mhz)
 - Touch Screen
 - Color Display (VGA, TFT LCD)
 - Multimedia (Audio Video Playback, mpeg4, .avi, mpeg3)
 - Communication (Wireless LAN , Infrared, Bluetooth)
 - Multiple OS (Windows CE, Blackberry O/S, Palm O/S, Symbian O/S)
- **Disadvantages**
 - Small Screen Size
 - Navigation Issue
 - Small keyboard, letter transcriber difficult to learn
 - Few Accessibility Features are bundled, but not good enough



Photos: www.blackberry.com

Photos: www.hp.com

Key aim : URCs for Medical Devices

- **Large Number of Target Devices and Services**
 - Monitoring Devices, Examination Equipment, Homecare Technologies, Exercise Equipment
- **Often Complicated devices**
 - Precise, complex interfaces
- **Multimodal**
 - Audio, graphs, speech
- **Medical Standards**
 - HL7 , SNOMED CT
- **Diverse Users**
 - Physicians, nurses, home caregivers



User Abilities

- **Diverse Users, Diverse Abilities**

- Disabilities
- Impairments
- Difficulties



- **Abilities impact use of computer interfaces and devices**

- Visual (colorblind, low vision, blind)
- Arm Related (reaching)
- Hand Manipulation (grasping, tremor)
- Hearing (hard of hearing, deafness)
- Posture Balance (standing, seating)
- Mobility

User Preferences

- **Diverse Users, Diverse Preferences**
 - Different Preferences for various criteria
 - Fonts (size, style, types)
 - Colors (background vs. text)
 - Controls (more text based vs. more GUI based)
 - Display (different resolutions, screens)
 - User vs. Designer

BP: 120/80 mmHg

**BP: 120/80
mmHg**

BP: 120/80 mmHg

BP: 120/80 mmHg

BP: 120/80 mmHg

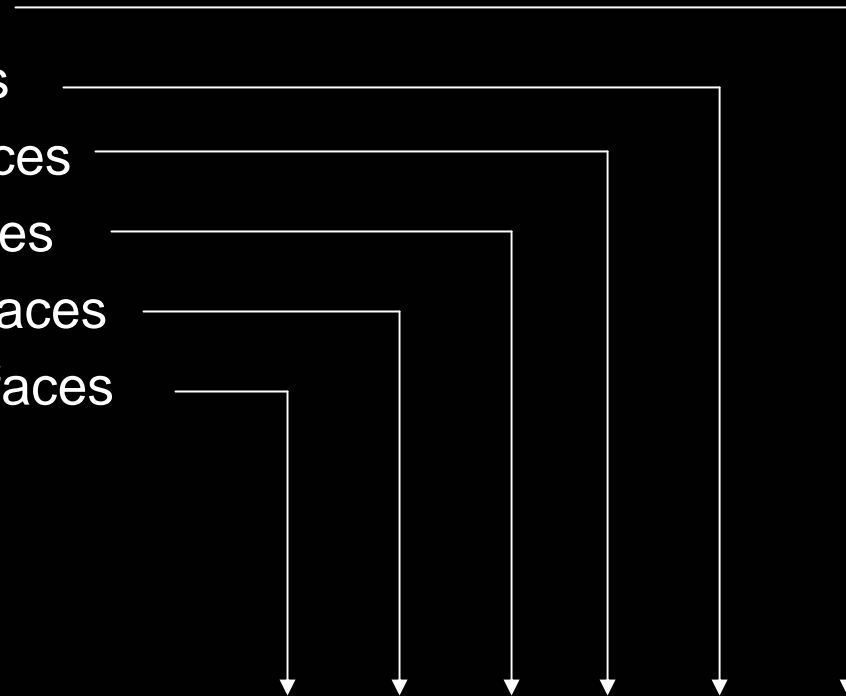
BP: 120/80 mmHg

Permutations and Combinations of user preferences and abilities equals

NO IDEAL USER INTERFACE !!!

Motivation : Need for Automatic user Interface generation

- Multiple target devices
- Complex user interfaces
- Multi modal user interfaces
- Accessible user interfaces
- Personalized user interfaces
- Universally usable interfaces

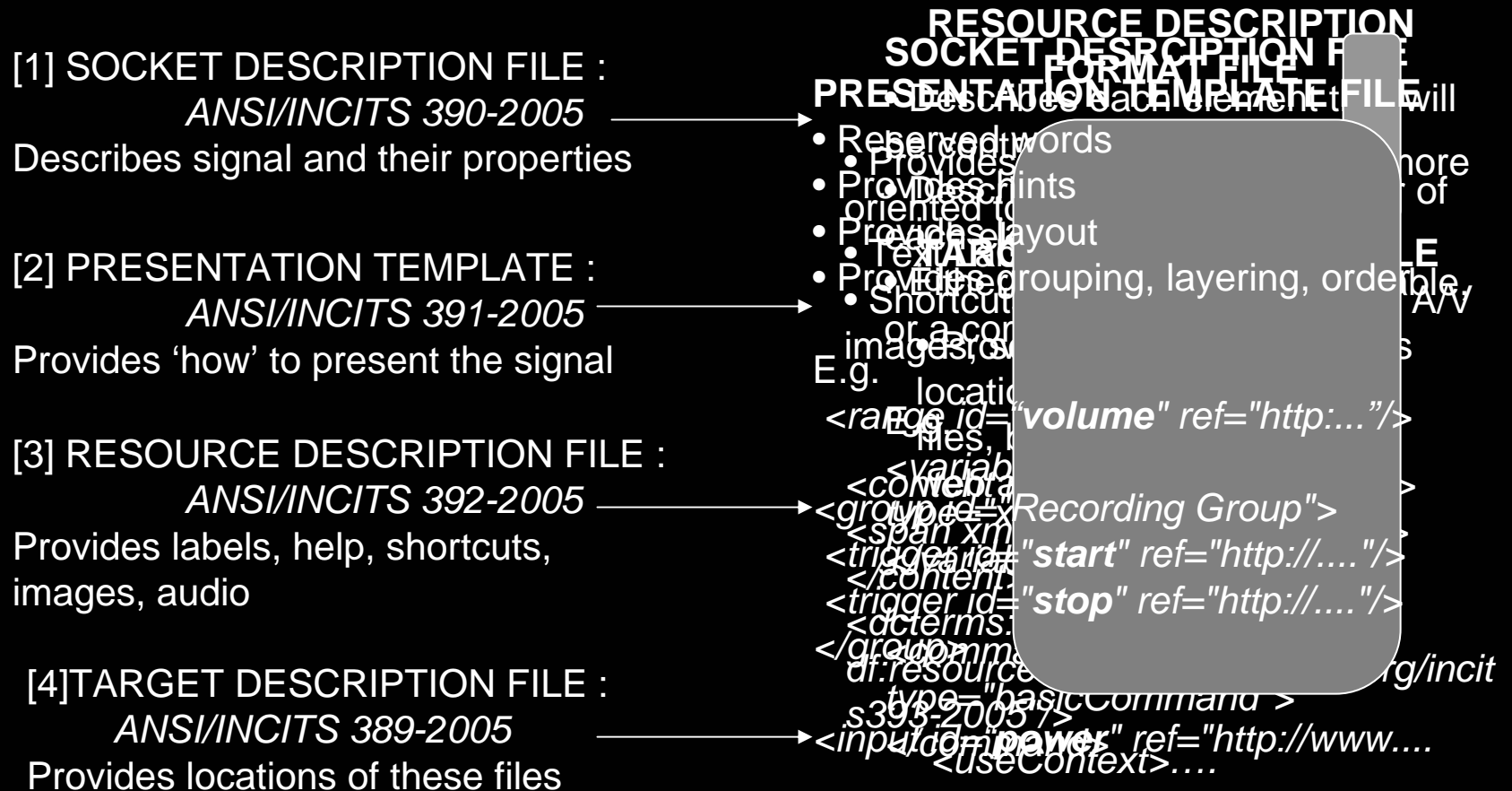


The ANSI/INCITS* 389-393-2005 Standards Collection

- **Why ANSI/INCITS 389-393-2005**
 - Provides framework and protocols to create a true Universal Remote Console
 - Framework built for Automatic UI generation
 - Target Device independent
 - Platform, OS independent
 - Universal language of programming; eXtensible Markup Language (XML)
 - Framework designed for multiple communication methodologies
 - Flexible and Robust
 - Allows for multimodal input/output
 - Allows for integration of accessibility
 - Allows for complex target devices to be controlled

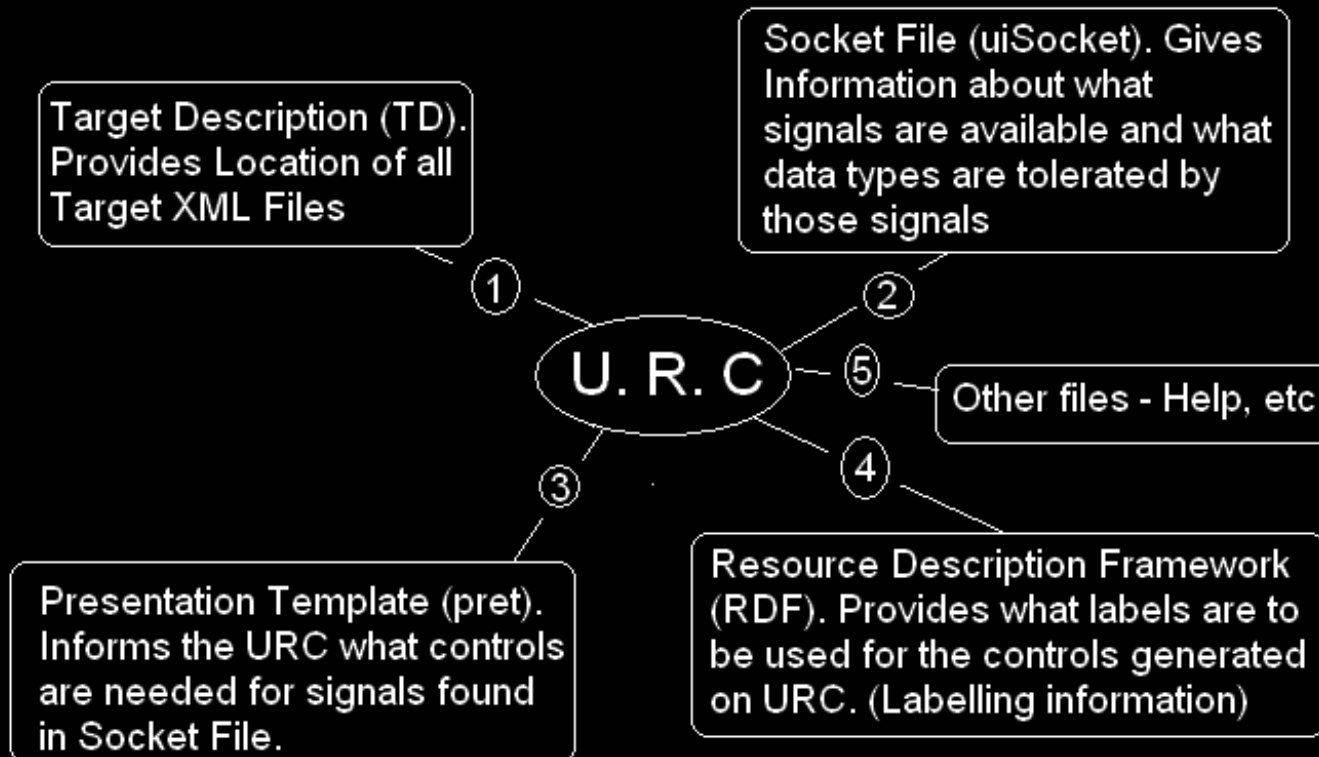
The ANSI/INCITS 389-393-2005 Standards Framework Summary

- Constructs a user interface for a remote control based on a set of eXtensible Markup Language (XML) files.
- Structured files, providing hints and sufficient information to build a user interface and initiate control of device.



Special Features of ANSI/INCITS 389-393 Standard (Relation to Automatic UI Generation)

- URC does not require programming each time a new device is added
- Automatic detection of devices
- Complex devices compatible
- Multiple Communication formats supported
- Can be programmed in any computing language
- Language not a barrier

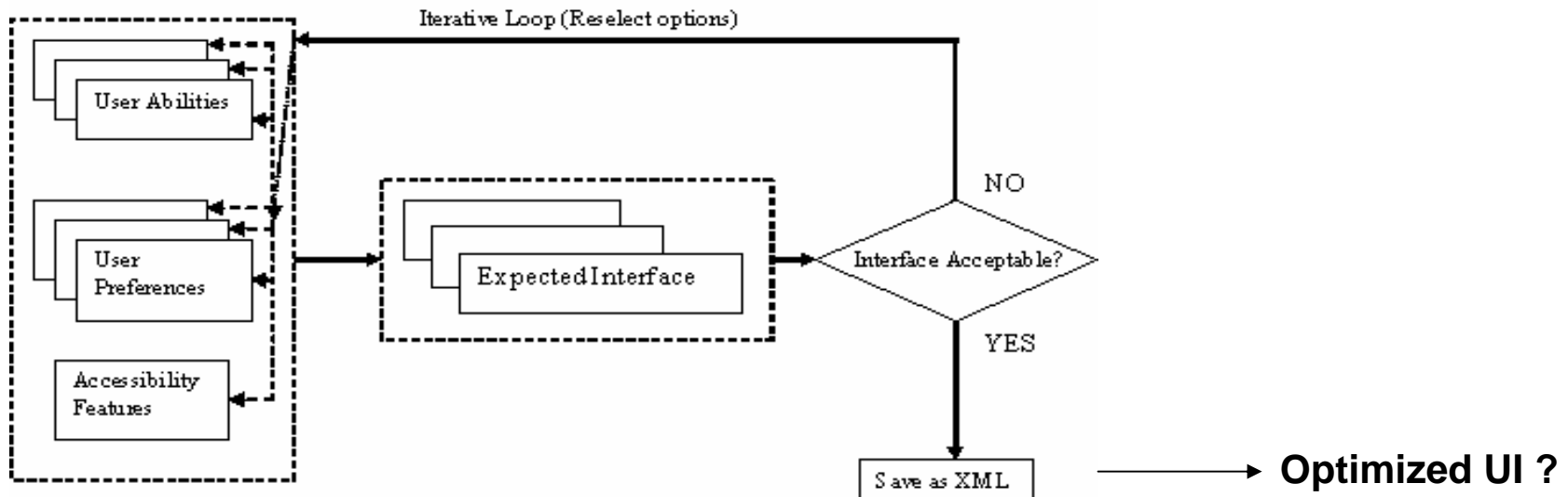


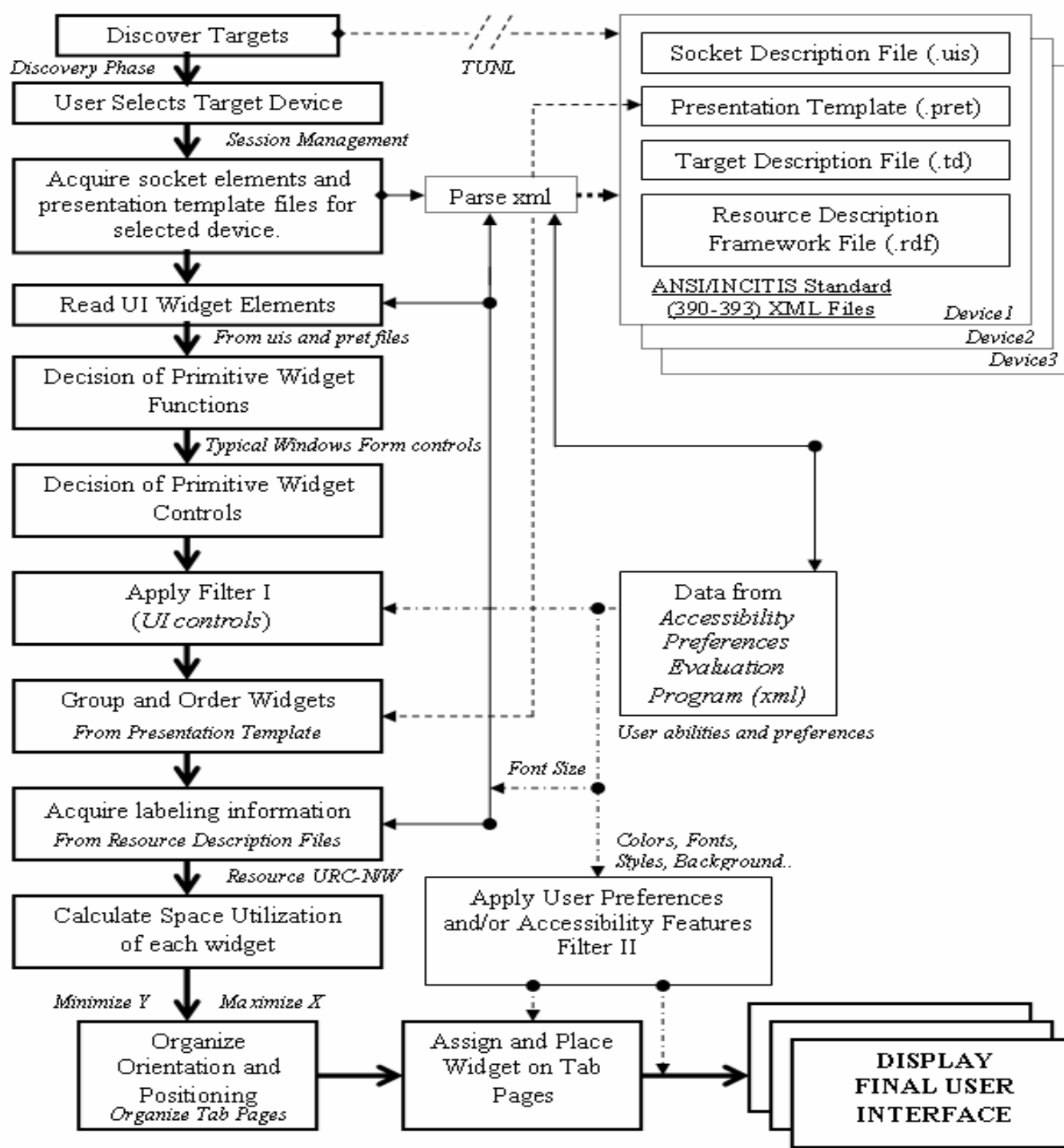
Algorithm to Automatically generate multi-modal interfaces for hand held devices based on user preferences and abilities.

User Evaluation

Accessibility and Preferences Evaluation Program

- **Prototype Software Collects Data about**
 - **User Abilities**
 - Categories Visual, Hearing/Speech, Hand/Arm Impairment, Balance and Posture
 - **User Preferences**
 - Font: styles, type, sizes, font colors, background colors, user controls
 - ‘What you see is what you get’ format
 - Saves data in xml format, prototype accessibility ‘schema’ developed





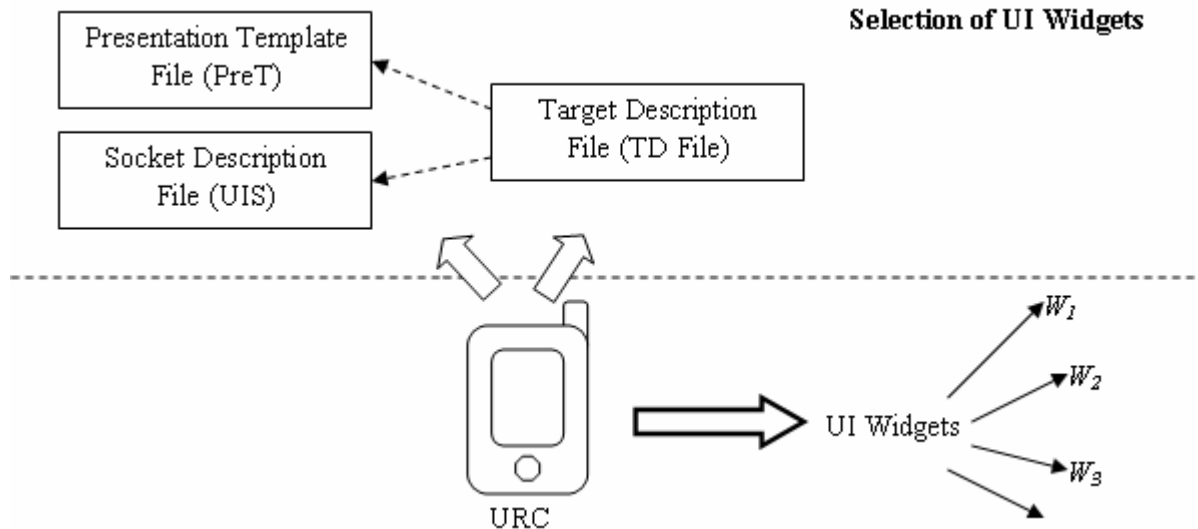
Flowchart of Algorithm

Algorithm continued...

•UI Widget

A Widget can be defined as a element which is controlled or displayed on a user interface

•Selection of UI Widgets



$$W_i = f(UIS, PreT).$$

Presentation template

```
<range id="volume"
      ref="#volume/>
<input id="power"
      ref="www...#power/>
```

Socket Description

```
<variable id="power"
  type="xsd:boolean">
</variable>

<variable id="volume"
  ref="www....#volume"
  type="xsd:volumenumbertype">
</variable>
<name="volumenumbertype">
<xsd:restriction
  base="xsd:integer">
<xsd:minInclusive value="1"/>
<xsd:maxInclusive value="10"/>
<xsd:totalDigits value="2"/>
<xsd:fractionDigits value="0"/>
</xsd:restriction>
```

• Decision of Primitive Widget Function (example)

| Interactor (.pret file) | Socket Element | Socket Type | Assigned Function |
|----------------------------|-------------------|----------------|---|
| <textarea> | variable | xsd:string | Text Input |
| <trigger> | Command | basicCommand | Command to be executed |
| <range> | variable | xsd:integer | Numeric Value with a Maximum or Minimum value |
| <output> | variable | xsd:string | Output to be Displayed |
| <secret> | variable | xsd:string | Hidden String |
| <select1> | variable | xsd:string | List of Strings (Select One) |
| <output> | static | xsd:string | Serial no, model no... |
| <input> | variable | xsd:date | Date Input |

id = power

input + boolean

Toggle, two state form

id = volume

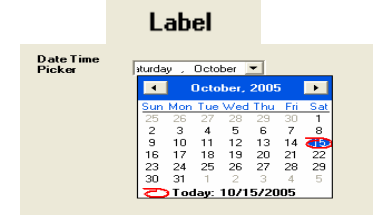
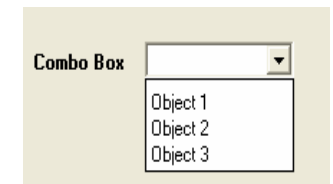
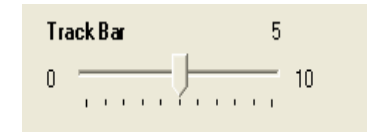
range + Schema

- integer
- min, max

Numeric value with
maximum, minimum

• Assignment of Primitive Widget Controls (default)

| Interactor | Socket Element | Socket Type | Assigned Function |
|------------|----------------|--------------|---|
| <textarea> | variable | xsd:string | Text Input |
| <trigger> | Command | basicCommand | Command to be executed |
| <range> | variable | xsd:integer | Numeric Value with a Maximum or Minimum value |
| <output> | variable | xsd:string | Output to be Displayed |
| <secret> | variable | xsd:string | Hidden String |
| <select1> | variable | xsd:string | List of String (Select One) |
| <output> | static | xsd:string | Serial no, model no... |
| <input> | variable | Xsd:date | Date Input |



- **Accessibility Filter I – Related to UI Controls**

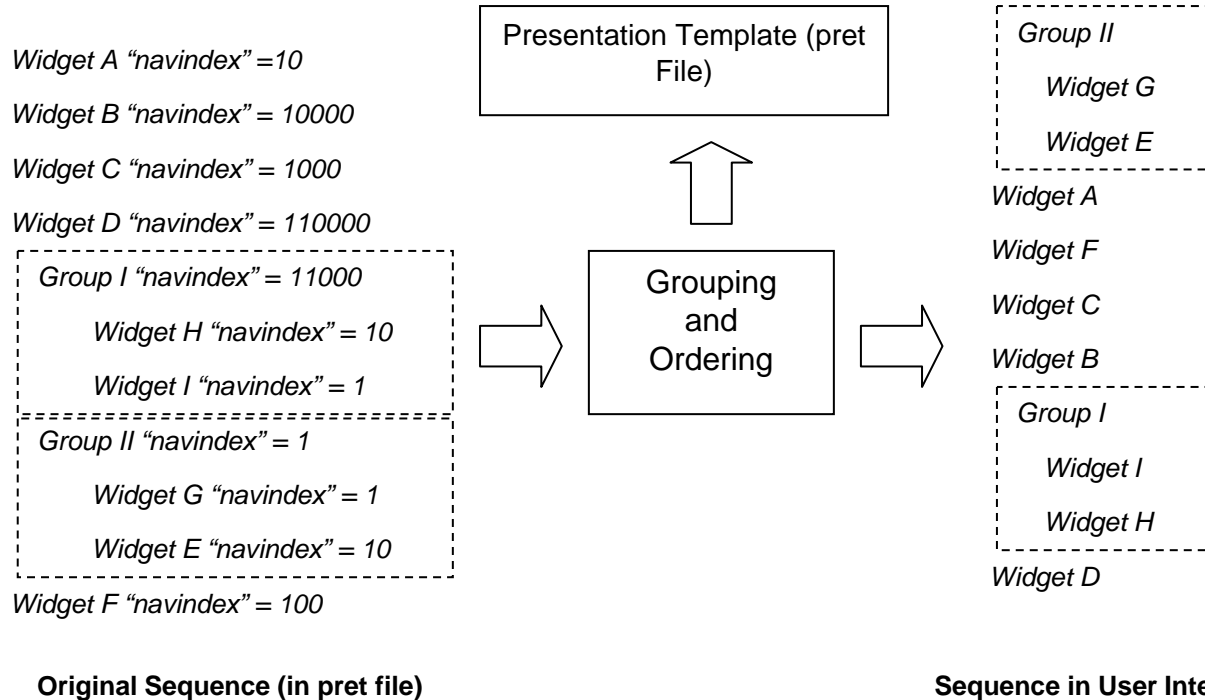
- **Based on data from users Abilities and Preferences**

| Impairment/Disability Ability | Original User Control | User Control After Filter |
|--|--------------------------------------|----------------------------------|
| <i>Color Blind</i> | Buttons | Larger Buttons |
| <i>Difficulty Following Images</i> | Picture Box | Larger Picture Boxes |
| <i>Difficulty Pushing Buttons</i> | Buttons | Larger Buttons |
| <i>Difficulty Pushing Buttons</i> | Numeric Up Down | Track Bar |
| <i>Difficulty Pushing Buttons</i> | Combo Box | Radio Buttons |
| <i>Unintentional Tremor</i> | Track Bar | Numeric Up Down |
| <i>Unintentional Tremor</i> | Buttons | Larger Buttons |
| <i>Unintentional Tremor</i> | Combo Box | Radio Buttons |
| <i>Grasping</i> | Track Bar | Numeric Up Down |
| <i>Grasping and Difficulty Pushing Buttons</i> | Track Bar Numeric Up Down | Text Box |

- **OR PREFERRED CONTROL FROM THE USER [IF RATED HIGHER]**

•Grouping and Ordering

- From Presentation Template
- Sequences order in which widgets appear on UI
- ‘navindex’ attribute also orders grouping and layering
- Default: Order in Presentation Template (if ‘navindex’ absent)



id = power


Check Box

id = volume

Track Bar 0 5 10

•Acquiring labeling and other information

- From Resource Description Format file (RDF)
- Each device can have multiple
- Labels, Images, Optional Labels, Audio/Video Image, Icons
- A core RDF file provides at least strings for labels

Temp 
99.7 Deg F

BP 
118/79 mmHg
SYST DIA

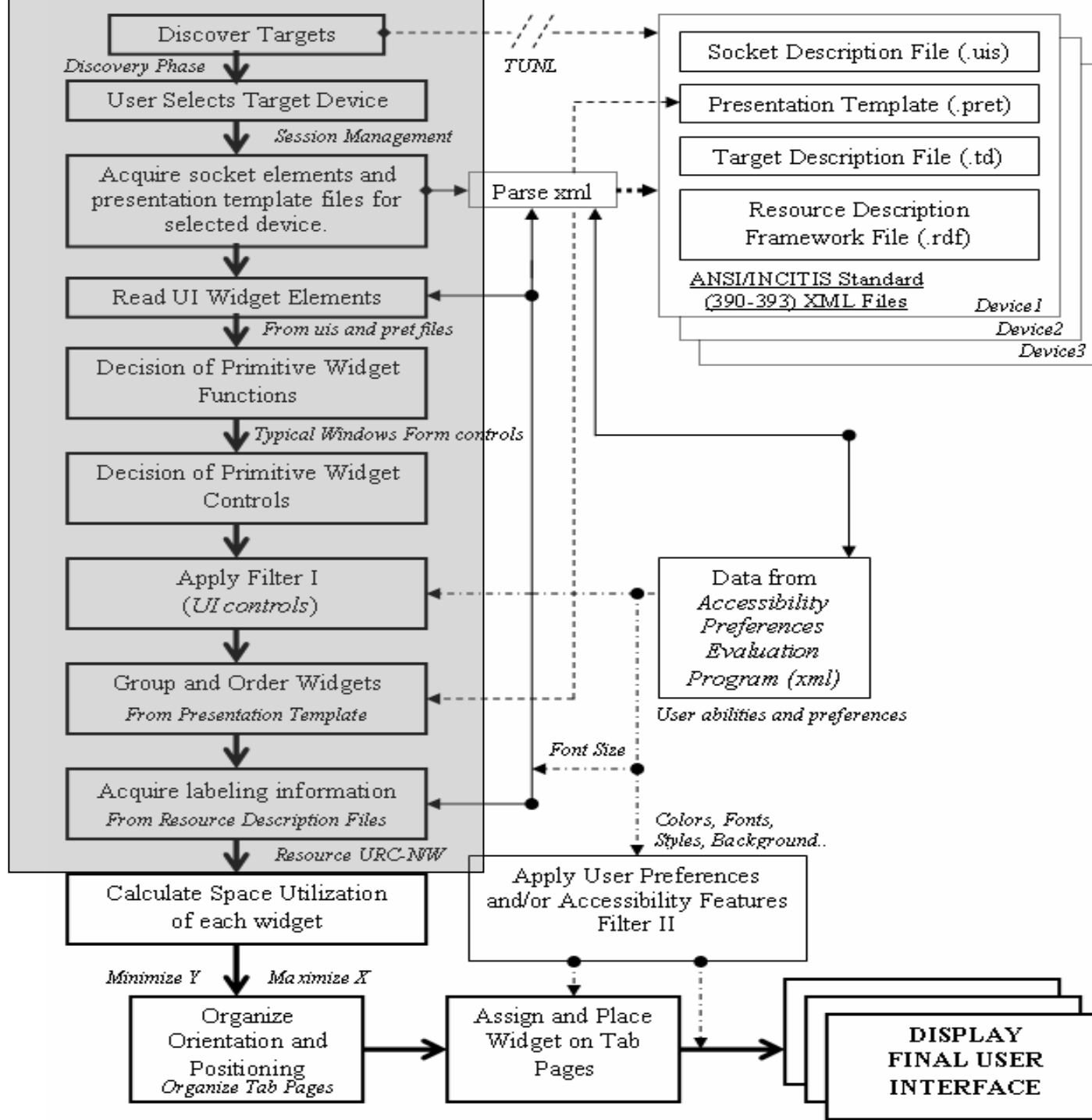
PR  
112 BPM

Power

Volume 1



Mute Audioreadout

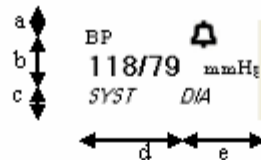


Flowchart of Algorithm

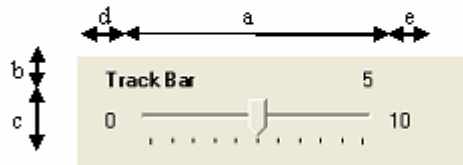
•Assignment of Spatial Dimension for each widget

•Dimension $(x, y) = f(p, F, L, Lf, o, i)$

- p = size in pixels
- F = font size
- L = label size in pixel
- Lf = label font size
- o = # of objects
- i = optional images' size



a Height of Widget Label
 b Height of Widget Value or Unit (whichever is larger)
 c Height of Optional Labels
 d Width of Widget Value
 e Width of Widget Unit
 Total Width = $d + e$ Total Height = $a + b + c$



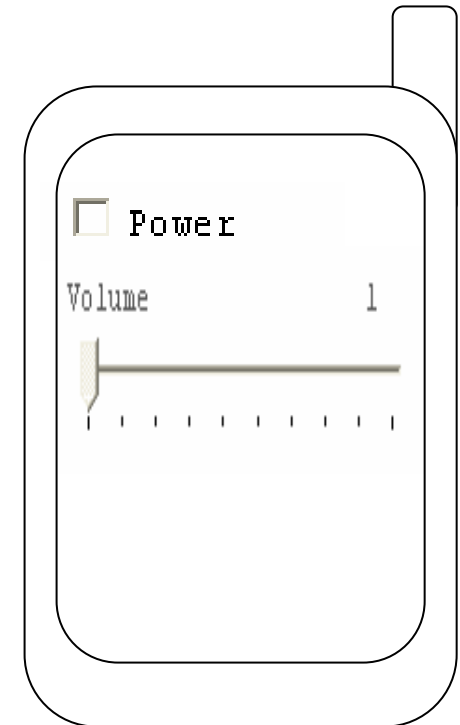
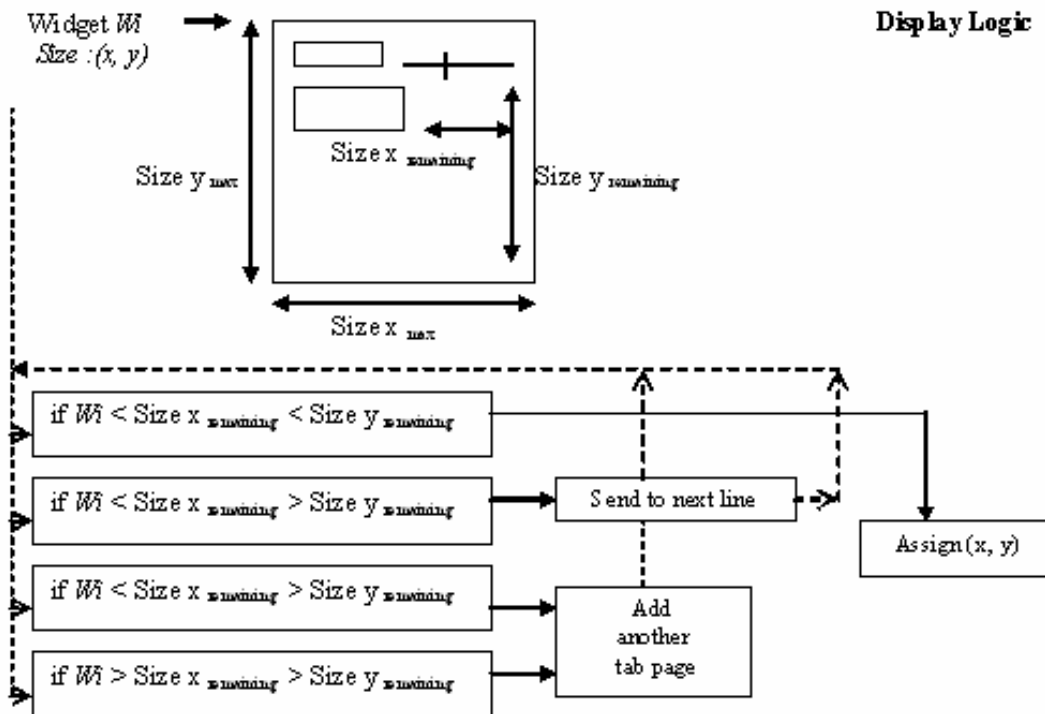
a Width of Track bar
 b Height of Widget Label
 c Height of Track bar
 d Width of Widget Minimum Value
 e Width of Widget Maximum Value
 Total Width = $a + d + e$ Total Height = $b + c$



Figure 3-14: Calculation of Spatial Dimension for each Widget

•Display Logic

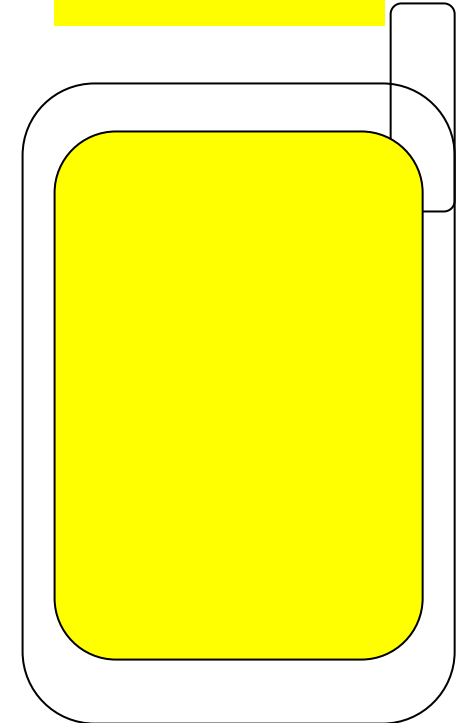
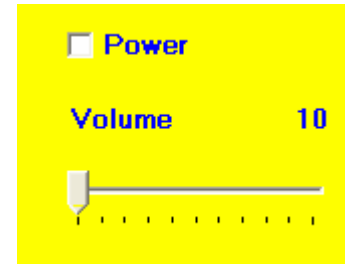
- Maximizes space utilization
- Groups related objects in group box
- Displays entire group on a single screen
- Attempts to reduce navigation
- Displays optimal font sizes
- Can be configured for portrait/landscape layouts



- **Accessibility Filter II – Related to UI Display**

- **Based on data from users Abilities and Preferences**

| Chosen Ability / Preference Impairment/Disability | Resultant Display /Accessibility Feature |
|--|---|
| Color Blindness | Blue Background, Yellow Font (See [12]) |
| Color Blindness | Font Size 11pt |
| Color Blindness | Point to Talk, Tab to Talk (indexed) |
| Reading Small Fonts | Font Size 12pt |
| Reading Small Fonts | Bold Fonts |
| Difficulty Following Images | Large Images |
| Blindness | Tab to Talk (indexed) |
| High Contrast | Black Background, White Font |
| Font Type (Arial, Bookman Old Style, etc.) | Corresponding Font Type |
| Bold Fonts | Bold Font |
| Background Color | Corresponding Background for UI |
| Font Color | Corresponding Font Color for UI |
| Font Size | Corresponding Font Size |



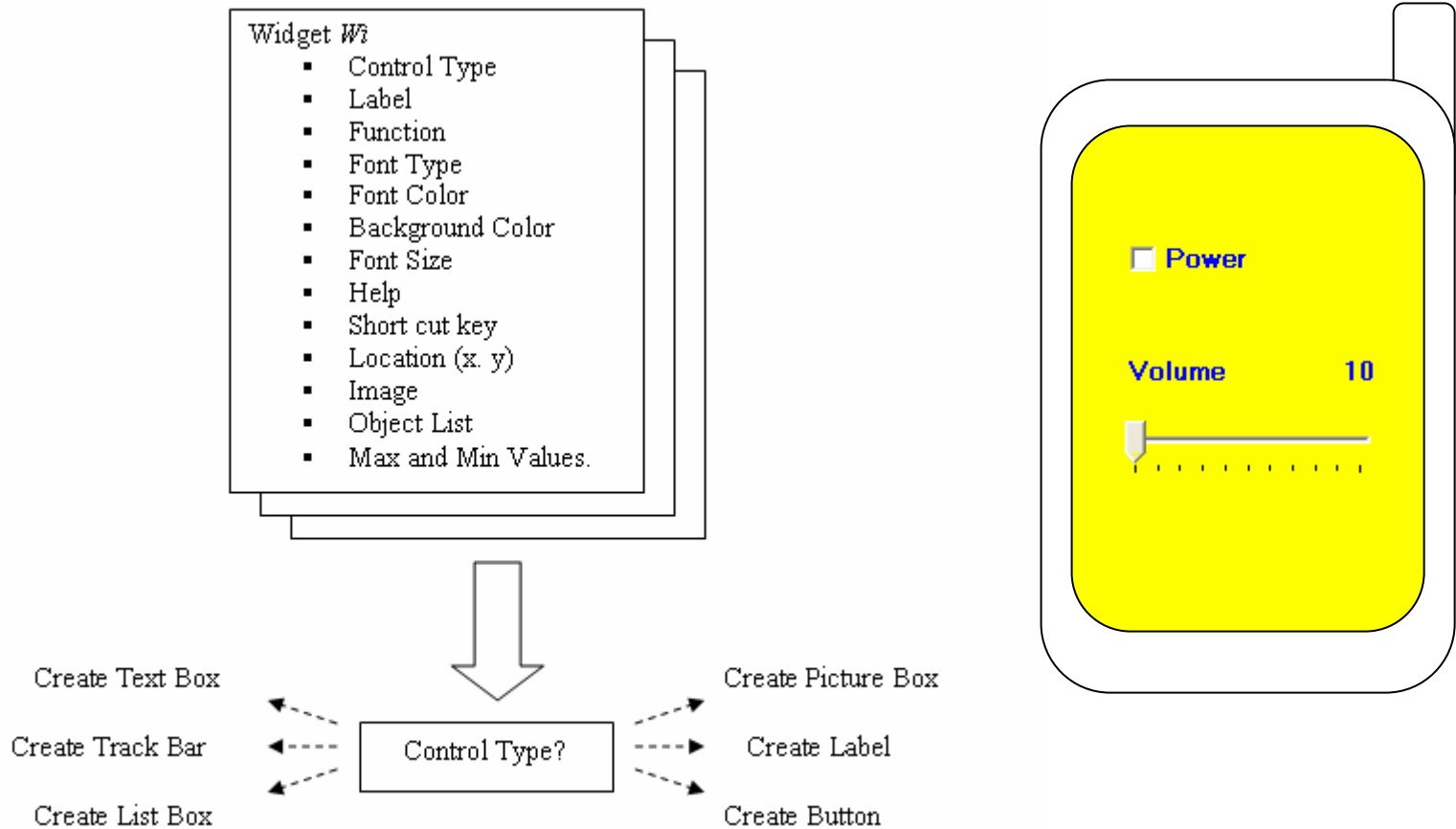
- **Point to Talk (Text to Speech – Accessibility Option)**
 - Uses Microsoft Speech SDK
 - ‘Reads’ out status, values , label and control type for each widget
 - Initiated by ‘mouse over’ or ‘tab stop’

Mute Audioreadout

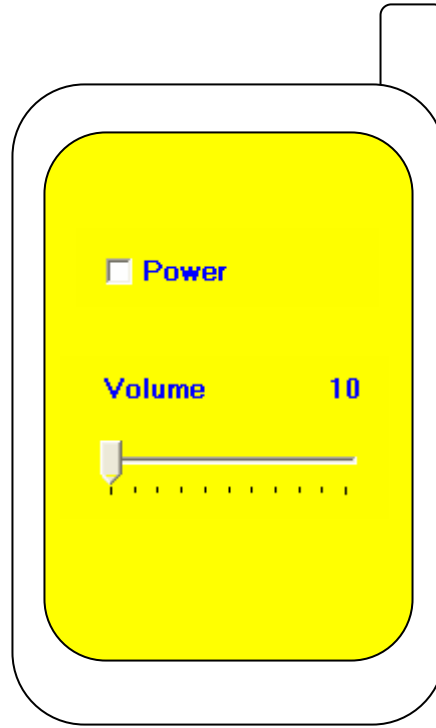
PR  
112 BPM

• Creating and Displaying each widget

- Creates 'actual' control based on assigned control
- Calls method that creates control at runtime
- Displays 'widget' at corresponding location, position, tab page

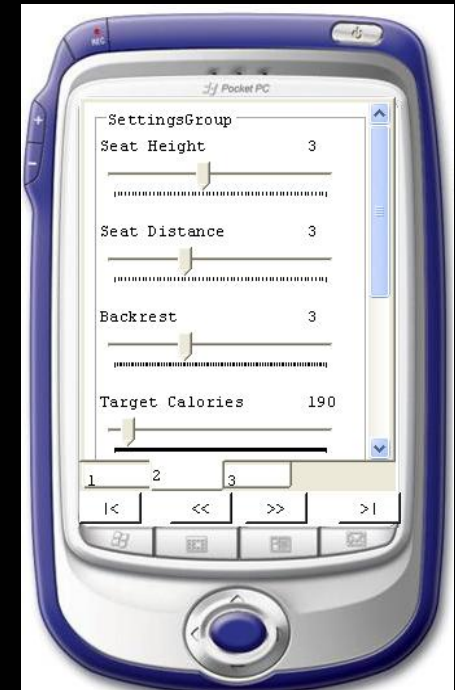


•Final User Interface



Implementation of Algorithm

- ANSI/INCITS 389-393 Standard compliant files for targeted devices created by RERC MU Staff
 - Vital Signs Monitor, CAS740
 - Exercise Ergo Meter
 - Examination Table
- Simulation Environment created by RERC MU Staff
 - Communication via TCP/IP, URC: Windows Development, Target : ASP.NET, RERC Server in CA



Algorithm Evaluation : Subject Testing

- Diverse Subjects (n=9)
 - Visual Difficulties (colorblind; low vision)
 - Hearing Difficulties
 - Mobility Impairment (stroke-induced impairments)
 - Hand/Arm Impairments (unintentional tremor)
 - Controls (n=4; age range 25-60)
- Generated Four UI Alternatives
 - Alternative I (Default)
 - Alternative II (UI based on user abilities and preferences)
 - Alternative III (UI based on user preferences only)
 - Alternative IV (Default with MS Accessibility Features)

These four alternatives were provided to the users randomly to perform goal oriented tasks.

- Performed Simple Goal Oriented Tasks
 - Four Target Devices
 - Vital Signs monitor, Ergo meter, Examination table, Unitherapy
 - All four devices for each alternative
 - Goal: Each user was made to get familiar with each type of alternative UI
- Filled out paper survey based on experience with the four alternatives generated
 - Multiple Choice Questions
 - Comparative Rated Scaling ('Extremely', 'Very', 'Somewhat', 'A little', 'Not at all')

Results : Subject Survey



Colorblind



Low Vision



Hearing Difficulty

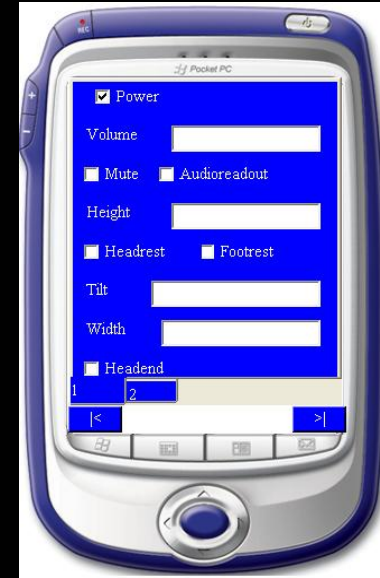
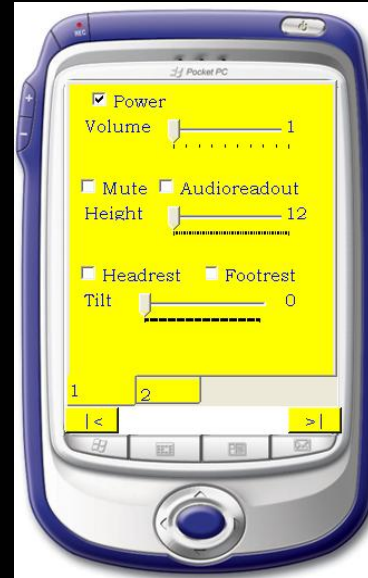


Stroke



Unintentional tremor

Results : Subject Survey (cont.)



Each user interface is different !!

- 5 prefer less pages, 4 prefer more pages for navigation
- None of the users were aware of available accessibility features by Windows
- Both the visually impaired individuals appreciated 'High Contrast'
- Individual with hearing difficulty appreciated 'Sound Sentry'

Results: Subject Survey (cont.)

mean – entire population

| INTERFACES COMPARED | Default User Interface | UI based on User abilities and preferences | UI based on User preferences only | Default UI with MS Accessibility |
|--|------------------------|--|-----------------------------------|----------------------------------|
| | Mean | Mean | Mean | Mean |
| Ability to see all labels | 2.78 | 3.56 | 3.33 | 1.78 |
| Ability to interpret all information | 2.78 | 3.44 | 3.33 | 1.89 |
| Ability to find all controls | 2.89 | 2.89 | 2.89 | 2.11 |
| Ability to understand status of interface | 2.67 | 3.00 | 2.89 | 2.11 |
| Ability to obtain feedback | 2.56 | 3.00 | 2.89 | 2.00 |
| Ability to operate controls | 2.78 | 3.33 | 3.33 | 2.22 |
| Ability to operate without mistakes | 2.33 | 2.89 | 2.78 | 1.67 |
| Text/Background colors | 2.22 | 3.22 | 3.44 | 1.00 |
| Fonts | 2.22 | 3.11 | 3.11 | 1.78 |
| Font size | 2.11 | 3.11 | 3.22 | 2.11 |
| Organization of controls | 2.22 | 3.22 | 3.00 | 1.33 |
| Navigation | 1.89 | 2.67 | 2.67 | 1.22 |
| Ability to complete task | 2.11 | 2.56 | 2.44 | 1.00 |
| Color contrast | 1.89 | 2.56 | 2.56 | 1.22 |

Results: Subject Survey (cont.)

means – non controls

| INTERFACES COMPARED | Default User Interface | UI based on user abilities and preferences | UI based on User preferences only | Default UI with MS Accessibility |
|--|------------------------|--|-----------------------------------|----------------------------------|
| | Mean | Mean | Mean | Mean |
| Ability to see all aabels | 2.88 | 3.50 | 3.38 | <i>1.75</i> |
| Ability to interpret all information | 2.88 | 3.50 | 3.38 | <i>1.88</i> |
| Ability to find all controls | 3.00 | 2.88 | 2.88 | <i>2.25</i> |
| Ability to understand status of interface | 2.75 | 3.13 | 3.00 | <i>2.25</i> |
| Ability to obtain feedback | 2.63 | 3.00 | 2.88 | <i>2.00</i> |
| Ability to operate controls | 2.75 | 3.38 | 3.38 | <i>2.25</i> |
| Ability to operate without mistakes | 2.25 | 2.88 | 2.63 | <i>1.63</i> |
| Text/Background colors | 2.25 | 3.25 | 3.38 | <i>1.00</i> |
| Fonts | 2.38 | 3.00 | 3.00 | <i>1.75</i> |
| Font size | 2.13 | 3.13 | 3.25 | <i>2.13</i> |
| Organization of controls | 2.25 | 3.38 | 3.13 | <i>1.38</i> |
| Navigation | 1.88 | 2.75 | 2.75 | <i>1.13</i> |
| Ability to complete task | 2.13 | 2.50 | 2.38 | <i>1.00</i> |
| Color contrast | 1.88 | 2.50 | 2.50 | <i>1.25</i> |

Results: Subject Survey (cont.) (paired T Test)

| | Default and UI with Acc/Pref | Default and UI with Pref. | UI with Acc/Pref and UI with Pref. | Default and Default with MS Acc. | UI with Acc/Pref. and Default with MS Acc. | UI with Pref. and Default with MS Acc. |
|---|------------------------------|---------------------------|------------------------------------|----------------------------------|--|--|
| Ability to see all labels | 0.0116 | 0.0477 | 0.1733 | 0.0139 | 0.0006 | 0.0004 |
| Ability to interpret all information | 0.0111 | 0.0255 | 0.2971 | 0.0258 | 0.0027 | 0.0006 |
| Ability to find all controls | 0.5000 | 0.5000 | 0.5000 | 0.0326 | 0.0870 | 0.0664 |
| Ability to understand status of interface | 0.0403 | 0.1733 | 0.2971 | 0.0477 | 0.0104 | 0.0040 |
| Ability to obtain feedback | 0.0176 | 0.0403 | 0.2971 | 0.0694 | 0.0200 | 0.0104 |
| Ability to operate controls | 0.0255 | 0.0255 | 0.5000 | 0.0694 | 0.0035 | 0.0014 |
| Ability to operate without mistakes | 0.0255 | 0.0176 | 0.2971 | 0.0706 | 0.0113 | 0.0067 |
| Text/Background colors | 0.0265 | 0.0113 | 0.1733 | 0.0027 | 0.0007 | 0.0001 |
| Fonts | 0.0176 | 0.0176 | 1.0000 | 0.1124 | 0.0036 | 0.0036 |
| Font Size | 0.0014 | 0.0014 | 0.1733 | 0.5000 | 0.0014 | 0.0035 |
| Organization of controls | 0.0265 | 0.0769 | 0.0845 | 0.0344 | 0.0062 | 0.0083 |
| Navigation | 0.0216 | 0.0040 | 0.5000 | 0.0403 | 0.0006 | 0.0006 |
| Ability to complete task | 0.1561 | 0.1986 | 0.1733 | 0.0014 | 0.0000 | 0.0000 |
| Color contrast | 0.1208 | 0.0845 | 0.5000 | 0.1311 | 0.0249 | 0.0325 |

* Values for $p \leq 0.05$ in **Bold**

Conclusion

- Successfully demonstrated ANSI/INCITS Standard to develop URCs for complex Medical Devices
- Standard is robust for **Automatic** multimodal user interfaces
- Standard is flexible, and enables more accessible user interfaces
 - RDF Files play a key role
- Users do prefer a personalized interface over a default one
- Personalized Interfaces do add value to a user interface
- User interfaces customized to user preferences and abilities improves user performance

Conclusion (cont.)

- Certain differences between a personalized interface, default and built in accessibility features are statistically significant ($p \leq 0.05$)
- Algorithm can be configured for multiple screens, resolution, layouts
- Data saved by Accessibility Evaluation Program can be used by other applications as well, start of 'standard' for accessibility documentation
 - All the user has to do is provide his personal profile file or a location where the file exists, and the application uses it.

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Questions ??

