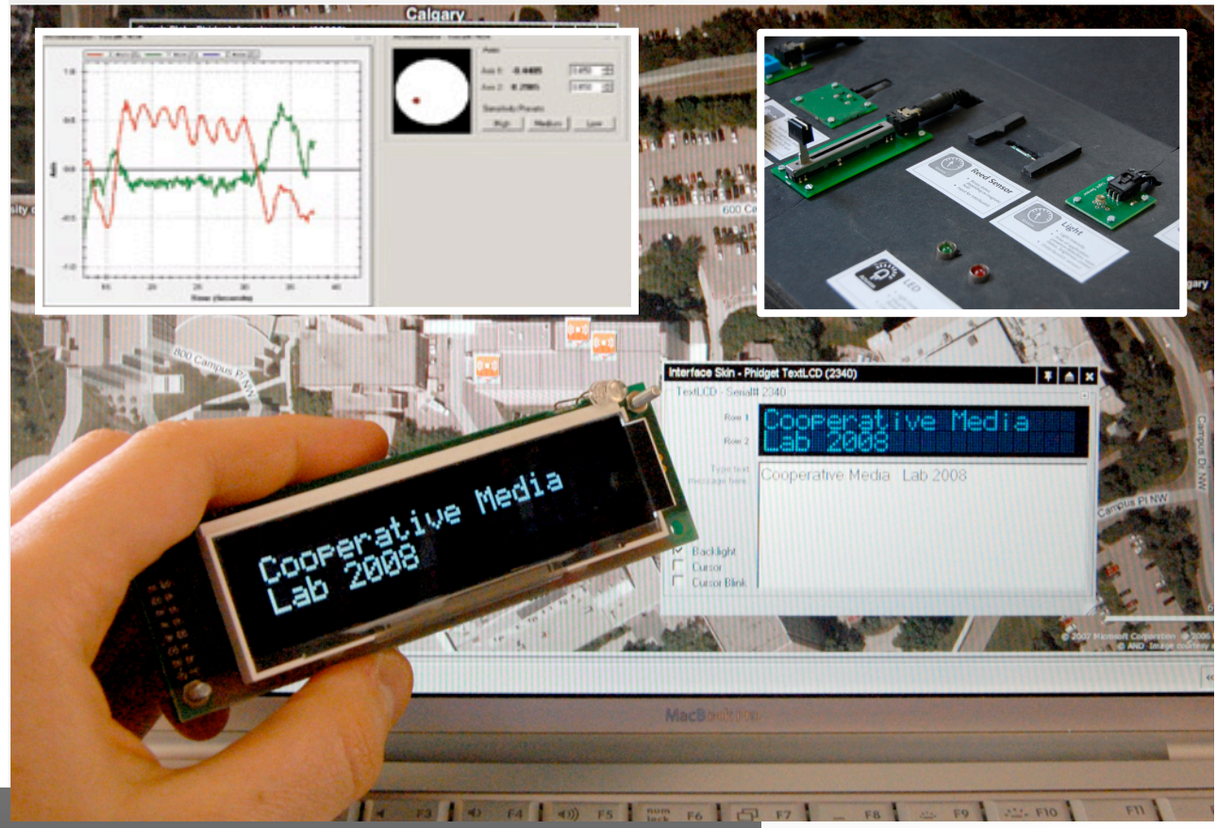
Bauhaus-Universität Weimar

CML Cooperative Media Lab

GroupLab University of Calgary



Developer Toolkit and Utilities for Rapidly Prototyping Distributed

Physical User Interfaces

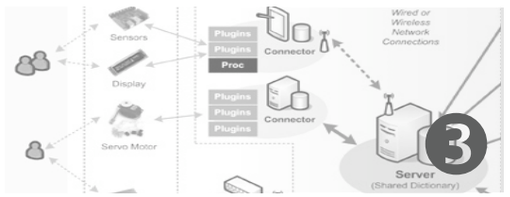
Nicolai Marquardt
Diploma Thesis Defence
May 2008

Cooperative Media Lab - Bauhaus-University Weimar
GroupLab - University of Calgary

Message

The *Shared Phidgets* toolkit supports developers when building rapid prototypes of distributed physical user interfaces.

Outline



Introduction and Related Work

Requirements and Concept

Implementation

Case Studies, Evaluation, Future Work

Vision of Ubiquitous Computing

"Next comes ubiquitous computing, or the age of calm technology, when technology recedes into the background of our lives."

Mark Weiser, Xerox PARC

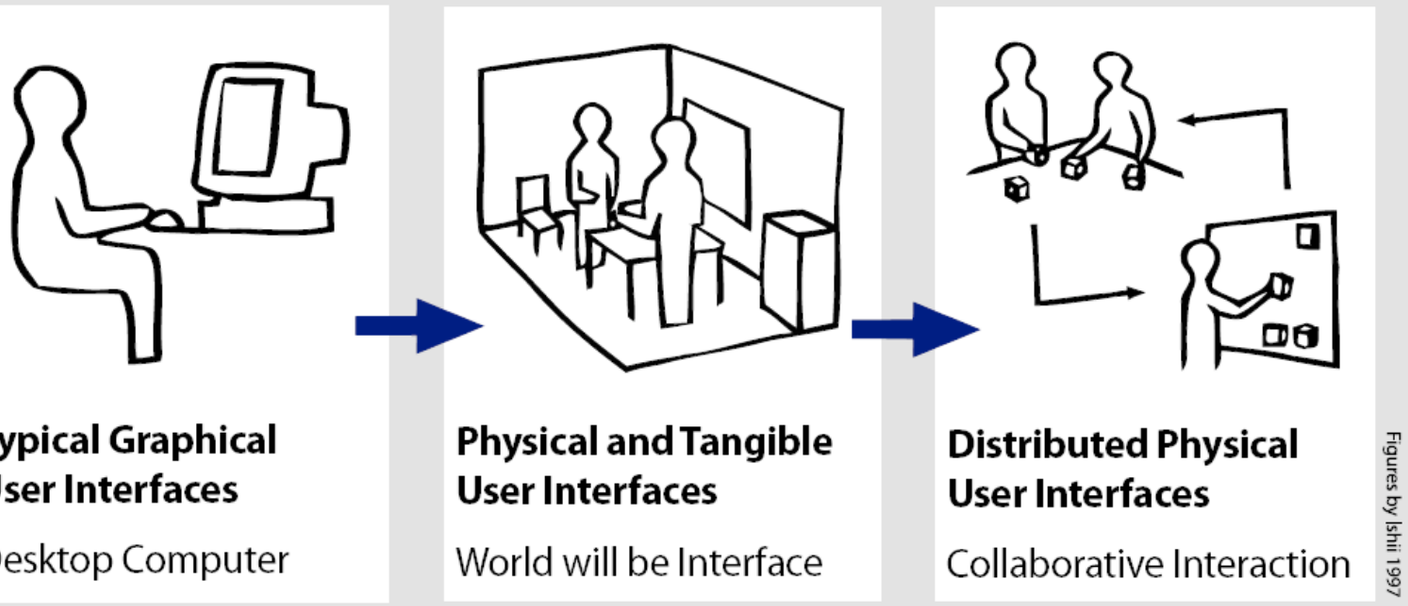
Vision of Ubiquitous Computing

"Next comes ubiquitous computing, or the age of calm technology, when technology recedes into the background of our lives."

"[...] its highest ideal is to make a computer so embedded, so fitting, so natural, that we use it without even thinking about it."

Mark Weiser, Xerox PARC

Tangible and Physical Interfaces



Typical Graphical User Interfaces

Desktop Computer

Physical and Tangible User Interfaces

World will be Interface

Distributed Physical User Interfaces

Collaborative Interaction

Figures by Ishii 1997

Hiroshi Ishii,
Tangible Media Group, MIT

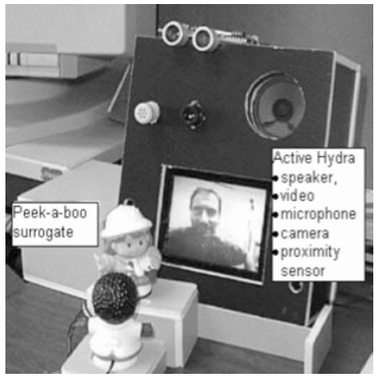
Definitions

- Physical and tangible user interfaces
- Information appliances vs. personal (mobile) devices
- Rapid prototyping and development cycle
- Developer support vs. end-user programming

Previous Research Projects

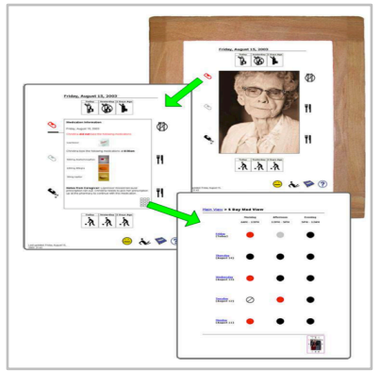
Tangible Bits
[Ishii and Ullmer, 2001]

HomeNote
[Sellen et al., 2006]



ActiveHydra
[Greenberg and Kuzuoka, 2000]

mediaBLOCKS
[Ullmer and Ishii, 1997]



Digital Family Portrait
[Mynatt and Rowan, 2001]
[Consolvo et al., 2004]

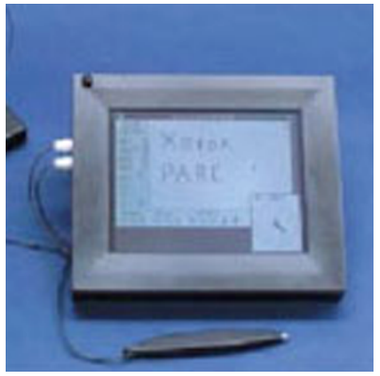
ambientROOM
[Ishii and Ullmer, 2001]

Gate Reminder
[Kim et al., 2004]

StickySpots
[Elliot et al., 2007]

Marble Answering Machine
by Durell Bishop
[Crampton Smith, 1995]

LumiTouch
[Chang et al., 2001]



Pad Prototype
[Weiser, 1996]

LiveWire
[Weiser and Brown, 1996]

Motivation

Tangible Bits
[Ishii and Ullmer, 2001]

[Sellen et al., 2006]

[Greenberg and Kuzuoka, 2000]

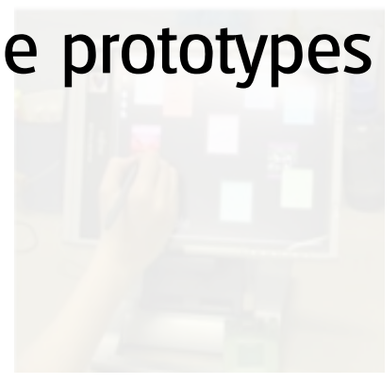
[Ullmer and Ishii, 1997]

[Mynatt and Rowan, 2001]
[Consolvo et al., 2004]

ambientROOM
[Ishii and Ullmer, 2001]

- Difficult to integrate physical hardware and build network
- Usually only local connected information appliances
- Single prototypes vs. iterative design cycle

Gate Reminder
[Kim et al., 2004]



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[Elliot et al., 2007]

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[Crampton Smith, 1995]

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[Chang et al., 2001]

Pad Prototype
[Weiser, 1996]

LiveWire
[Weiser and Brown, 1996]

Related Work: Toolkits

	Phidgets (Greenberg and Fitchett, 2001)	Context Toolkit (Dey, 2000, Salber et al., 1999)	Peripheral Display Toolkit (Matthews et al., 2004)	Papier Mâché (Klemmer et al., 2004)	Calder, BOXES (Hudson and Mankoff, 2006)	Equator - ECT (Greenhalgh et al., 2004)	Voodoo IO Toolkit (Villar and Gellersen, 2007)	iStuff Toolkit (Ballagas et al., 2003)
Runtime Platform and Infrastructure								
Hide hardware access	■	■	■	■	■	■	■	■
Adding/removing hardware dynamically (plug&play)	■	■	■	■	▪	■	■	■
Integrate distributed networking layer		■	■	▪		■		■
Flexible runtime reconfiguration		■		▪		▪		■
Facilitate extensions and integration of custom hardware (e.g., plug-in based)		■	▪	■		▪		■
Development and Prototyping Support								
Development library and OOP concepts	■	■	■	▪	■	■	■	■
Event-driven architecture	■	■	■	■	■	■	■	■
Software proxy objects for hardware components (e.g., JavaBeans, .NET)	■	▪			▪	■	▪	
Visual user interface representations of hardware components	■			▪			▪	
Transparent accessable distributed data model		■				▪		▪
High-level abstractions / events		■	■	■		▪		■
Metadata integration		▪	■			▪		
Seamless integration into development tools (e.g., infrastructure exploration as IDE plug-in)	▪			■		■	▪	
Development Utilities (Monitoring, Controlling, Debugging, Simulating)								
Infrastructure explorer / observer	■	▪	▪	■	▪	■	▪	■
Controlling and initialising of hardware		▪				▪	■	
Application / appliance observer and control						▪		▪
Event visualisations (e.g., network)		▪		■		▪		▪
Testing and debugging support (e.g., *Wizard of Oz* simulations, test cases)	▪	■	▪	■				

Common Characteristics:

- Hardware integration
- Object-oriented programming

Drawbacks:

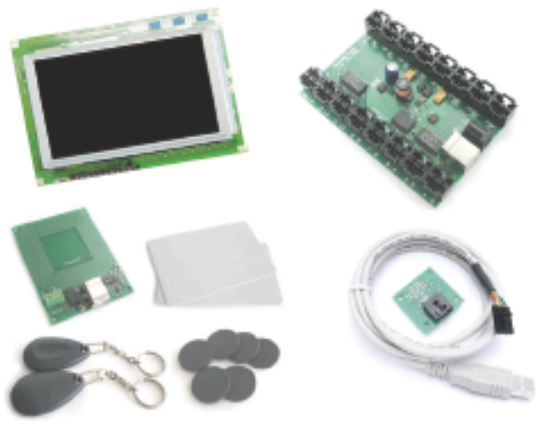
- Partially only for local hardware, and not specifically designed for distributed architectures
- Expert knowledge needed
- High-level assemblies

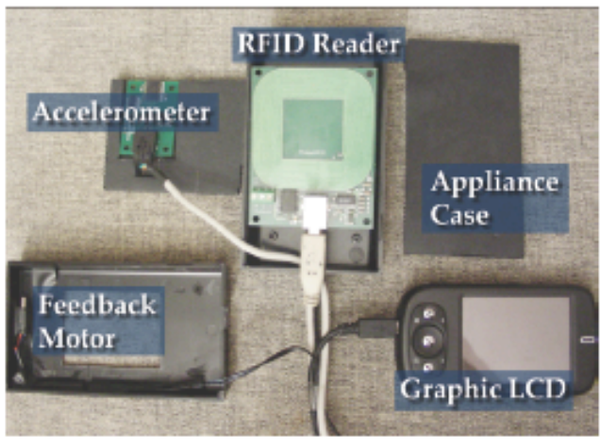
Requirements

1. Hide hardware implementation and provide shared access
2. Address *low threshold* and *high ceiling* [Myers et al., 2000]
3. Provide utilities for exploration and control
4. Support testing and debugging of distributed hardware and information appliances
5. Build extensible architecture

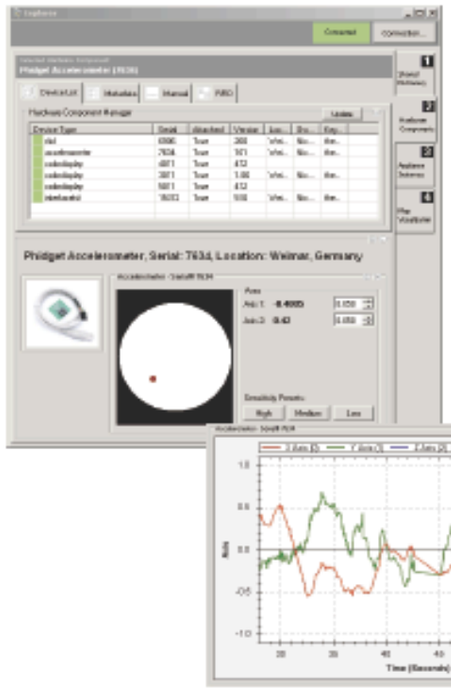
Building Prototypes

Physical Hardware

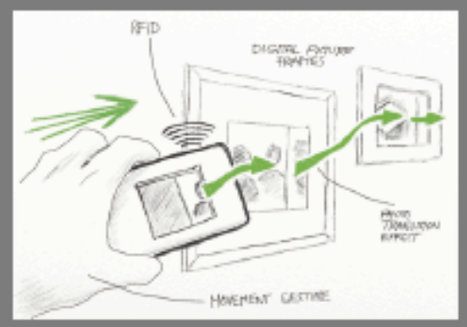




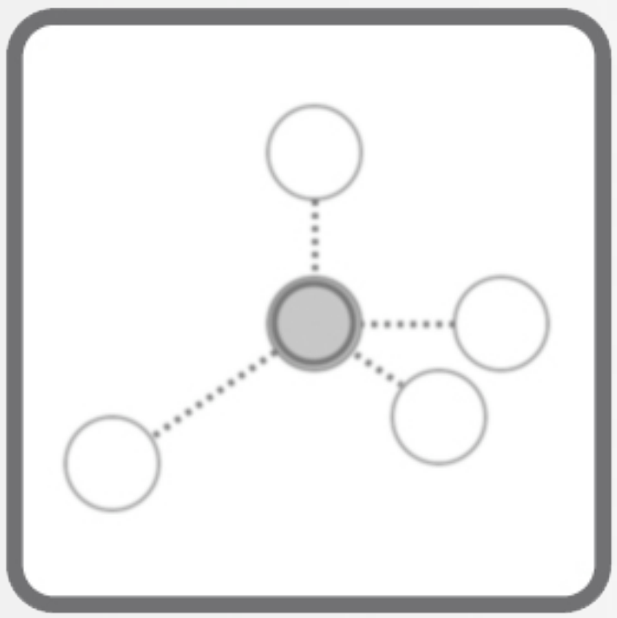
Implemented Software



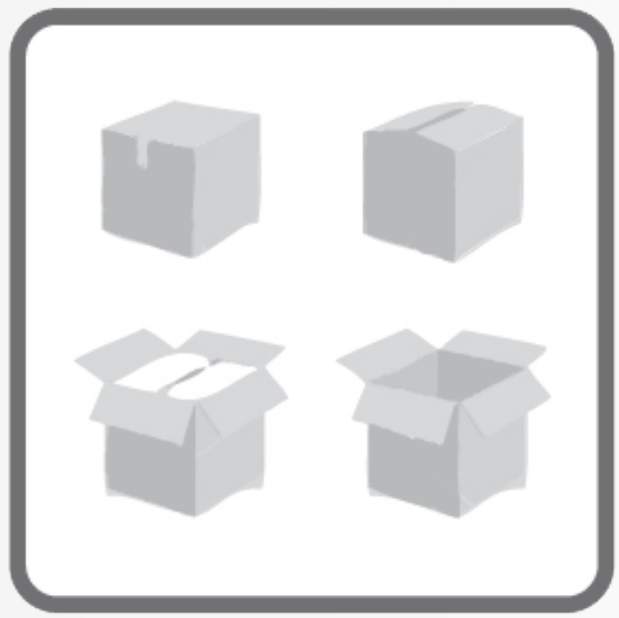
Information Appliance Prototype



Shared Phidgets Toolkit



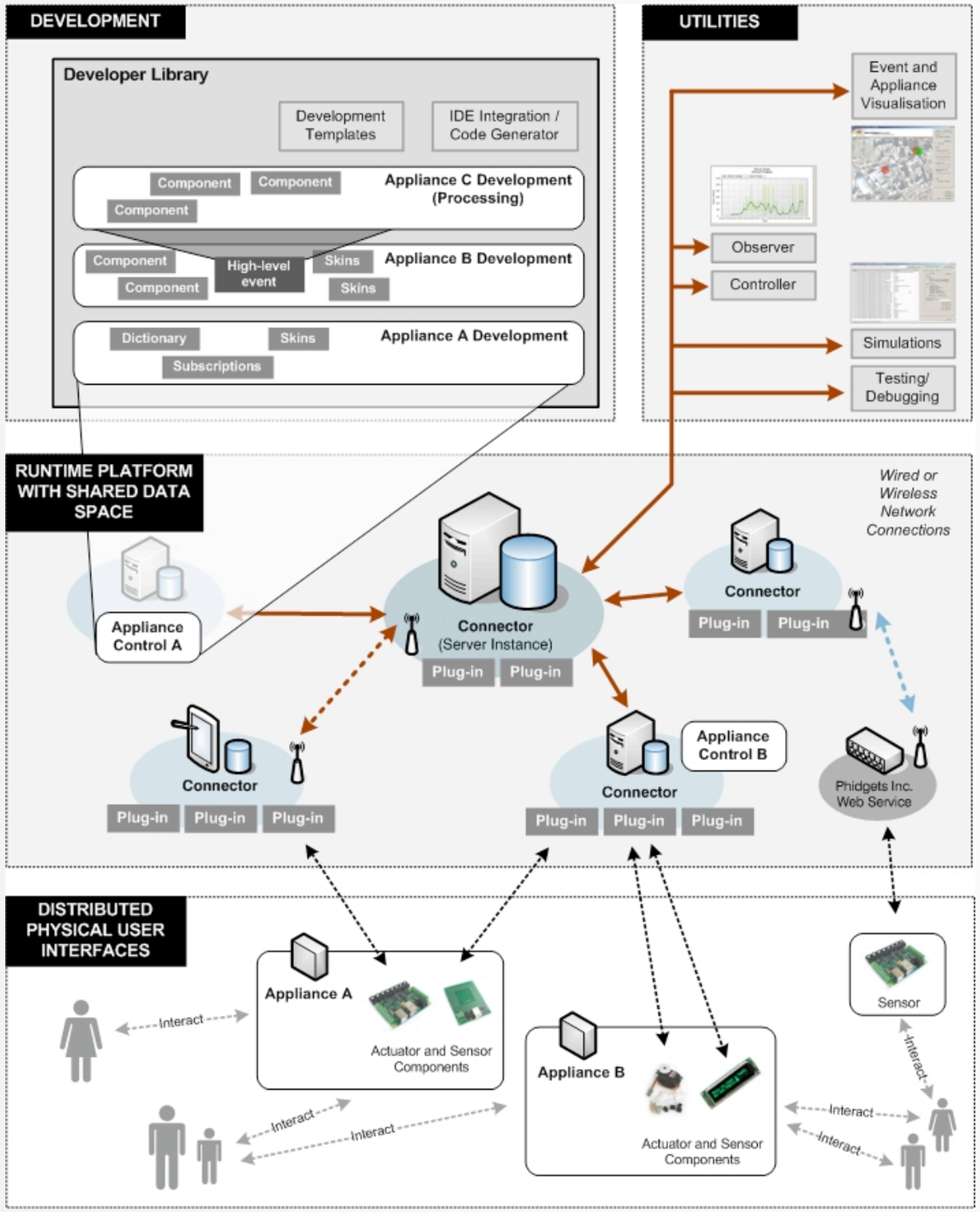
Runtime Platform



Developer Support

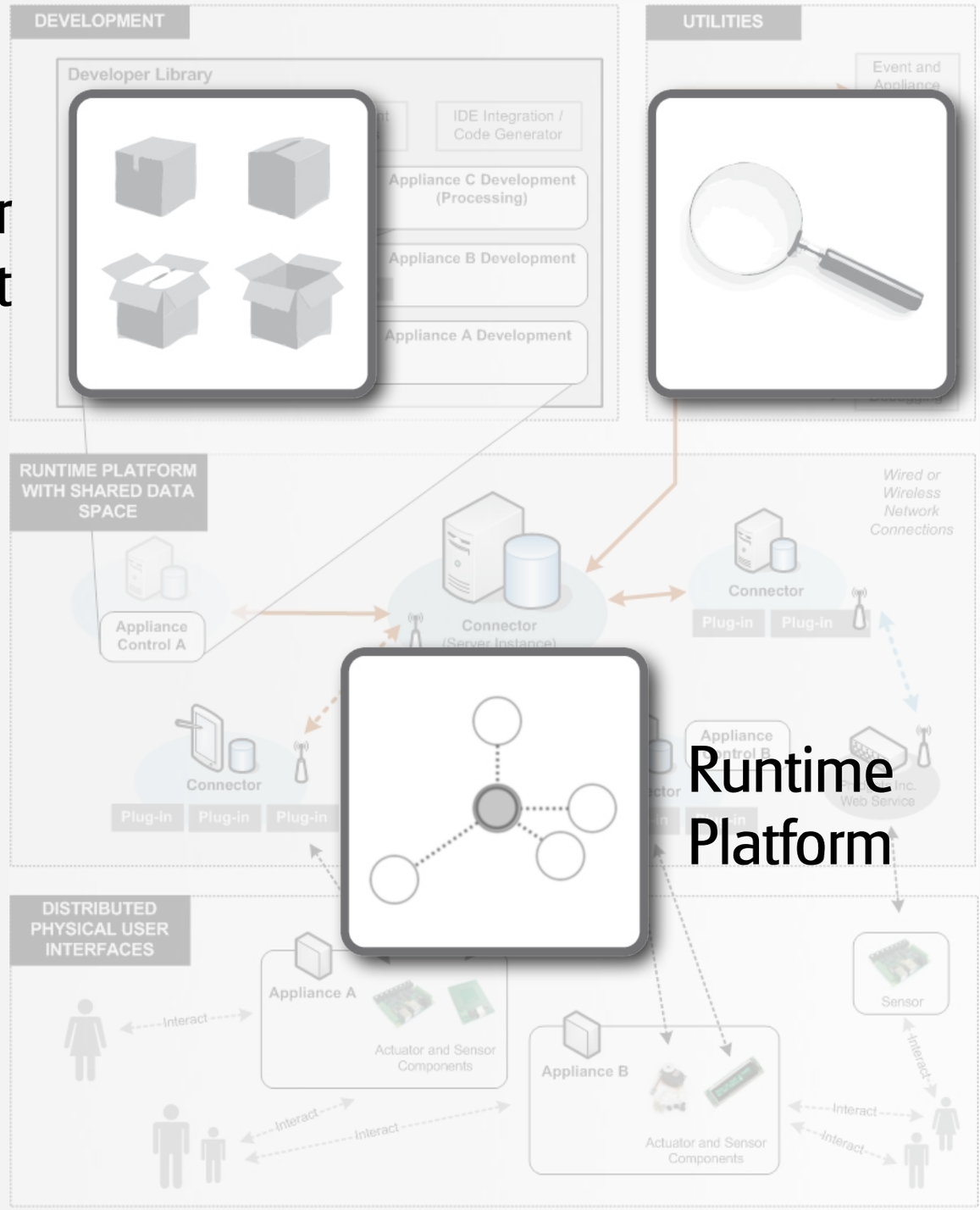
Utilities

Architecture Overview



Architecture Overview

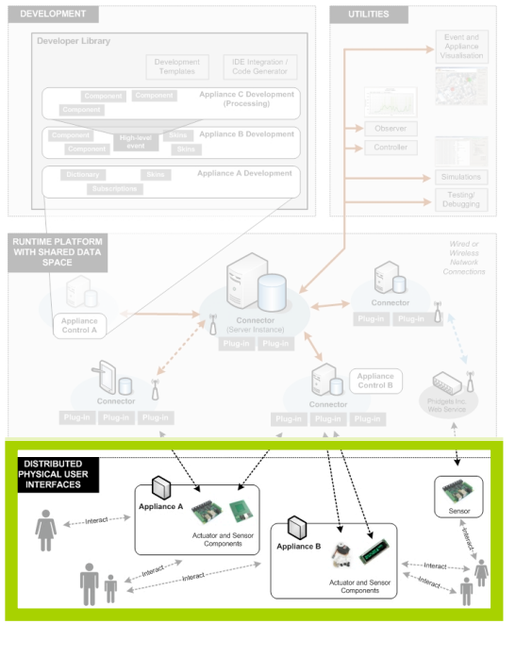
Developer Support

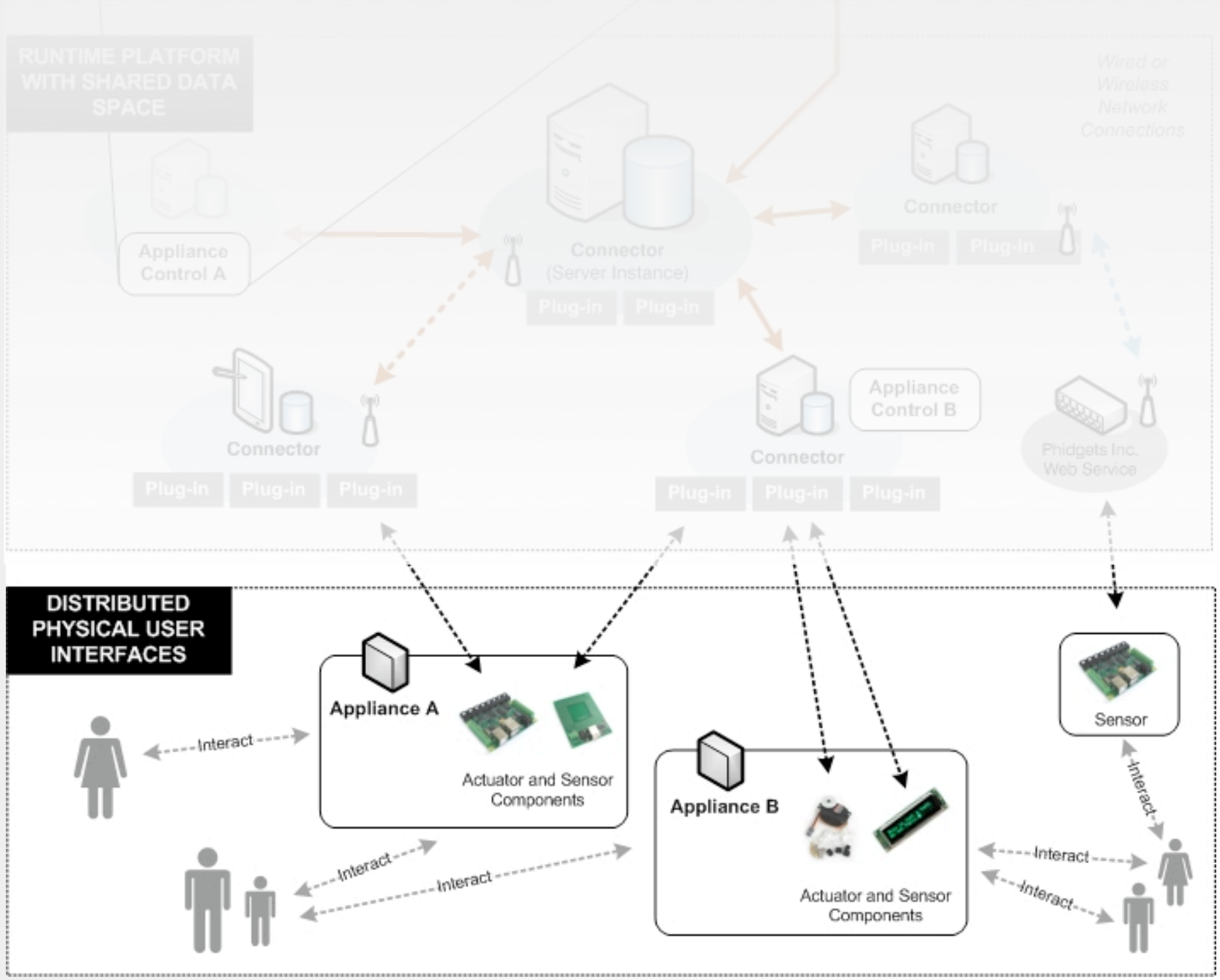


Utilities

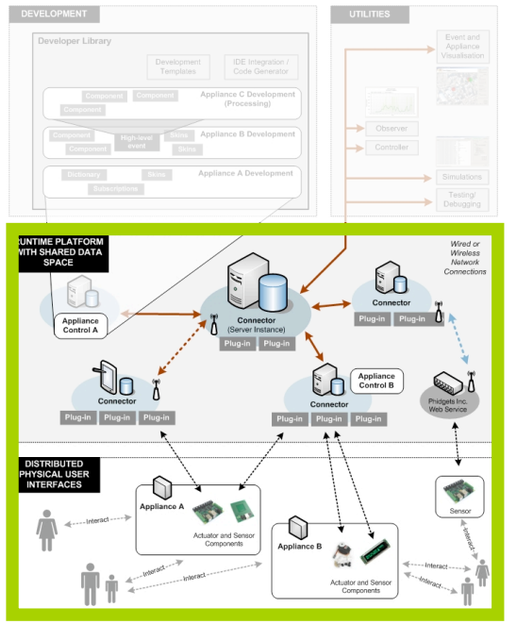
Runtime Platform

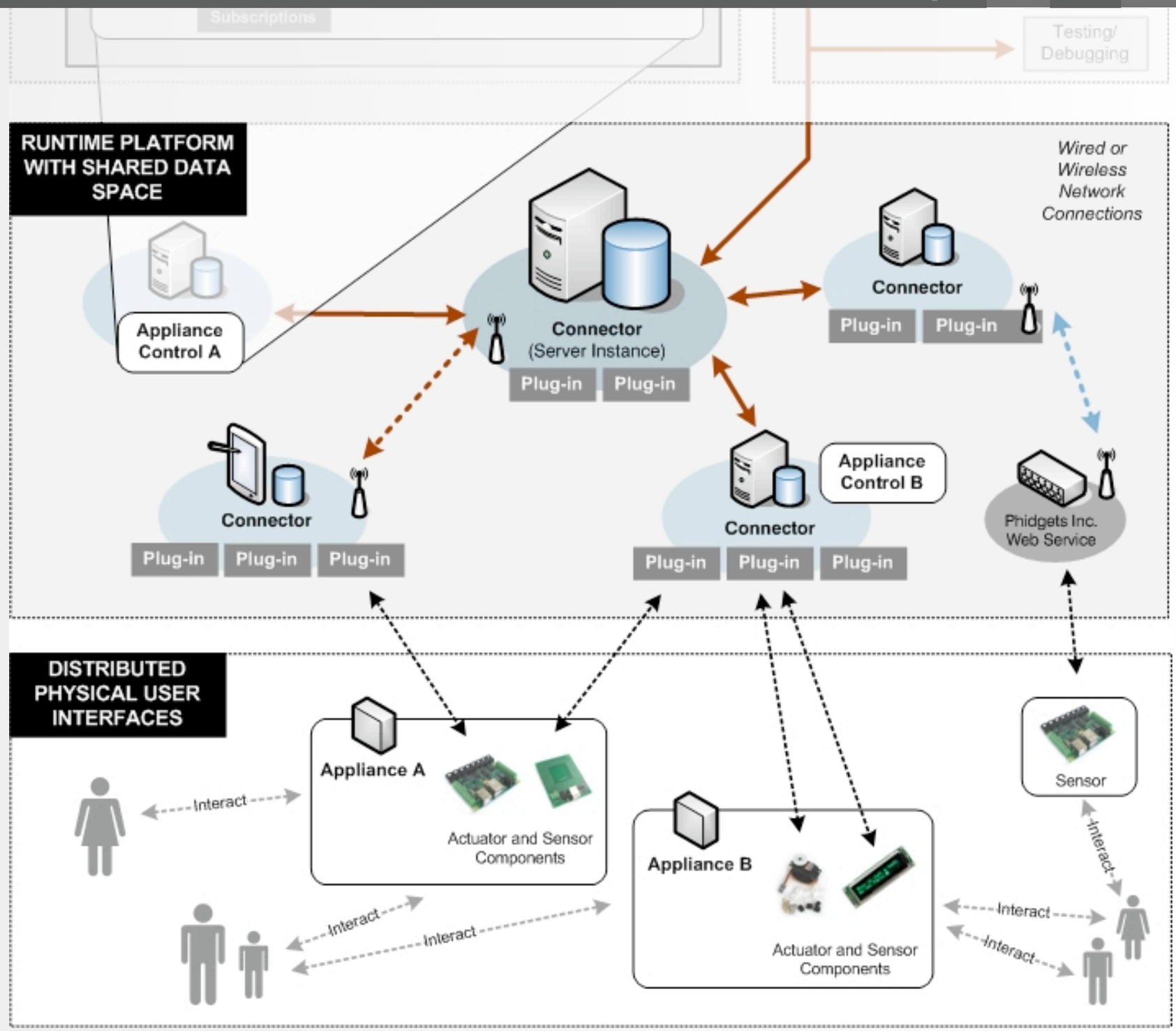
Architecture





Architecture





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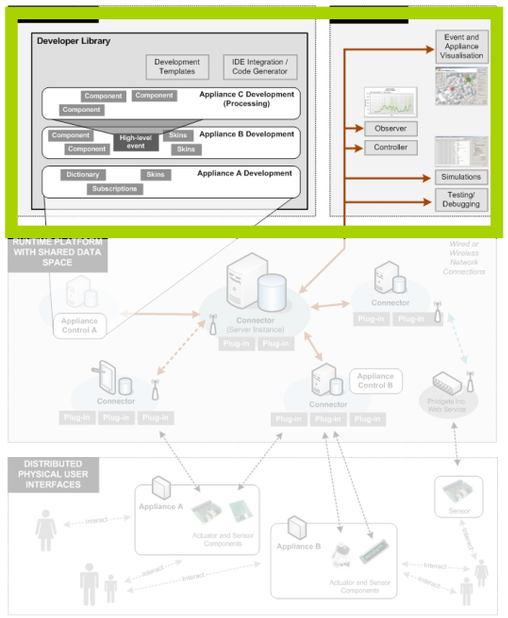

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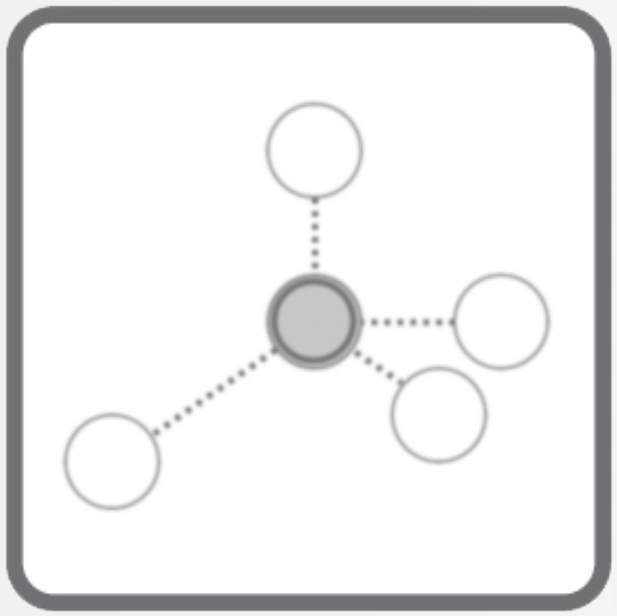
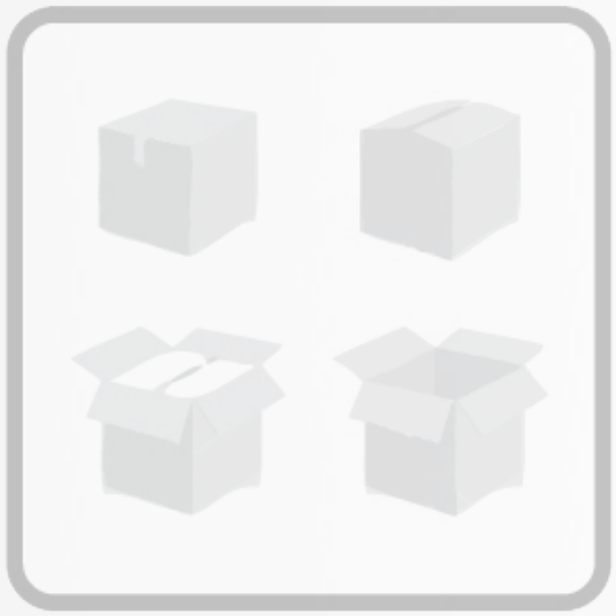




Runtime Platform Developer Support Utilities

Physical Components

[Greenberg and Fitchett, 2001]
[Phidgets Inc., 2008]

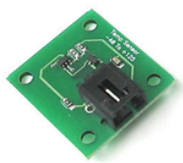
INPUT

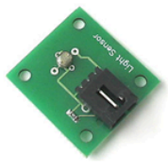
SENSORS


Pressure


Force


Vibration


Temperature


Light


Distance


Motion

USER CONTROLS

Switches

RFID Reader and Tags

Accelerometer

Slider Control

OUTPUT

ACTUATORS

Motors

Servos

DISPLAYS

Colour Graphic
LC Display

Text
LC Display

Physical Components

[Greenberg and Fitchett, 2001]
[Phidgets Inc., 2008]

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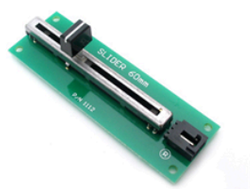
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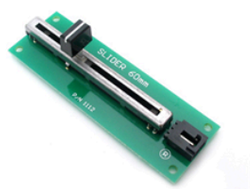
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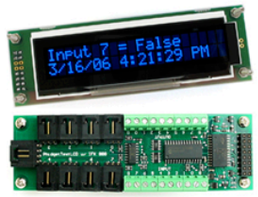
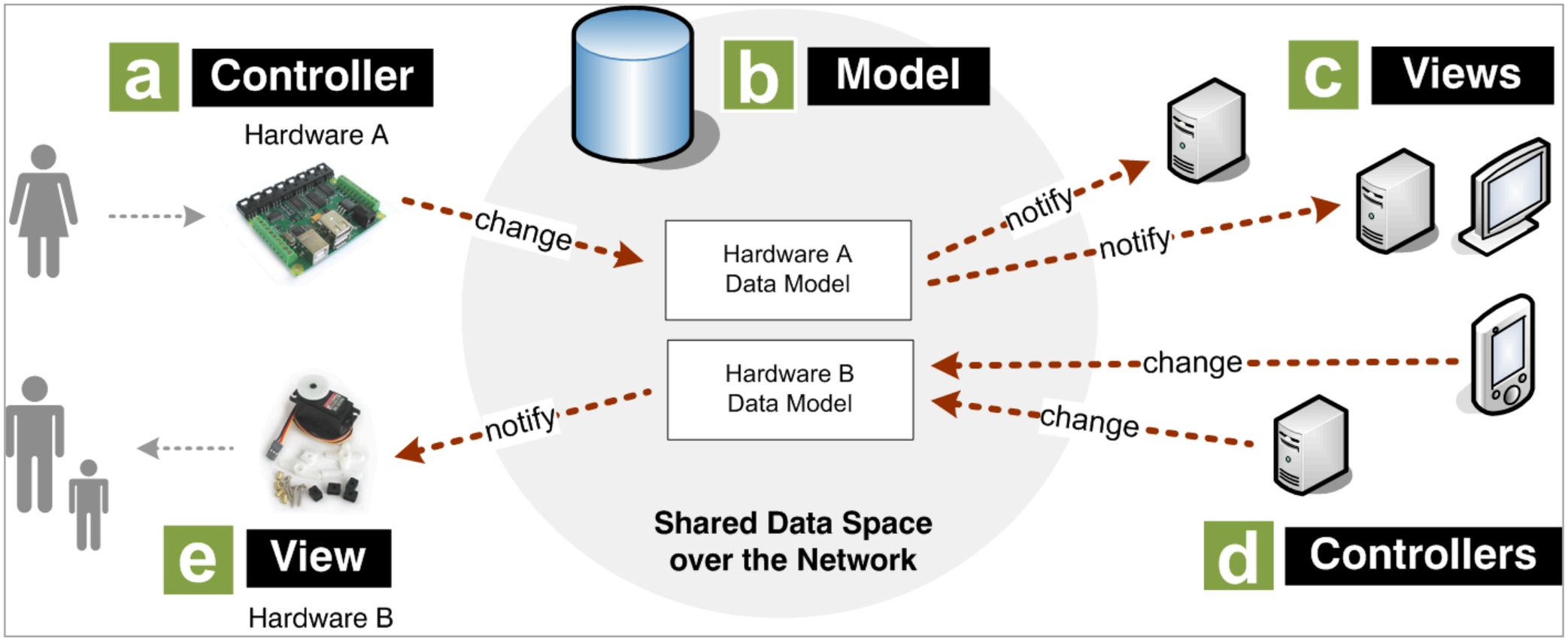


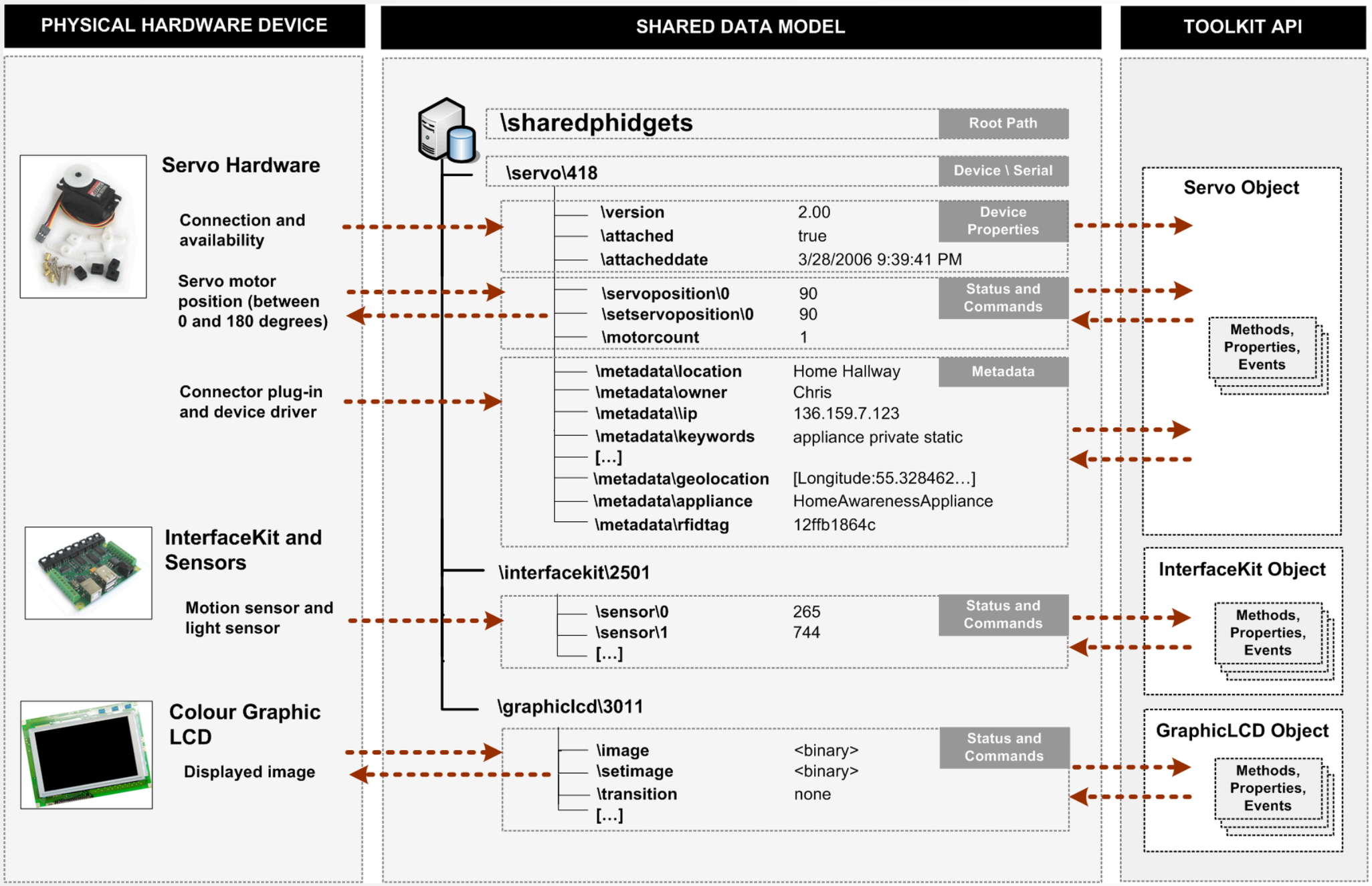
Text
LC Display

Data Model

[Boyle and Greenberg, 2005]



Hardware Data Model



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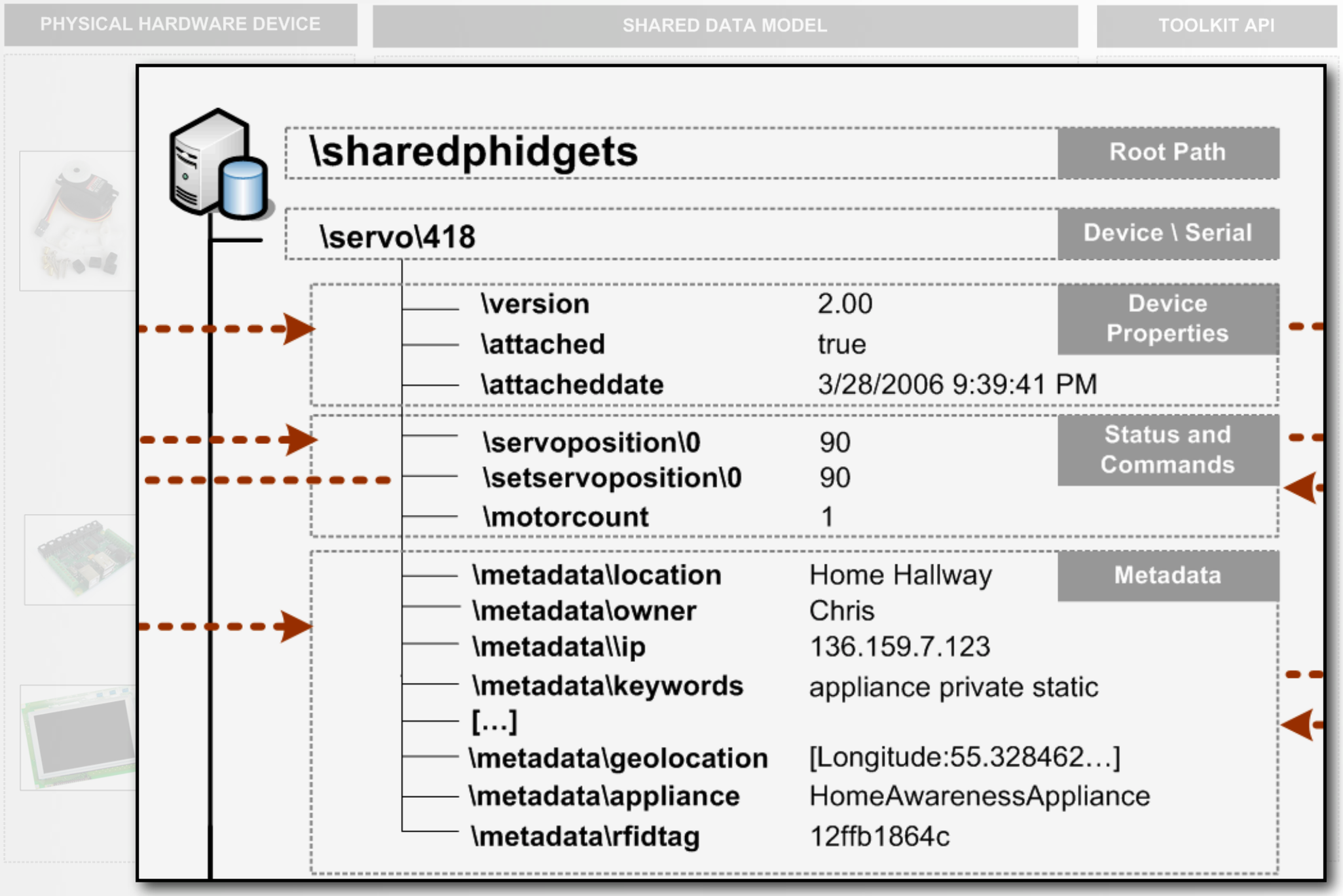

Hardware and Appliance Data Model

- Path expressions to access the hardware data model directly:

```
/sharedphidgets/servo/?/setservoposition/?/
/sharedphidgets/*/sensor/0/
/sharedphidgets/*/metadata/geolocation/
```

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```
/sharedphidgets/servo/?/setservoposition/?/
/sharedphidgets/*/sensor/0/
/sharedphidgets/*/metadata/geolocation/
```

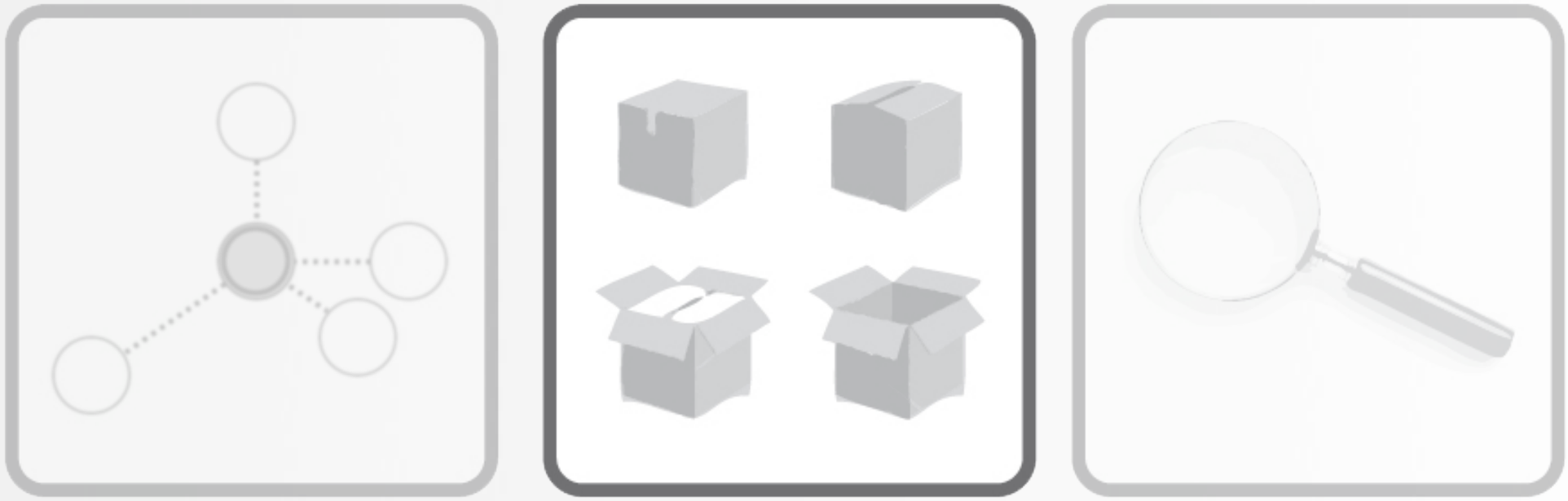
- Appliance data model:

```
/appliance/<guid>/appliancename                    = Sticky Spots
/appliance/<guid>/timestamp                        = 20/10/2007 04:56:45
/appliance/<guid>/ip                               = 192.168.178.20

/appliance/<guid>/components/<cid>/type            = rfid
/appliance/<guid>/components/<cid>/serial          = 2967
/appliance/<guid>/components/<cid>/externalserial  = 2967
/appliance/<guid>/components/<cid>/path            = /sharedphidgets/rfid/2967/
/appliance/<guid>/components/<cid>/timestamp       = 20/10/2007 05:22:07

/appliance/<guid>/processing/<subpath1>            = 42
/appliance/<guid>/processing/<subpath2>            = True
```

Developer Support

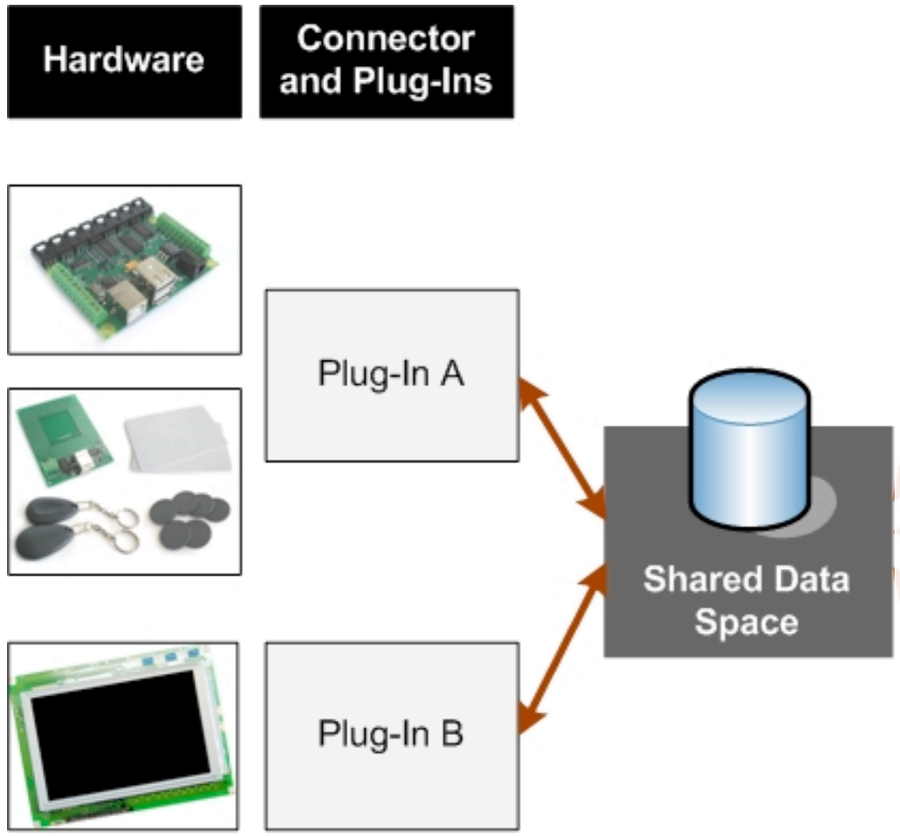


Runtime Platform

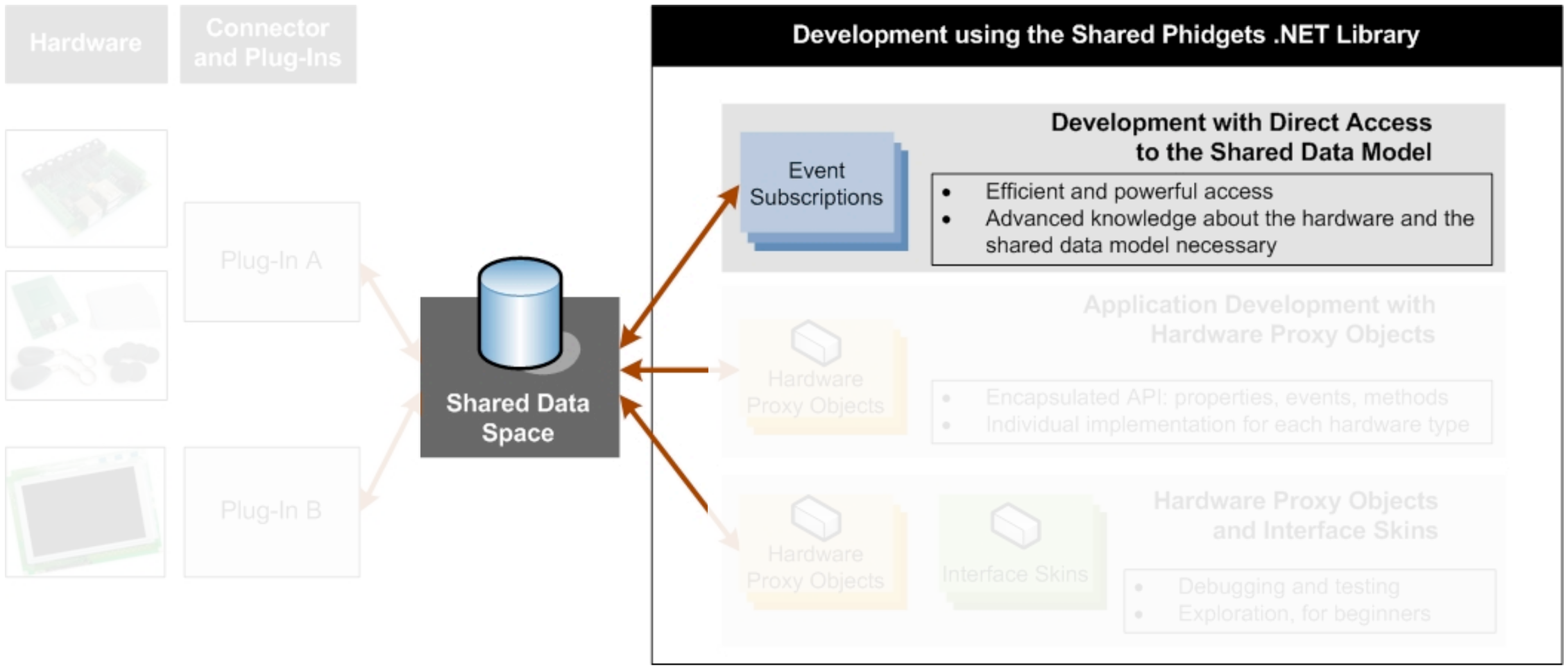
Developer Support

Utilities

Development Support



Development Support



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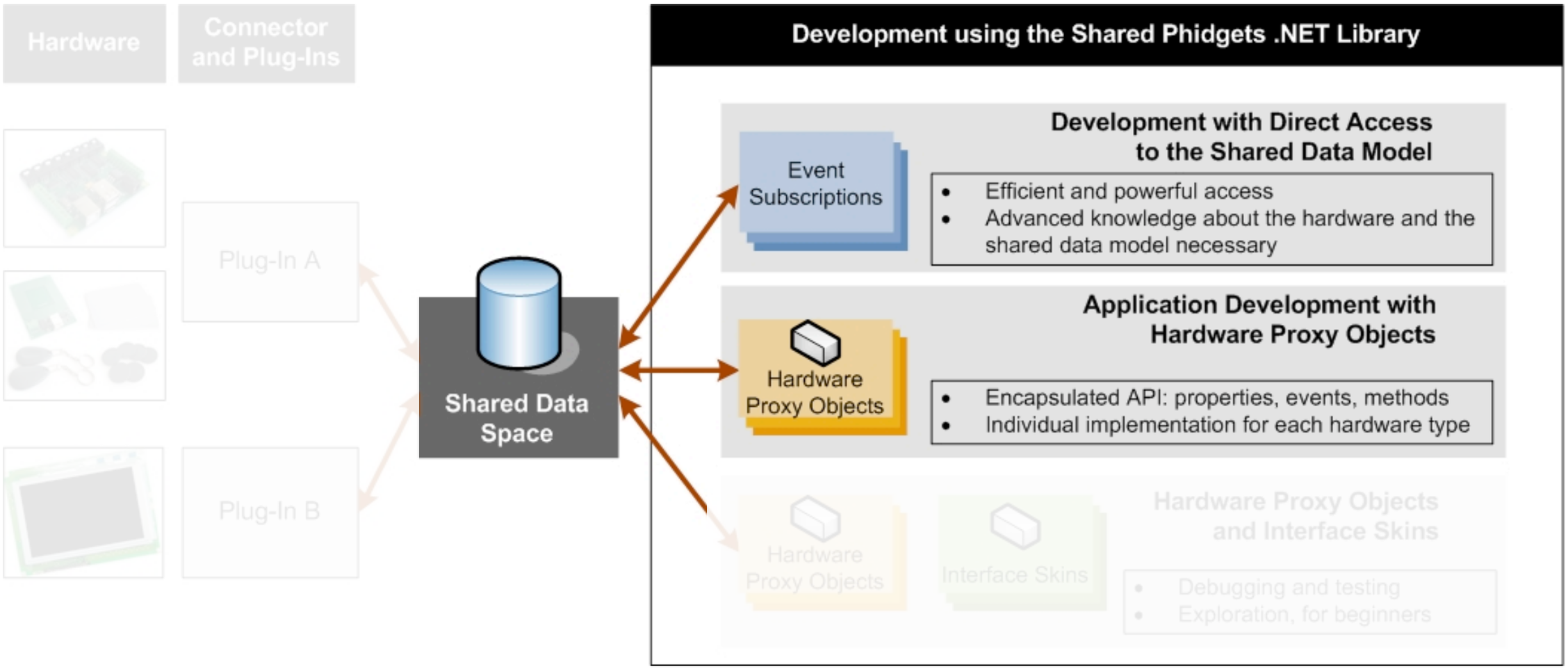

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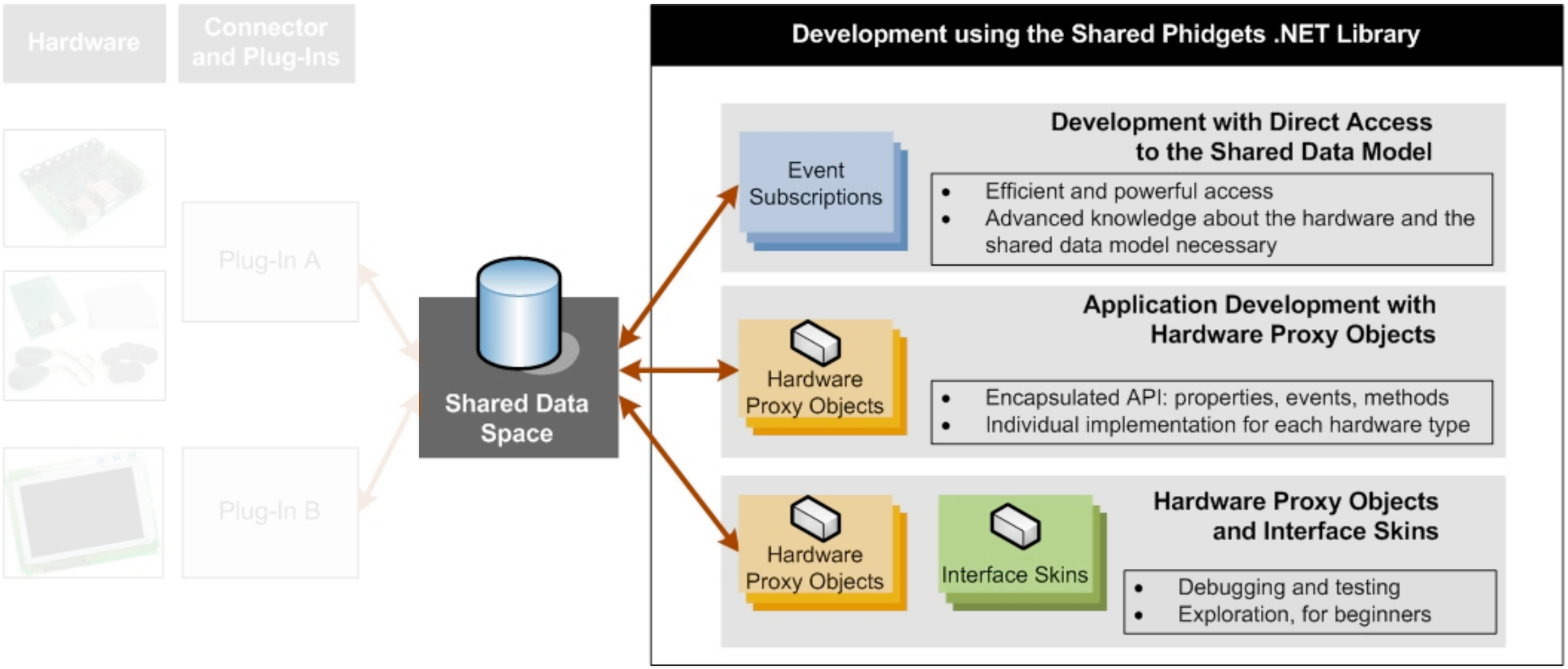
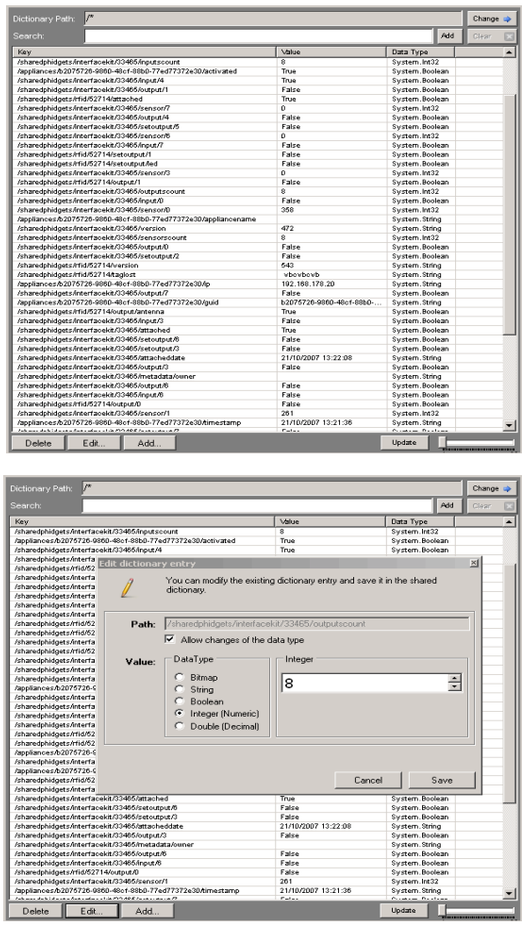


Interface Skins

Concept ❷



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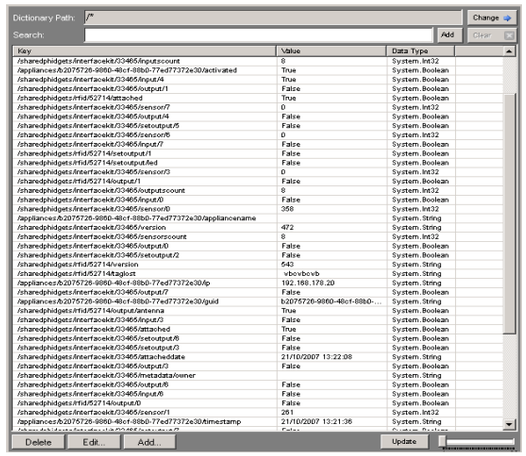

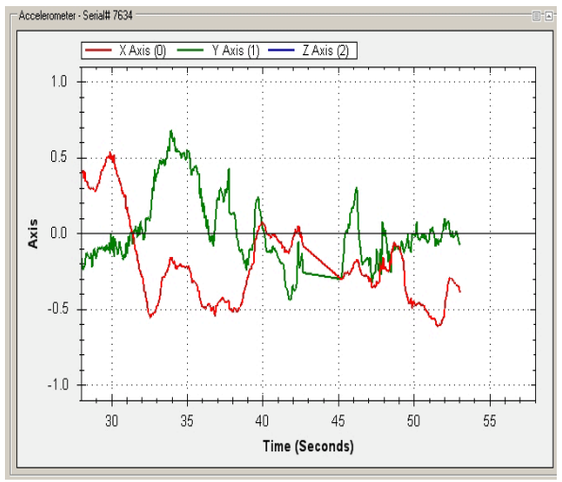

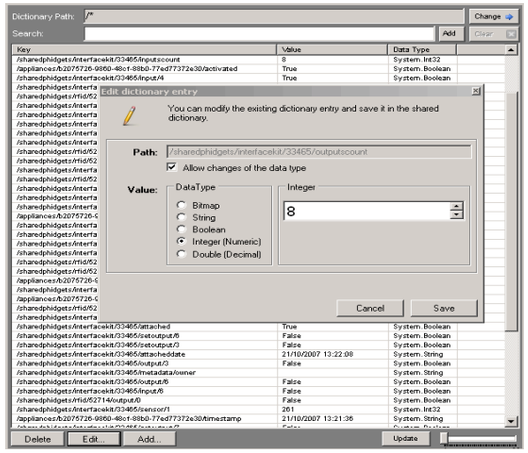

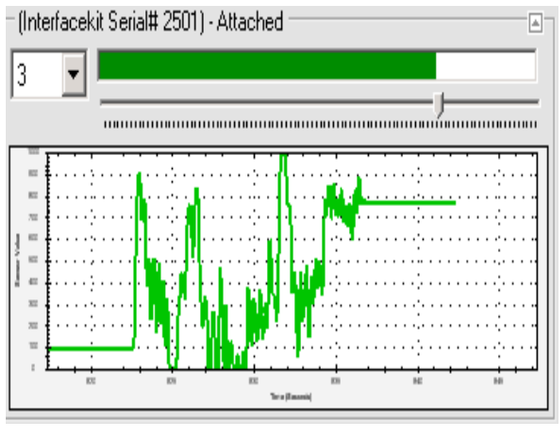

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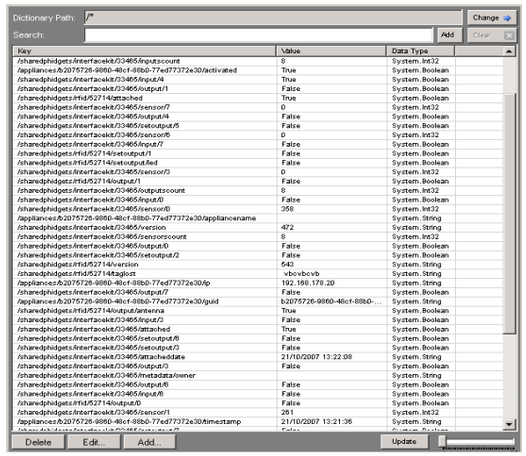
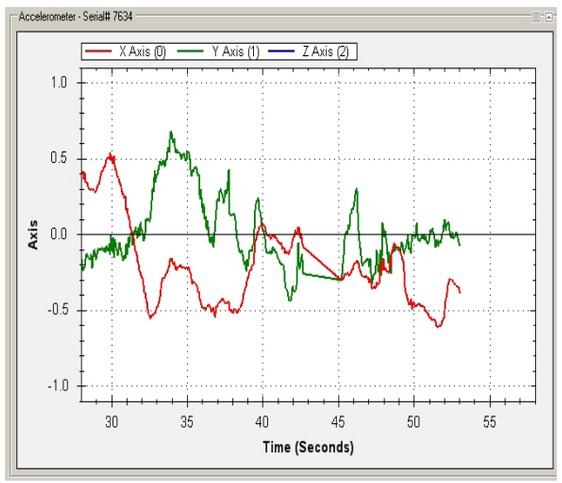
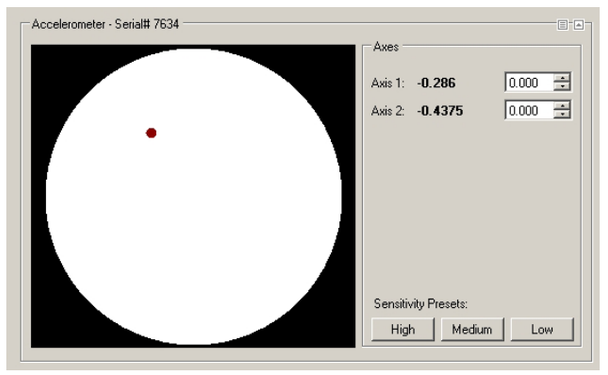
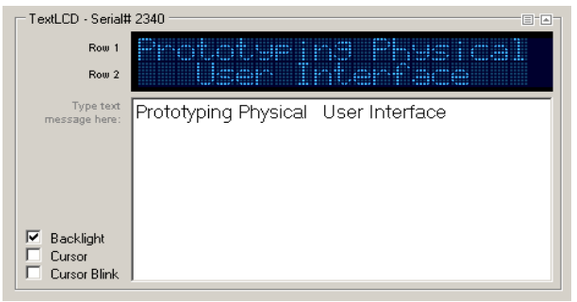
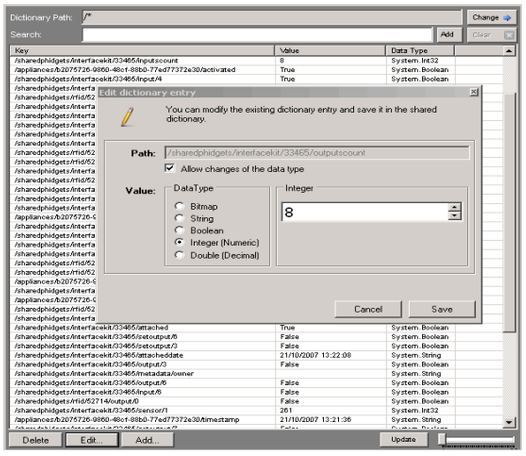
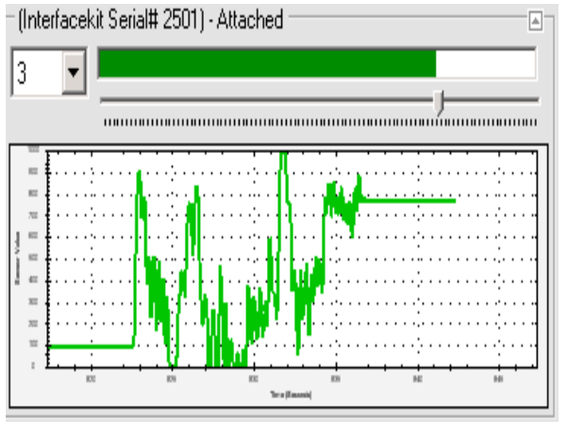


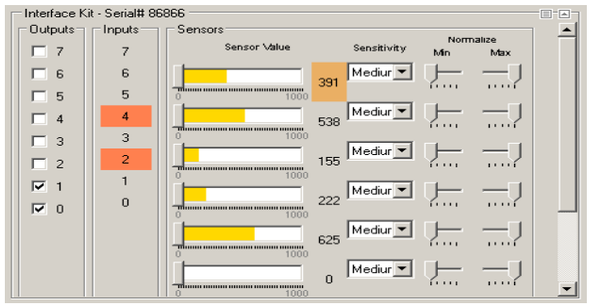


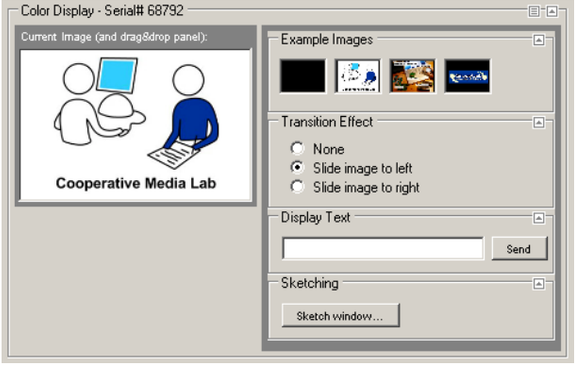


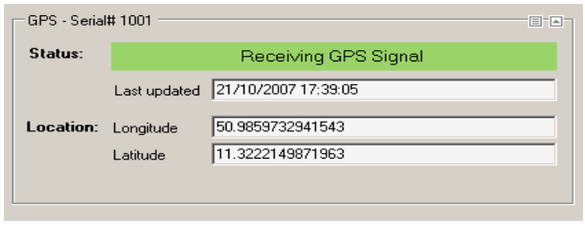


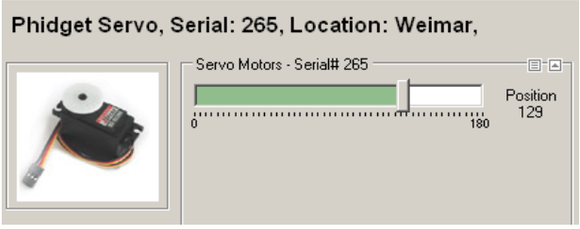




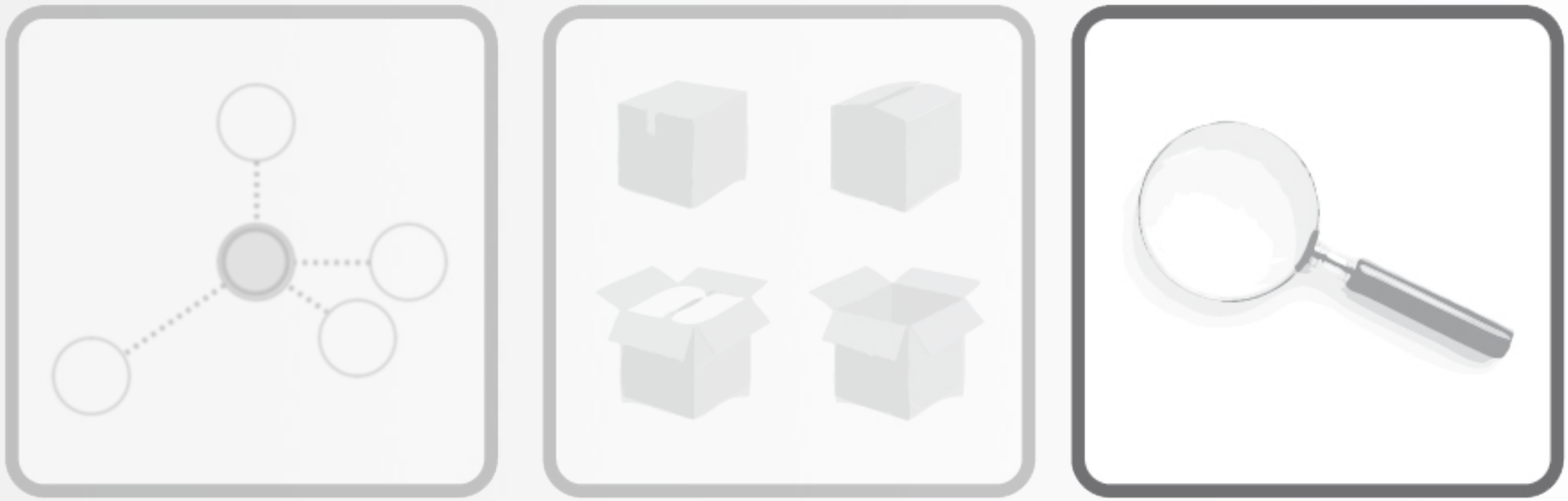








Utilities

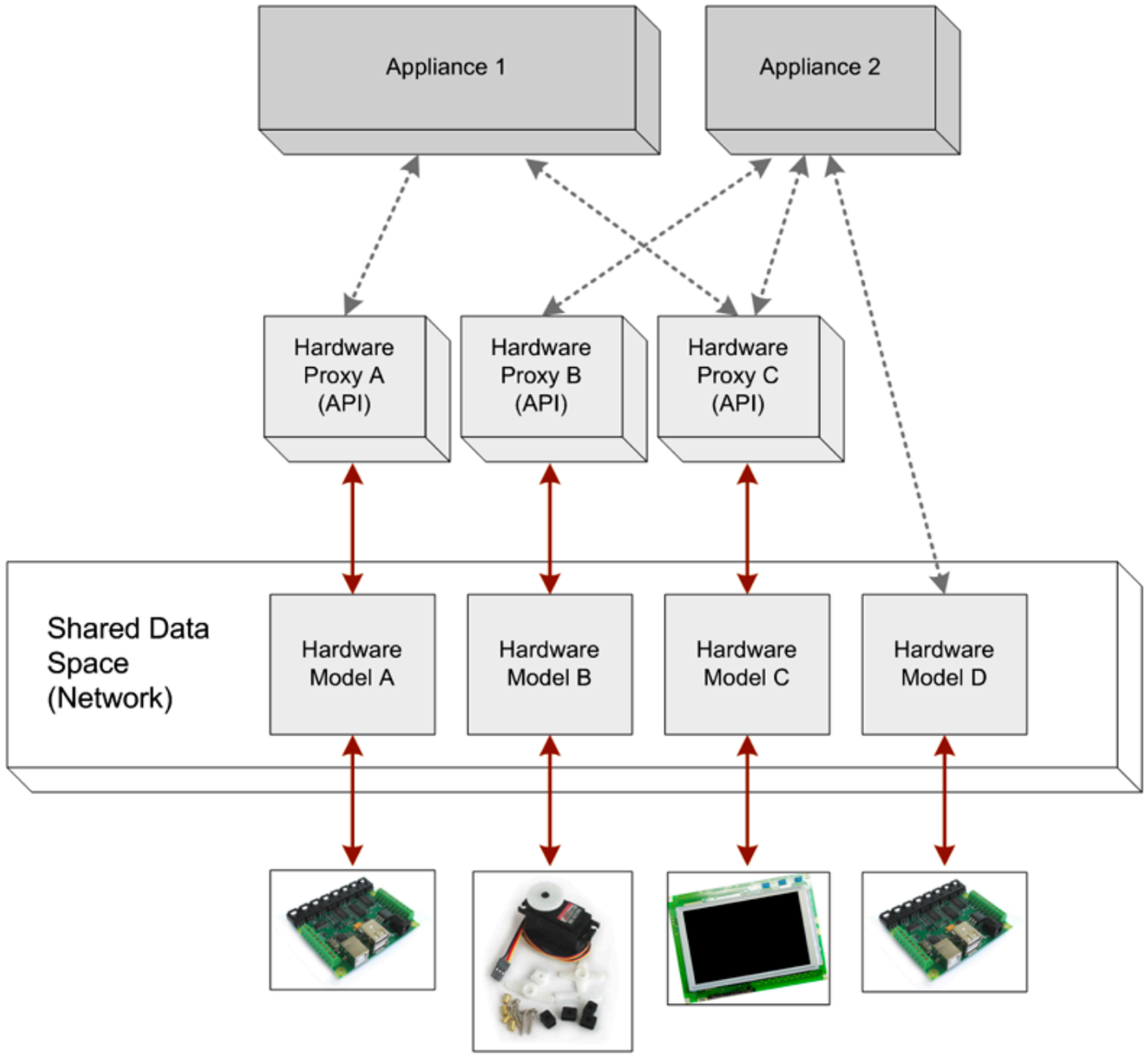


Runtime Platform

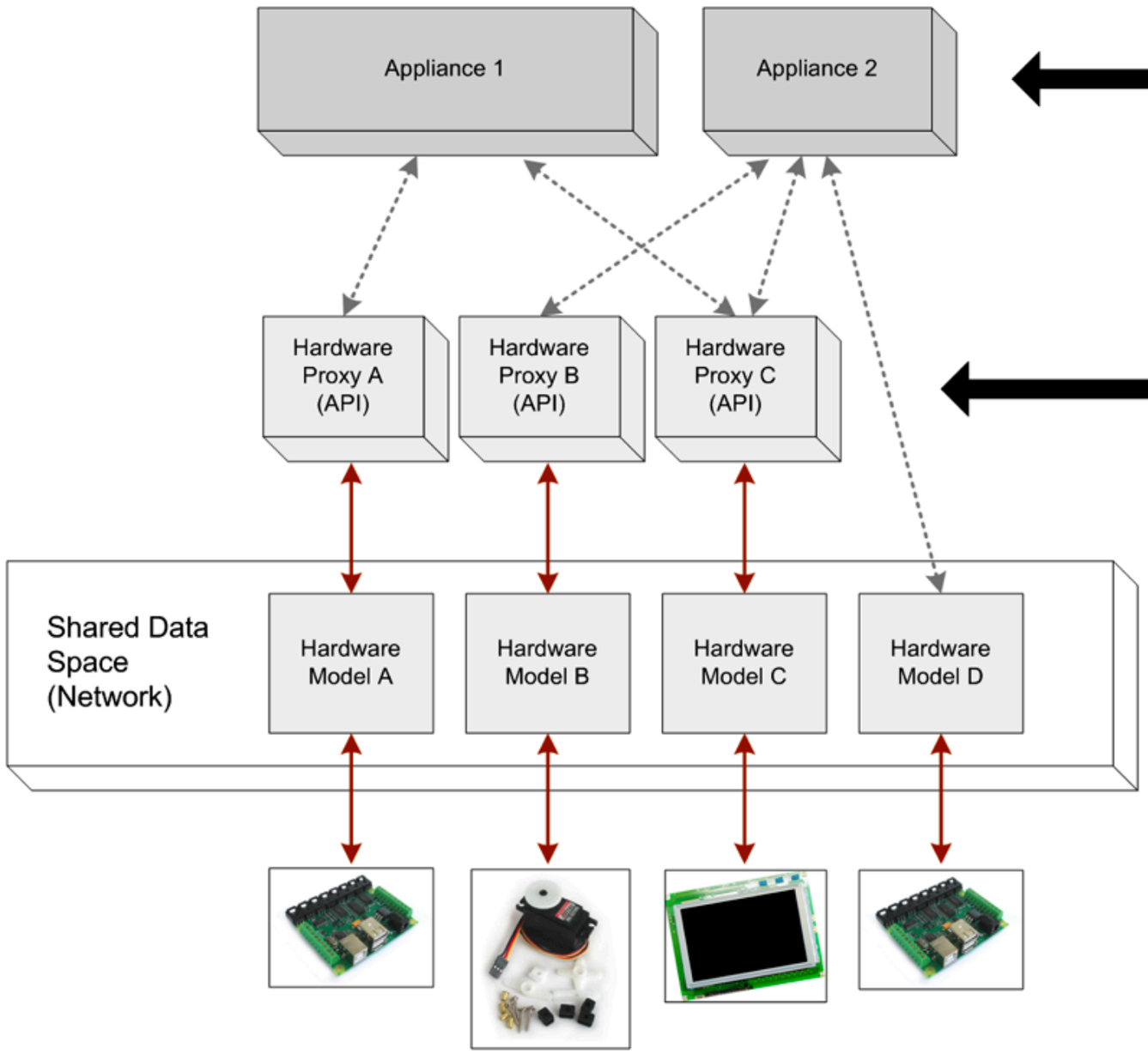
Developer Support

Utilities

Utilities


Appliance 1
Appliance 2
Hardware Proxy A (API)
Hardware Proxy B (API)
Hardware Proxy C (API)
Shared Data Space (Network)
Hardware Model A
Hardware Model B
Hardware Model C
Hardware Model D

Utilities



Appliance Level

- Observe appliances
- Reconfigure (change hardware connections)
- View processing events

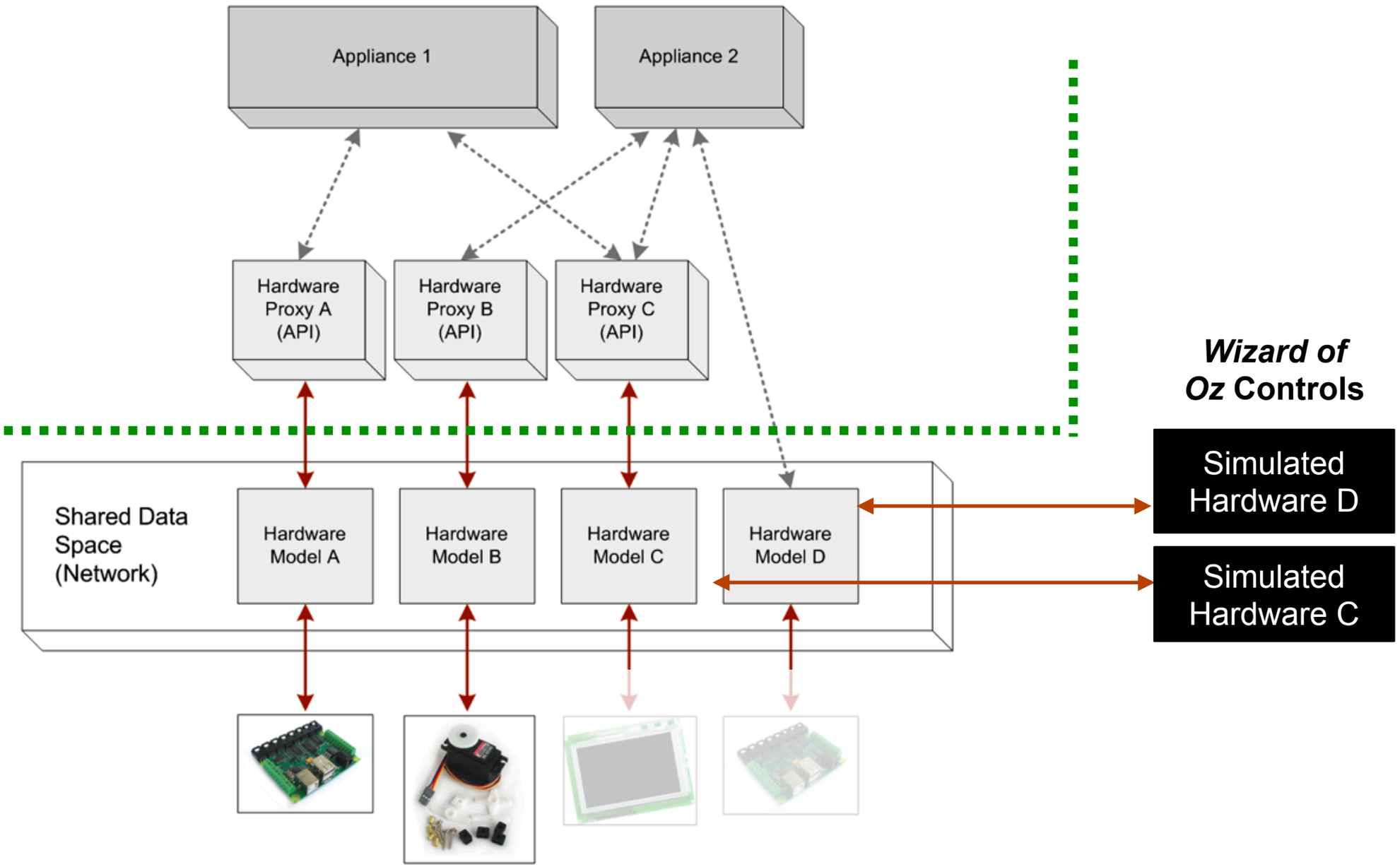
Hardware Level

- View current hardware status
- Initialise hardware
- Explore hardware capabilities

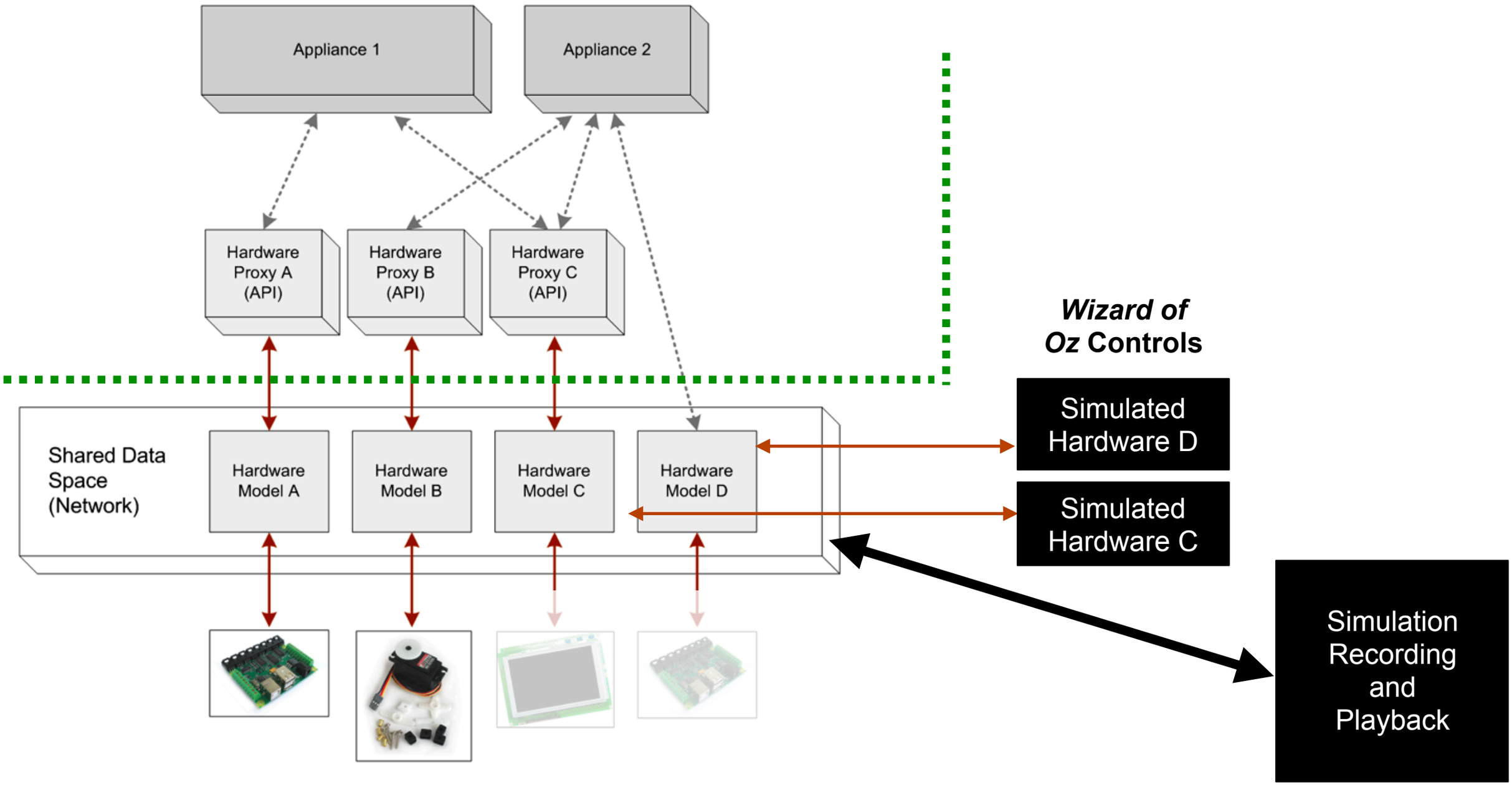
Network Level

- Review hardware data model and events
- View and change metadata

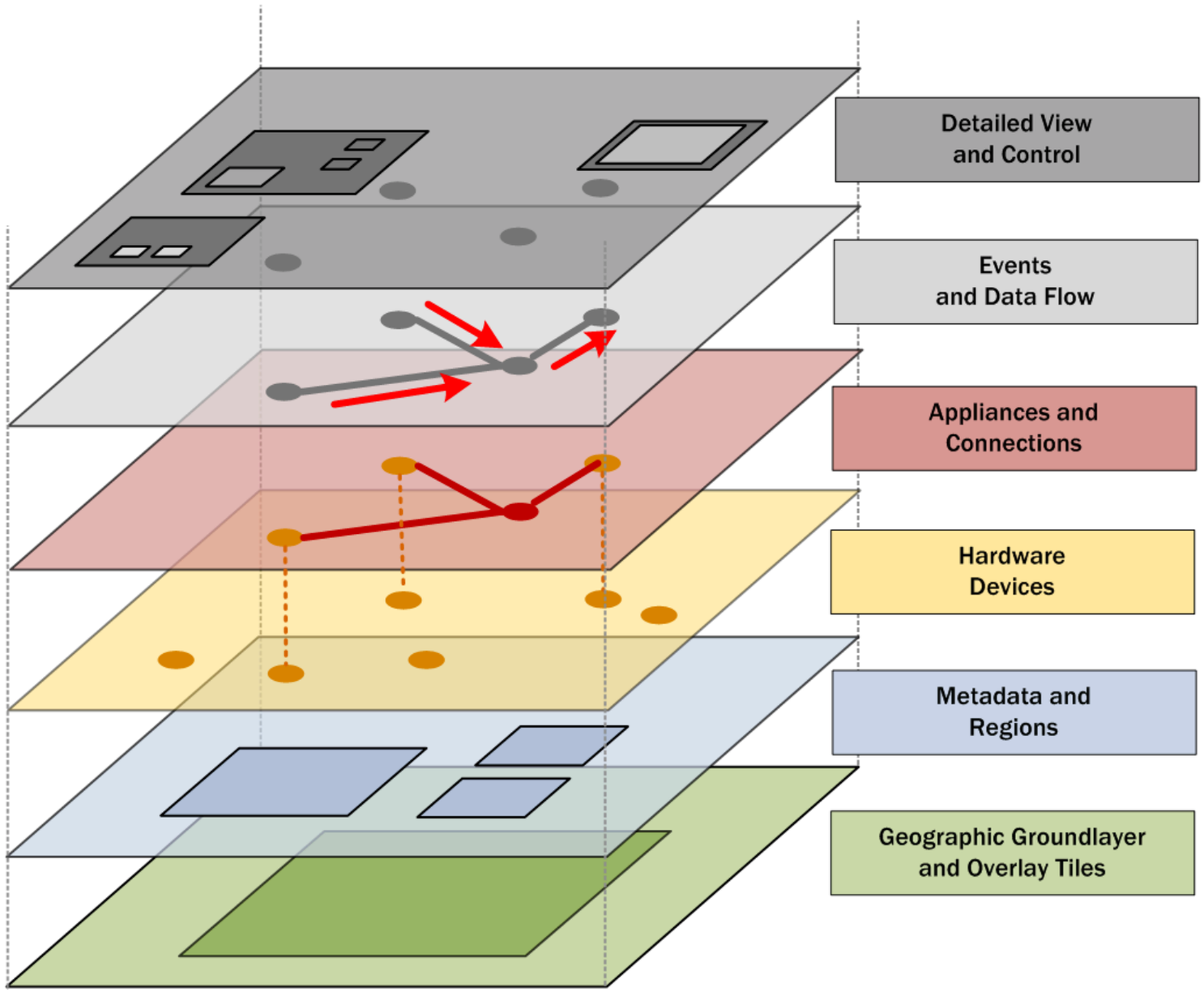
Simulations



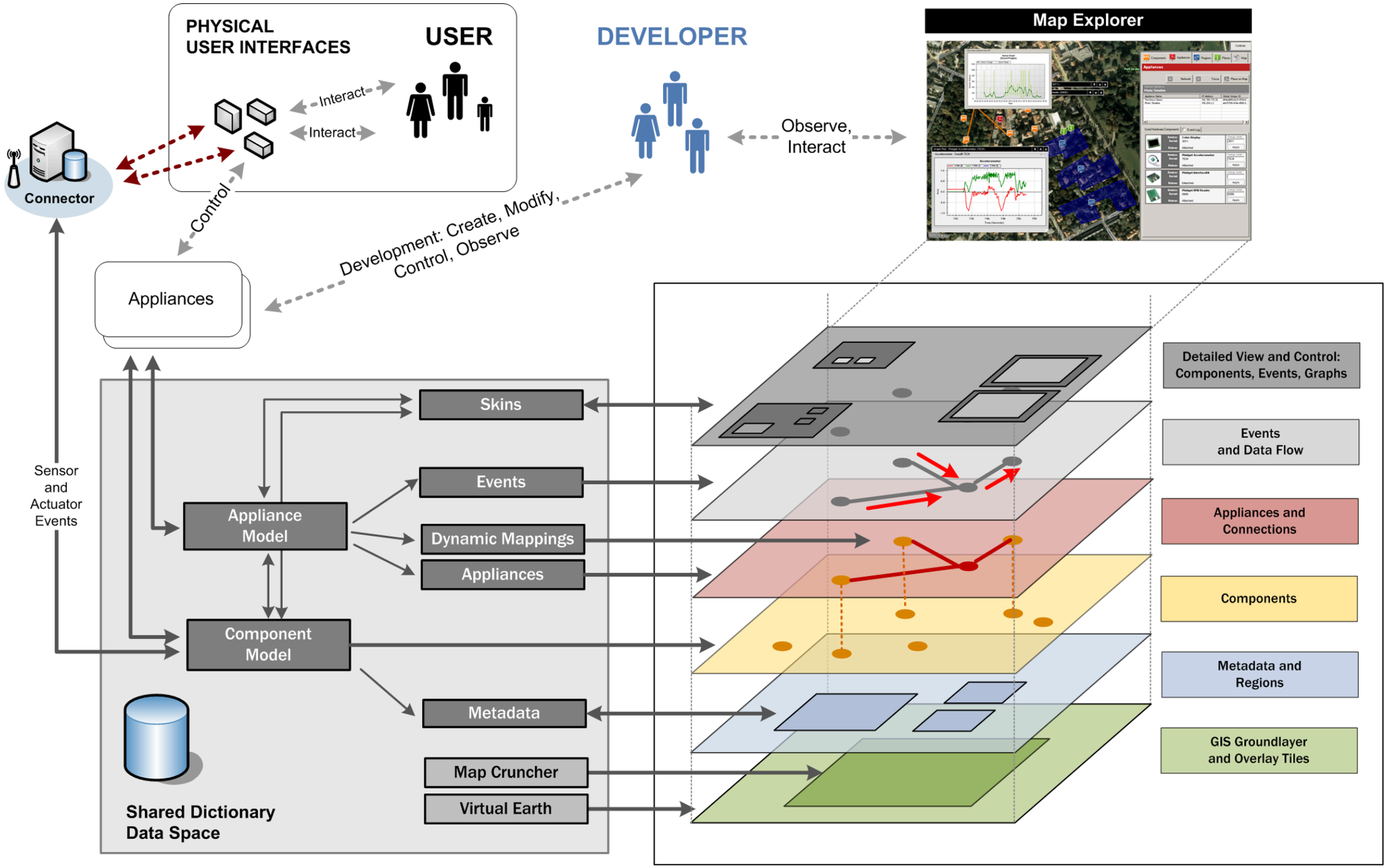
Simulations



Utilities: Visualisation

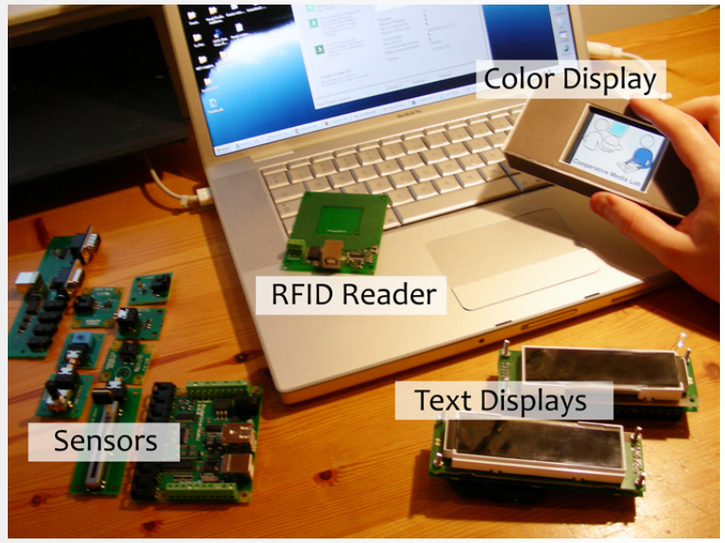


Utilities: Visualisation

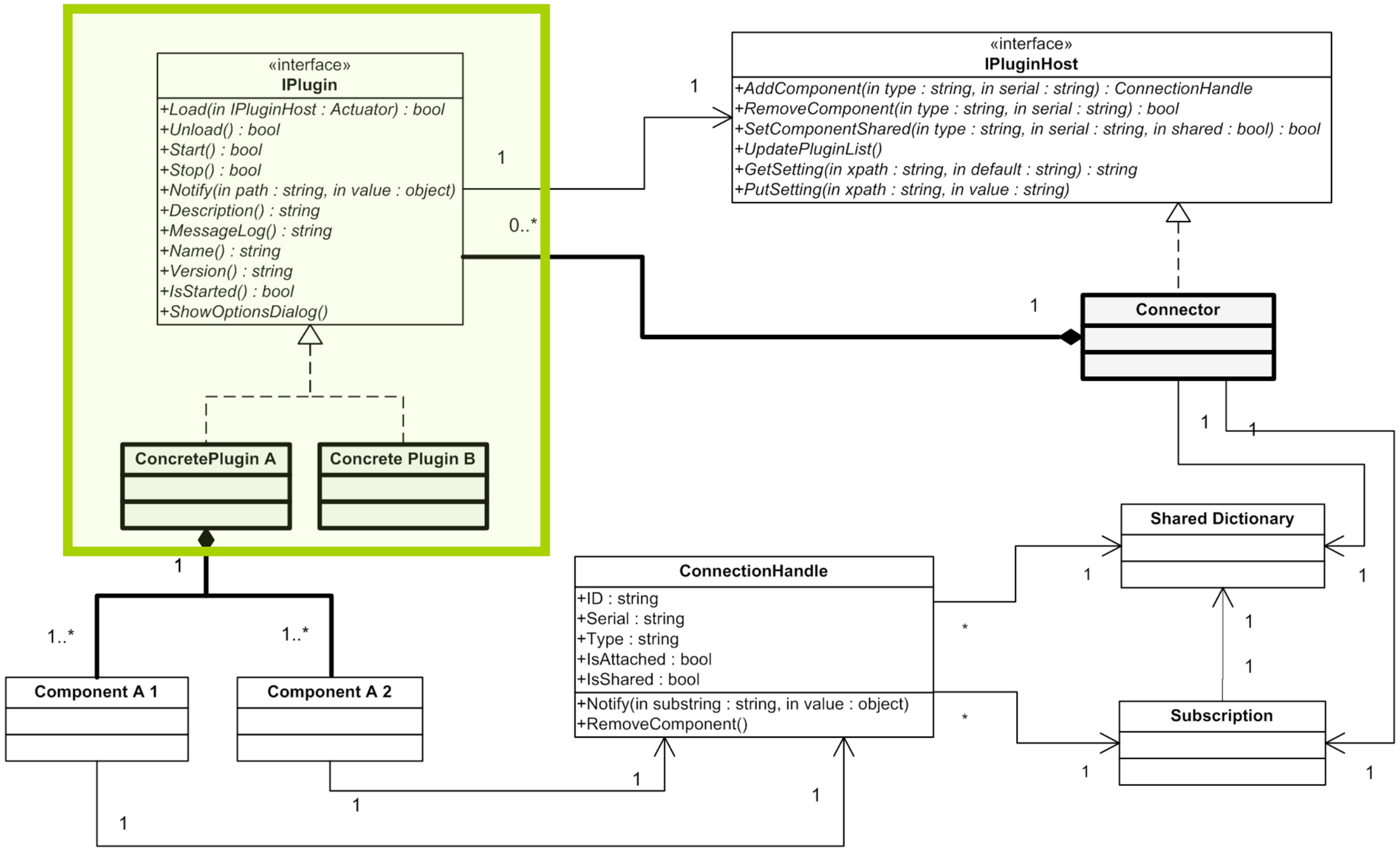


Implementation Overview

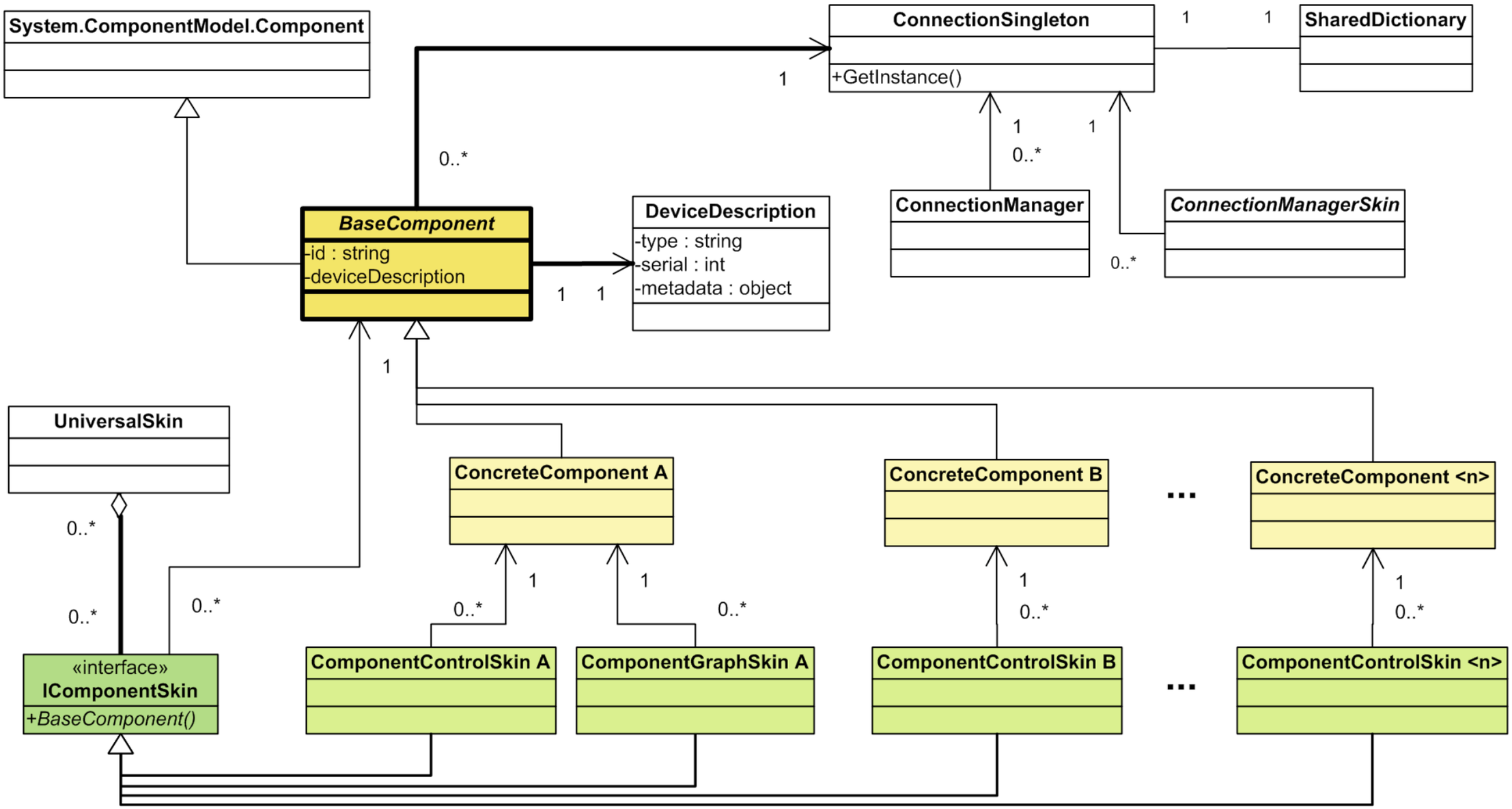
- Microsoft Windows platform (2000, XP, Vista, Server 2003, Server 2008)
- .NET framework 2.0
- Language: C# (supported are furthermore J#, Visual Basic, and C++)
- Integration into VisualStudio IDE



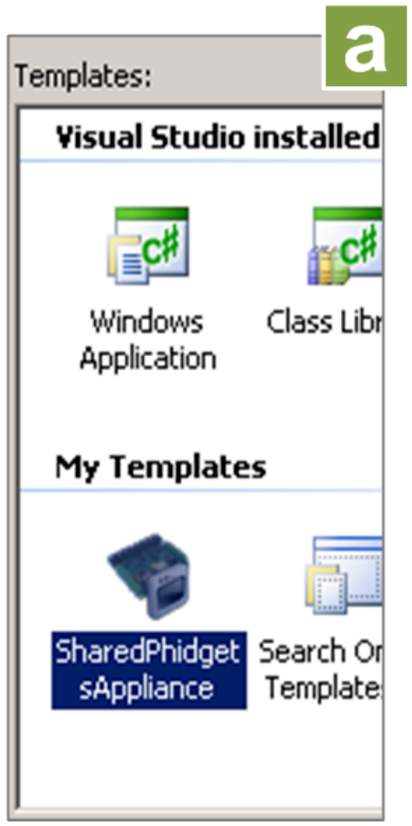
Plug-in Architecture



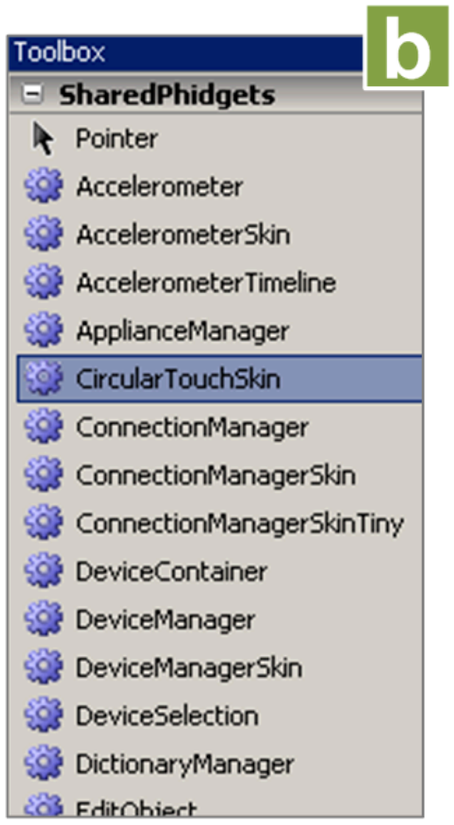
Developer Library



IDE Integration

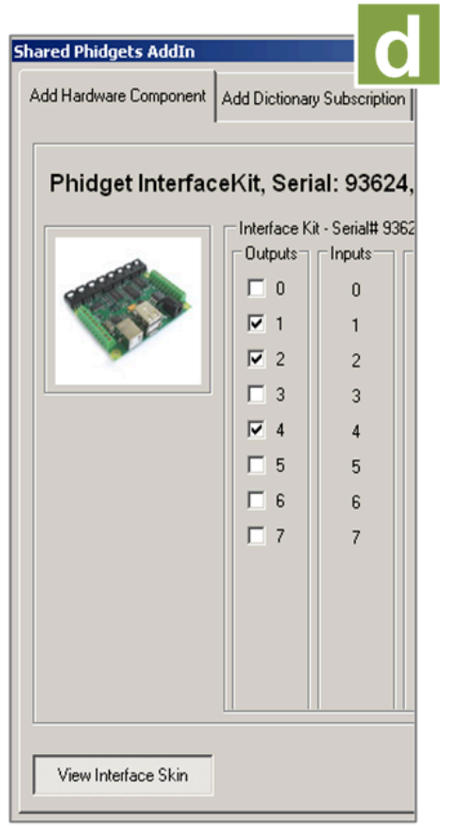


Appliance project template

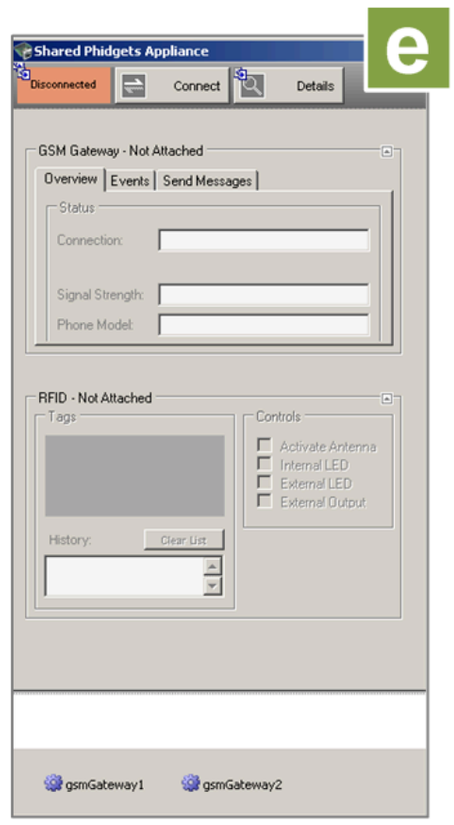


Visual designer integration

Tutorials and examples



IDE infrastructure exploration



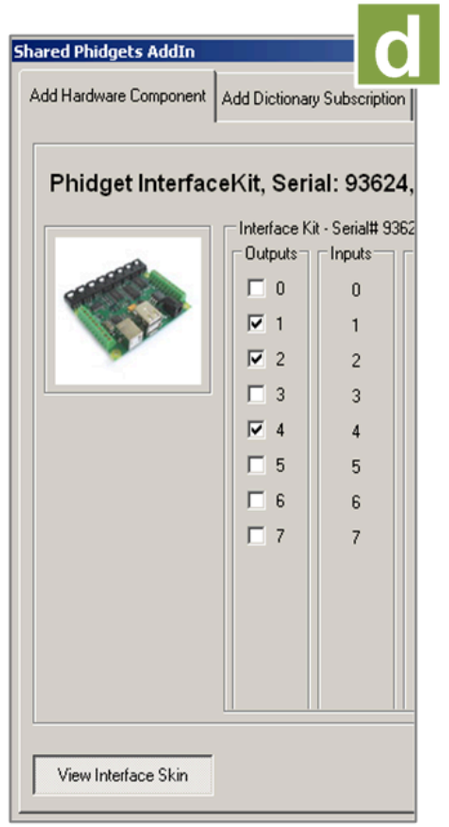
IDE code framework generator

IDE Integration

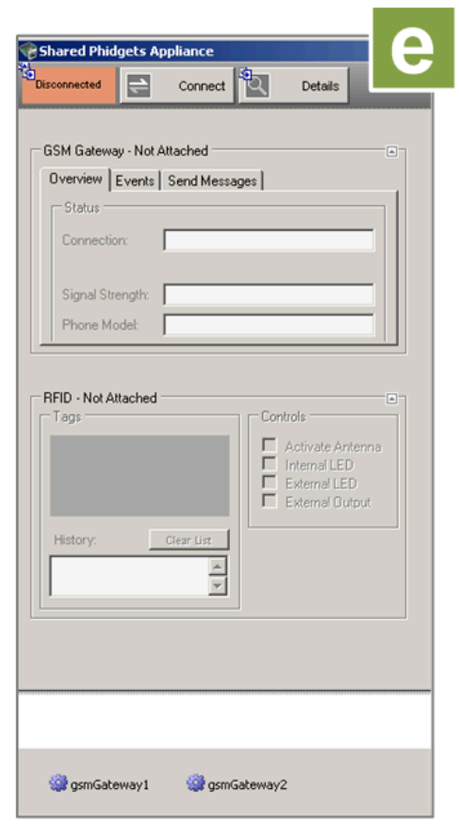
Appliance project template

Visual designer integration

Tutorials and examples

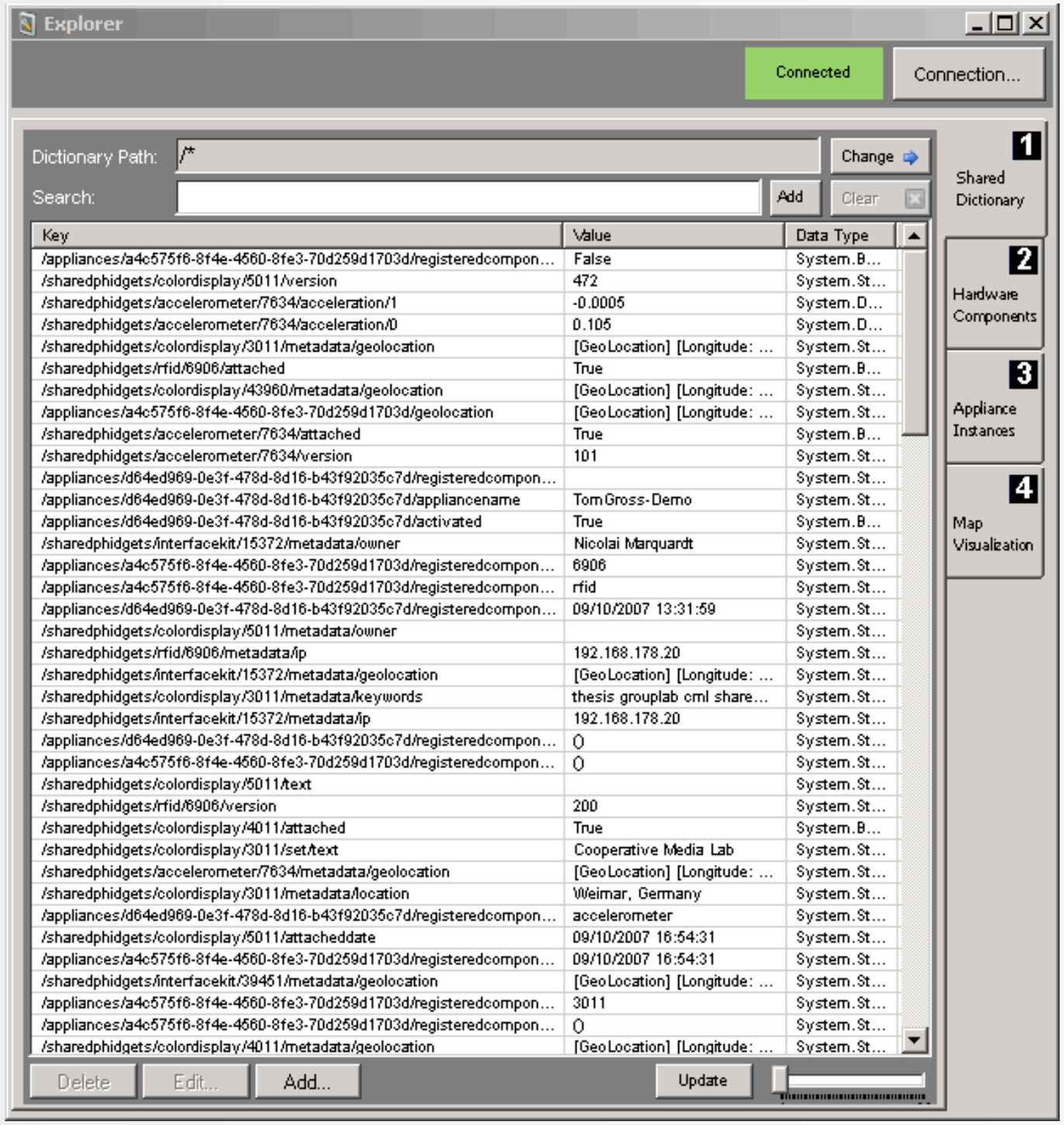


IDE infrastructure exploration



IDE code framework generator

Utilities


Explorer
Connected
Connection...
Dictionary Path:
/*
Change
Search:
Add
Clear
1
Shared Dictionary
2
Hardware Components
3
Appliance Instances
4
Map Visualization
Key
Value
Data Type
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/sharedphidgets/colordisplay/5011/version 472 System.St...
/sharedphidgets/accelerometer/7634/acceleration/1 -0.0005 System.D...
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/sharedphidgets/interfacekit/15372/metadata/ip 192.168.178.20 System.St...
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/sharedphidgets/rfid/6906/version 200 System.St...
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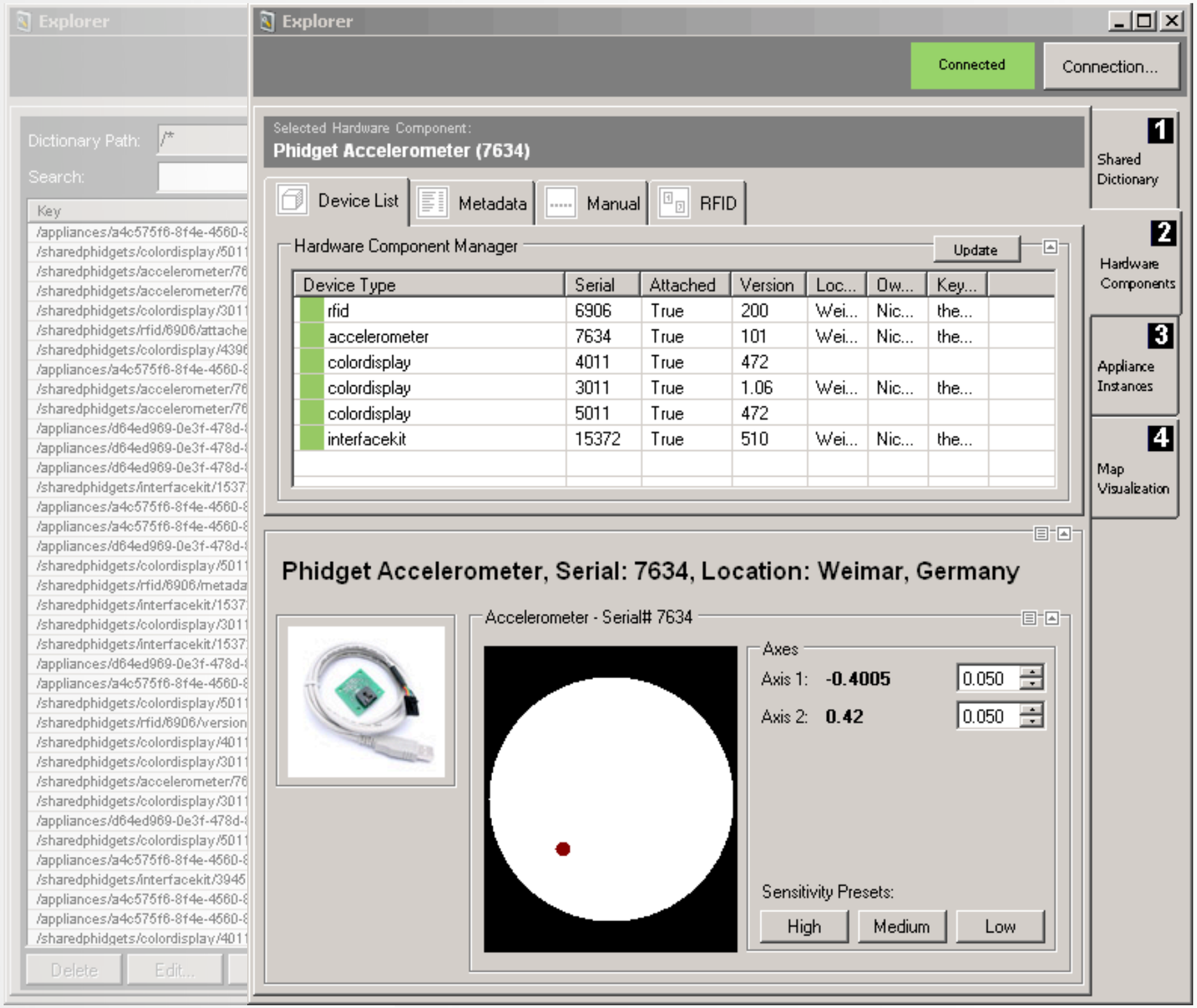
Delete
Edit...
Add...
Update

Utilities


Explorer
Explorer
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Dictionary Path: /*
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Key
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/sharedphidgets/accelerometer/76
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/sharedphidgets/rfid/6906/attache
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/sharedphidgets/accelerometer/76
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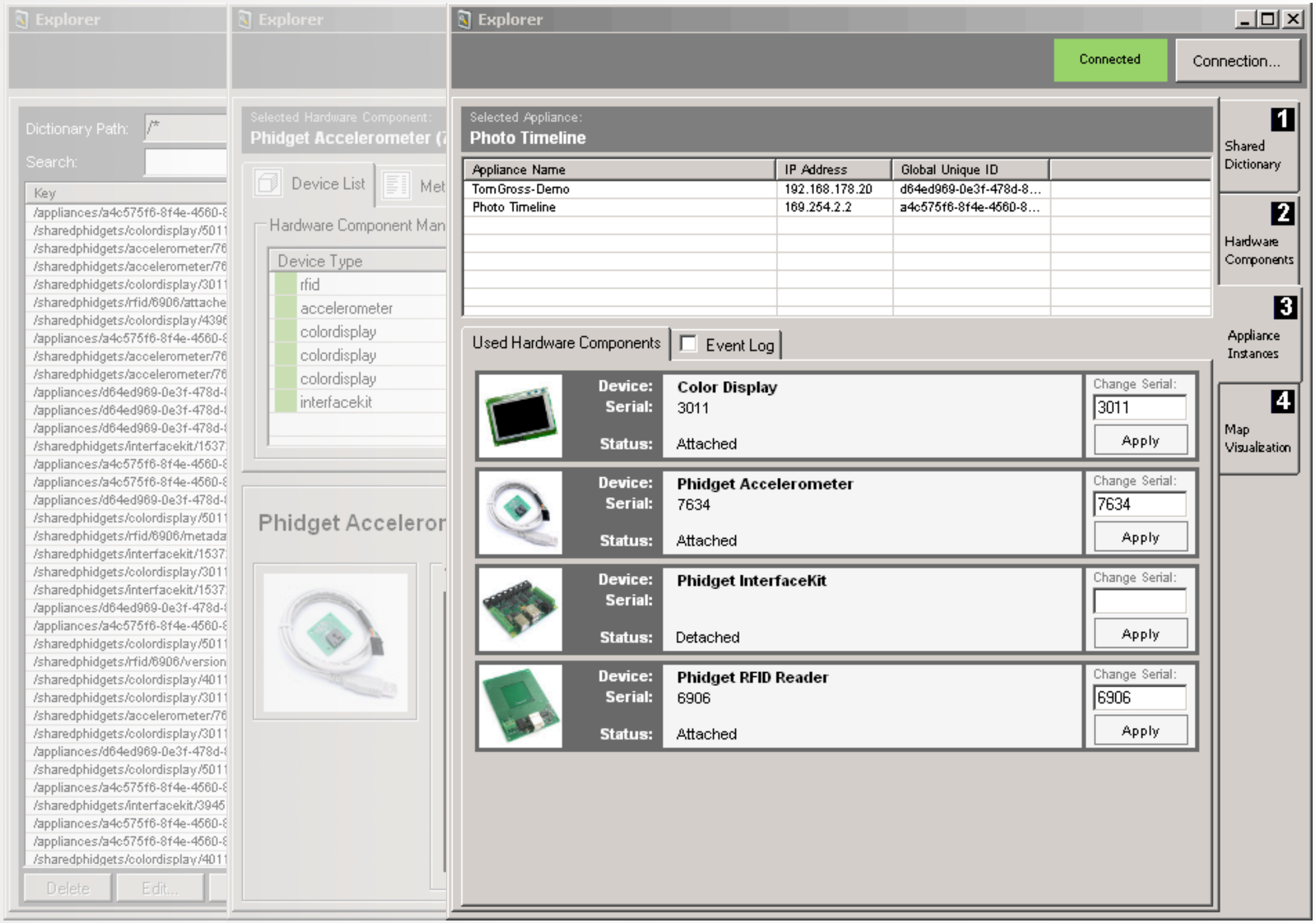
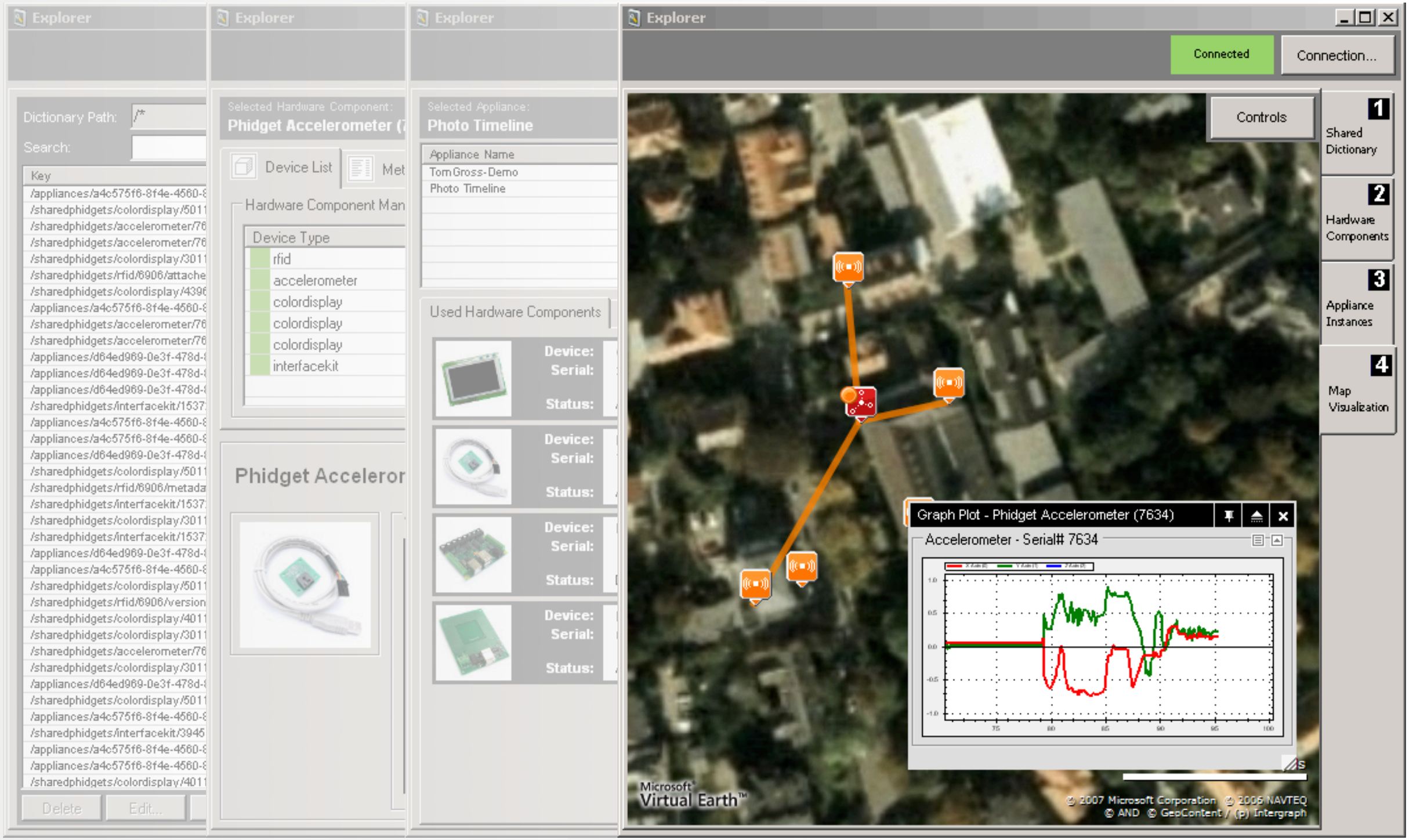
/sharedphidgets/interfacekit/3945
/appliances/a4c575f6-8f4e-4560-8
/appliances/a4c575f6-8f4e-4560-8
/sharedphidgets/colordisplay/4011
Delete
Edit...
Selected Hardware Component:
Phidget Accelerometer (7634)
Device List
Metadata
Manual
RFID
Hardware Component Manager
Update
Device Type
Serial
Attached
Version
Loc...
Ow...
Key...
rfid 6906 True 200 Wei... Nic... the...
accelerometer 7634 True 101 Wei... Nic... the...
colordisplay 4011 True 472
colordisplay 3011 True 1.06 Wei... Nic... the...
colordisplay 5011 True 472
interfacekit 15372 True 510 Wei... Nic... the...
1 Shared Dictionary
2 Hardware Components
3 Appliance Instances
4 Map Visualization
Phidget Accelerometer, Serial: 7634, Location: Weimar, Germany
Accelerometer - Serial# 7634
Axes
Axis 1: -0.4005
0.050
Axis 2: 0.42
0.050
Sensitivity Presets:
High
Medium
Low

Utilities


Explorer
Explorer
Explorer
Connected
Connection...
Dictionary Path:
/*
Search:
Key
Selected Hardware Component:
Phidget Accelerometer (
Device List
Met
Hardware Component Man
Device Type
rfid
accelerometer
colordisplay
colordisplay
colordisplay
interfacekit
Phidget Acceleror
Delete
Edit...
Selected Appliance:
Photo Timeline
Appliance Name
IP Address
Global Unique ID
TomGross-Demo
192.168.178.20
d64ed969-0e3f-478d-8...
Photo Timeline
169.254.2.2
a4c575f6-8f4e-4560-8...
1
Shared Dictionary
2
Hardware Components
3
Appliance Instances
4
Map Visualization
Used Hardware Components
Event Log
Device:
Color Display
Serial:
3011
Status:
Attached
Change Serial:
3011
Apply
Device:
Phidget Accelerometer
Serial:
7634
Status:
Attached
Change Serial:
7634
Apply
Device:
Phidget InterfaceKit
Serial:
Status:
Detached
Change Serial:
Apply
Device:
Phidget RFID Reader
Serial:
6906
Status:
Attached
Change Serial:
6906
Apply

Utilities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Dictionary Path: /*
Search:
Key
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/sharedphidgets/accelerometer/76
/sharedphidgets/accelerometer/76
/sharedphidgets/colordisplay/3011
/sharedphidgets/rfid/6906/attache
/sharedphidgets/colordisplay/4396
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/sharedphidgets/accelerometer/76
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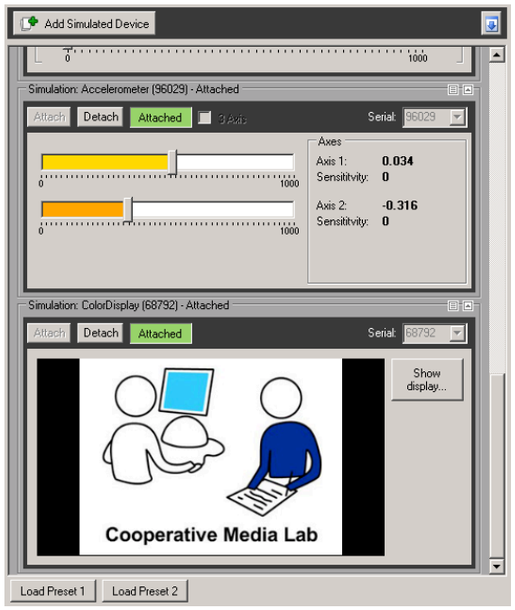
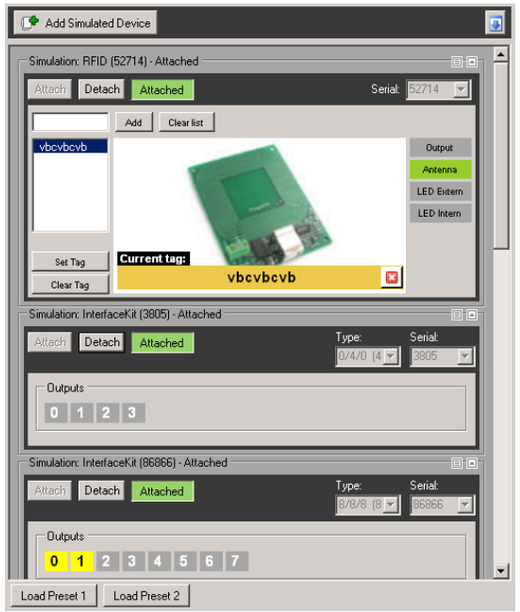
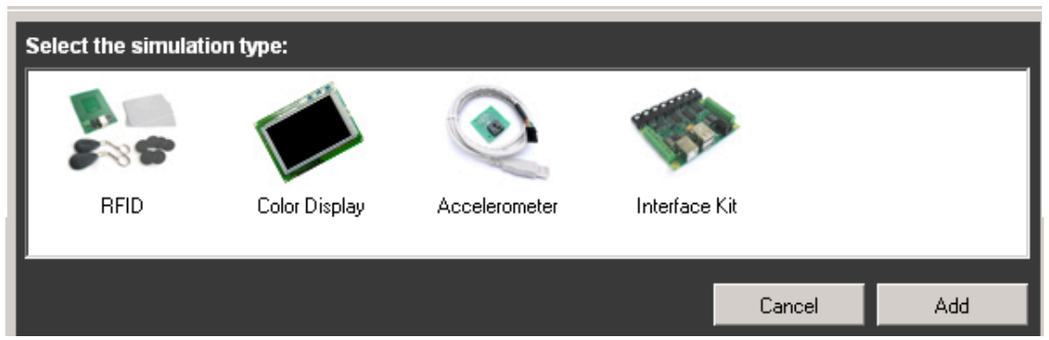
/sharedphidgets/colordisplay/4011
Delete
Edit...
Explorer
Selected Hardware Component:
Phidget Accelerometer (7
Device List
Met
Hardware Component Man
Device Type
rfid
accelerometer
colordisplay
colordisplay
colordisplay
interfacekit
Phidget Acceleror
Explorer
Selected Appliance:
Photo Timeline
Appliance Name
TomGross-Demo
Photo Timeline
Used Hardware Components
Device:
Serial:
Status:
Device:
Serial:
Status:
Device:
Serial:
Status:
Device:
Serial:
Status:
Explorer
Connected
Connection...
Controls
1 Shared Dictionary
2 Hardware Components
3 Appliance Instances
4 Map Visualization
Graph Plot - Phidget Accelerometer (7634)
Accelerometer - Serial# 7634
Microsoft Virtual Earth™
© 2007 Microsoft Corporation © 2006 NAVTEQ
© AND © GeoContent / (p) Intergraph

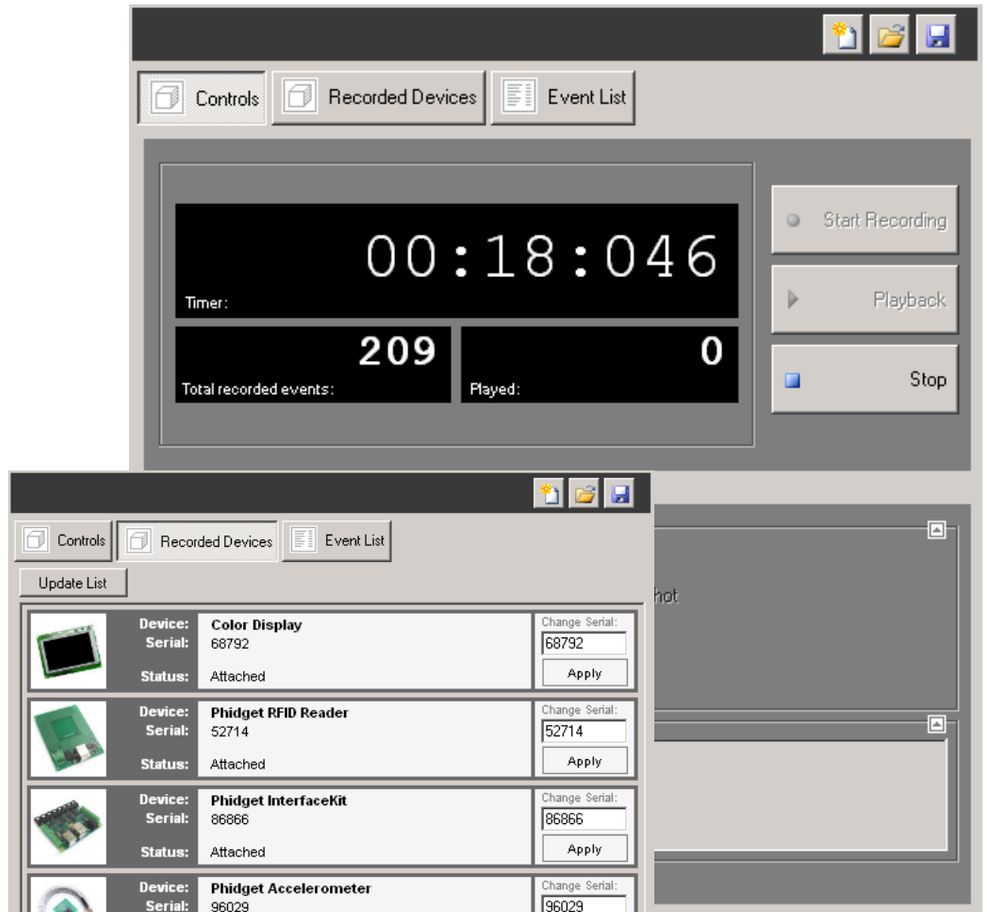
Visualisation

Simulations

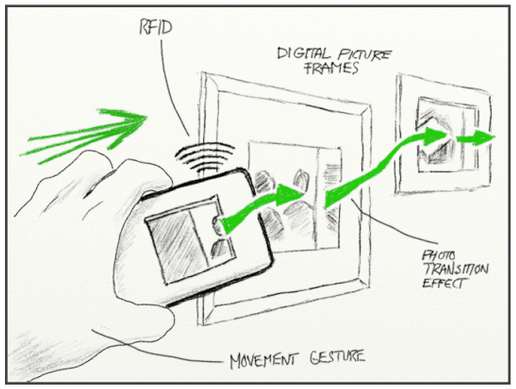


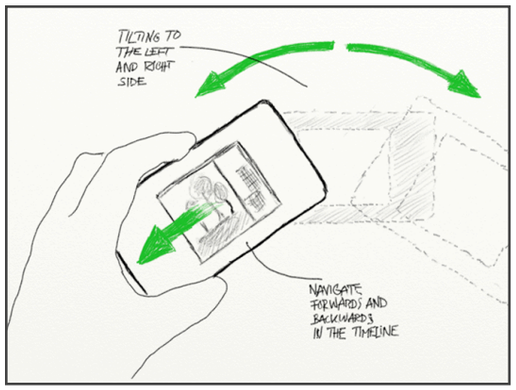


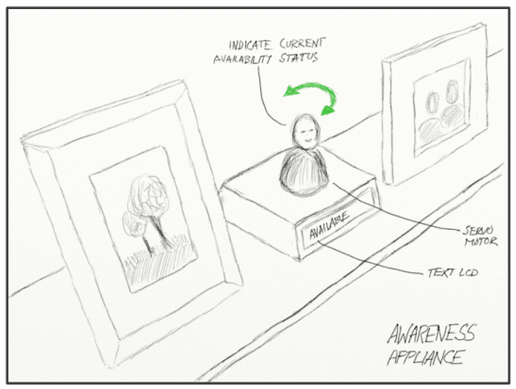


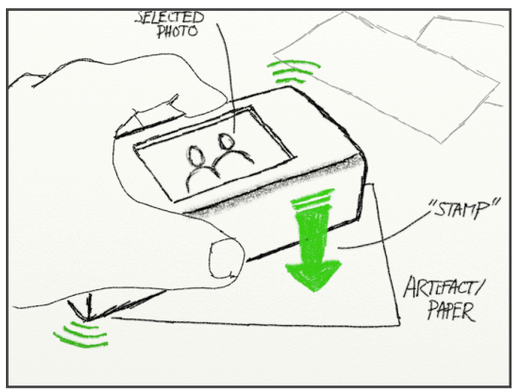


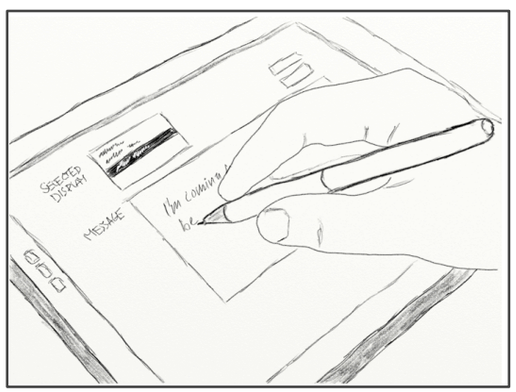
Case Studies







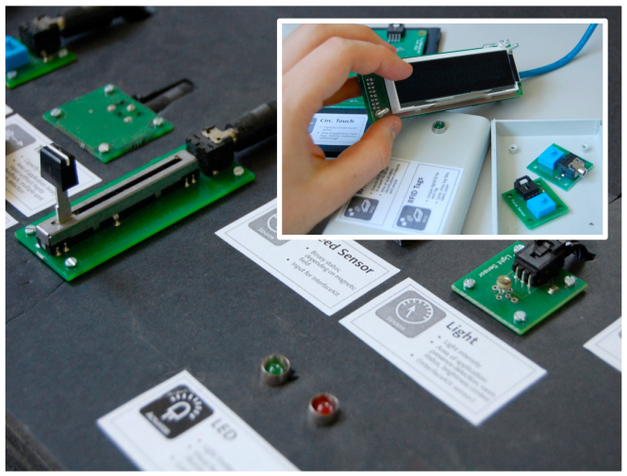




- Evaluation by applying the toolkit for rapid prototyping
- Utilised in two HCI courses as well as academic and industrial research labs
- 10 thesis case study information appliances

Case Studies

- Tangible digital media
- Location-based messaging
- Ambient displays and awareness
- Location-dependent object controller
- Augmented map
- Assigning digital metadata
- Sensor processing
- LumiTouch reimplementation



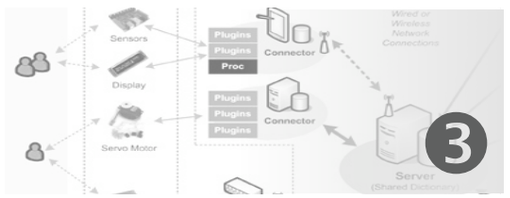
Discussion

- Applicability of the toolkit
- Ease of use and *low threshold*
- Advanced programming and *high ceiling*
- Performance, scalability, latency, reliability
- Usability of tangible user interfaces

Future Work

- Further evaluations: developers, end users
- Library extensions: hardware, filters, skins
- Sensor data processing: high-level events
- Utilities and visualisation: history, advanced interaction

Summary



- Introduction of tangible user interfaces
- Motivation and research overview

- Requirements
- Concept: *Runtime Platform, Development Library, Utilities*

- Implementation details
- Using connector, library, utilities

- Case studies and prototyping
- Discussion

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Thank you for your attention!

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