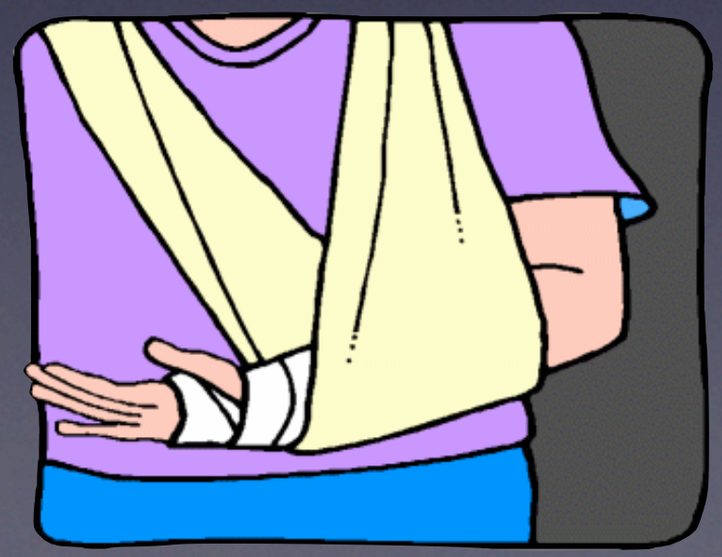
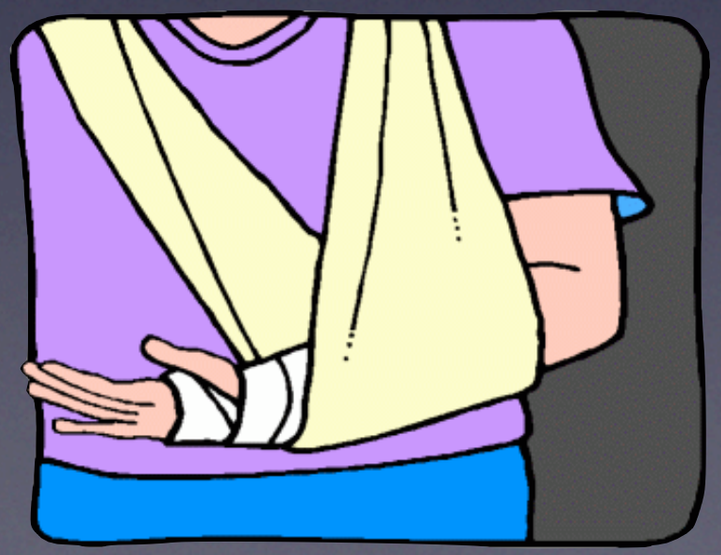
Automatically Generating User Interfaces Adapted To Users' Motor And Vision Capabilities

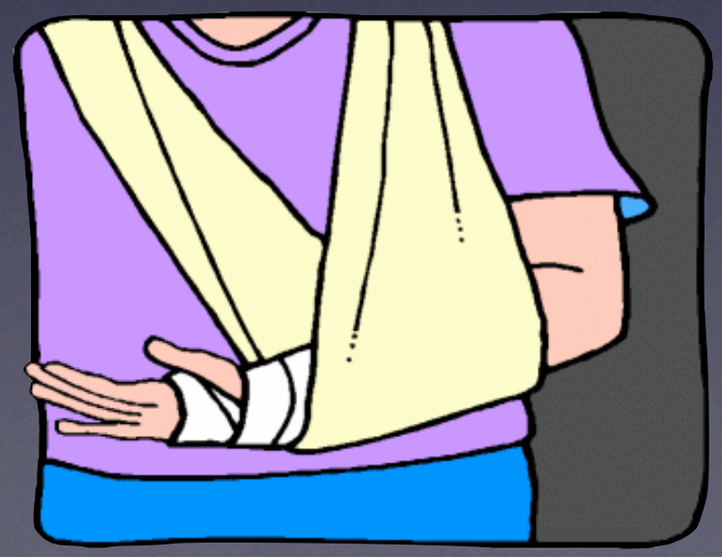
Krzysztof Z. Gajos,
Jacob O. Wobbrock
and Daniel S. Weld

University of Washington
Computer Science & Engineering

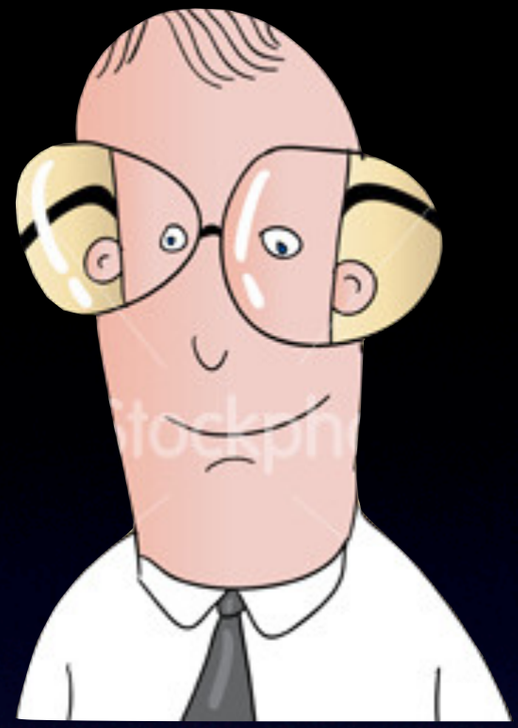
dub
design:
use:
build:
university of washington

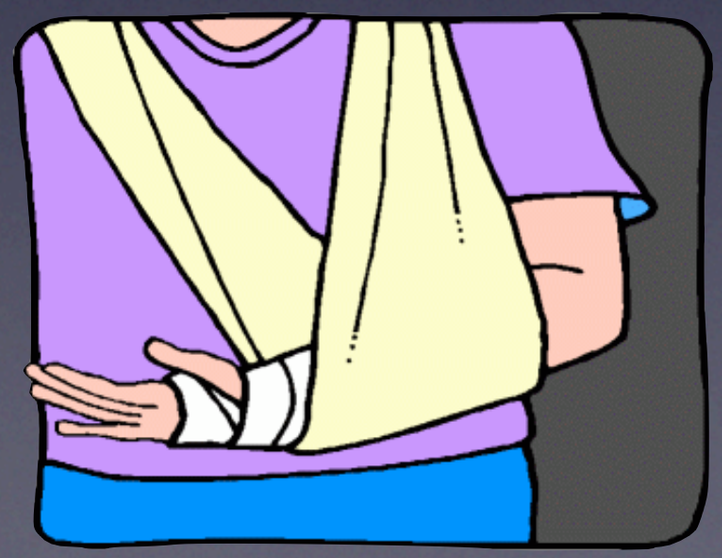




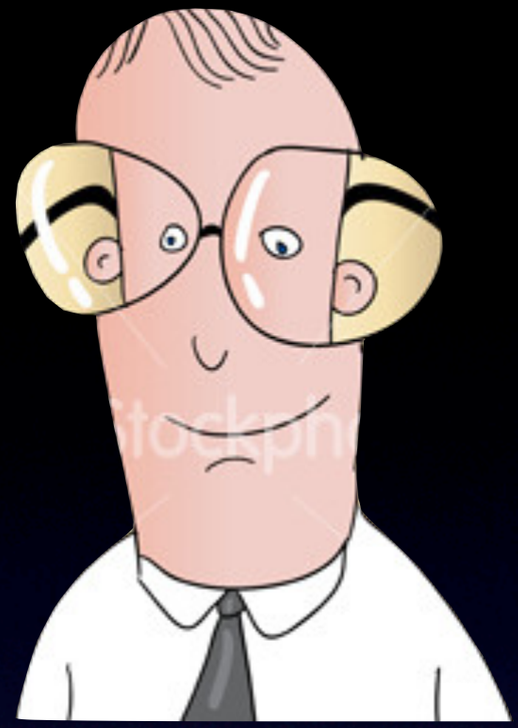


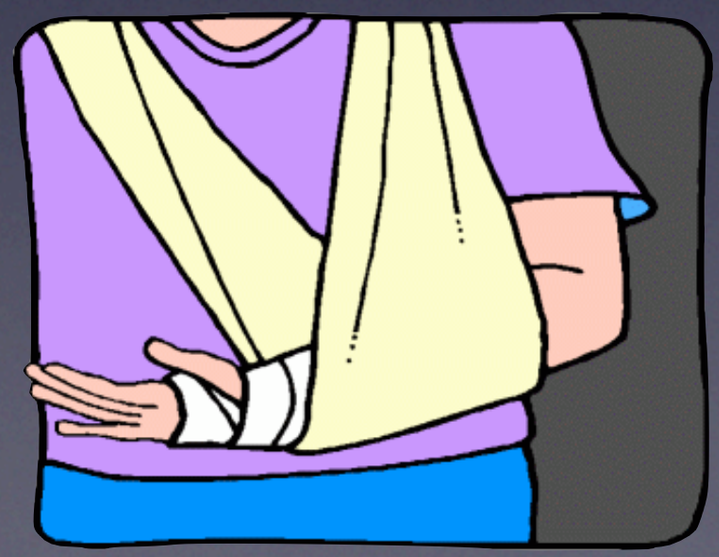

SCHOOL BUS
21






SCHOOL BUS
21



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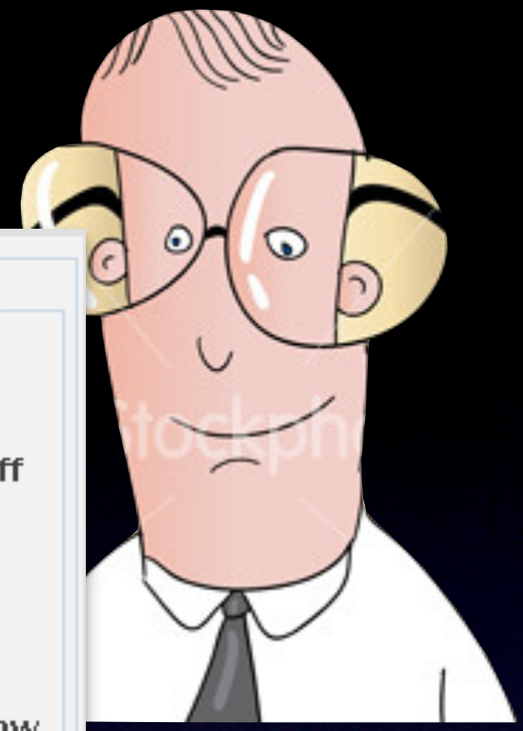
21



Classroom

Light Bank

Left

Light

Level

0 5 10

Center

Light

Level

0 5 10

Right

Light

Level

0 5 10

A/V Controls

Projector

Power

Input

Computer 1

Computer2

Video

Screen

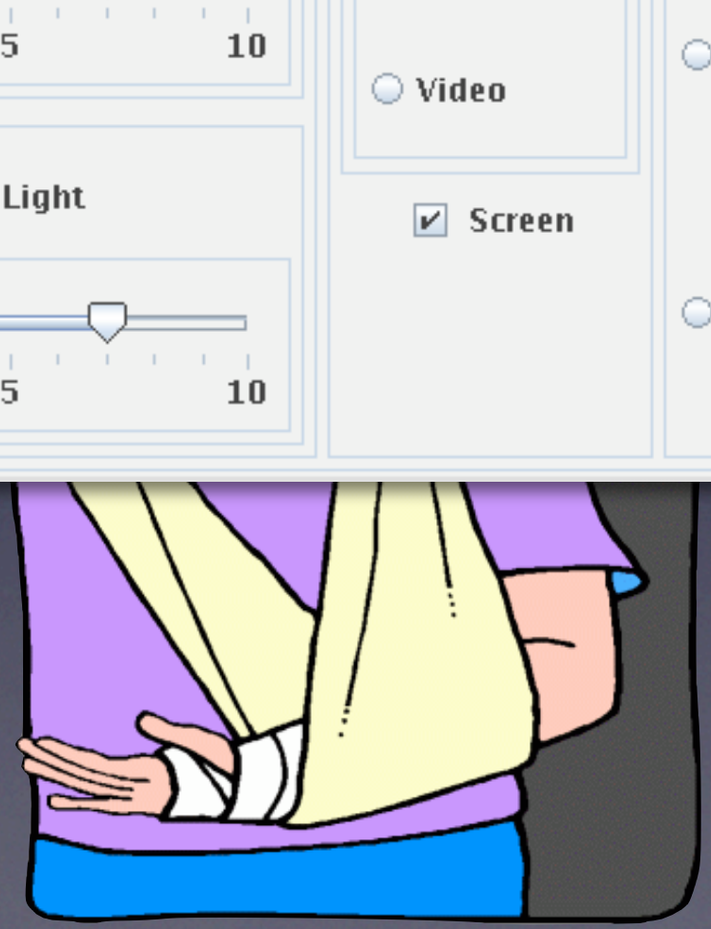
Vent

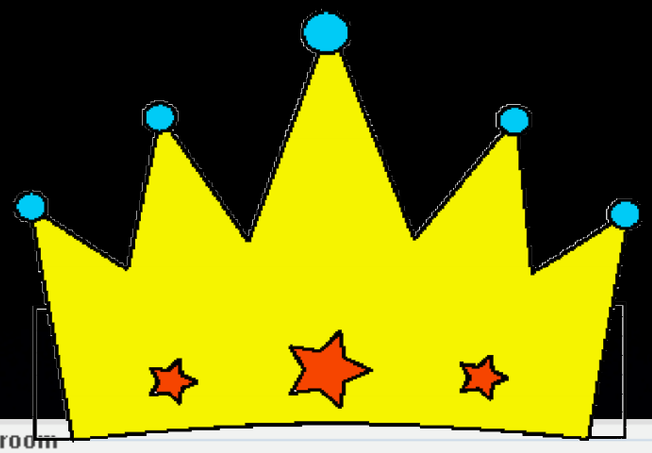
Off

Low

Med

High





Classroom

Light Bank

Left

Light

Level

0 5 10

Center

Light

Level

0 5 10

Right

Light

Level

0 5 10

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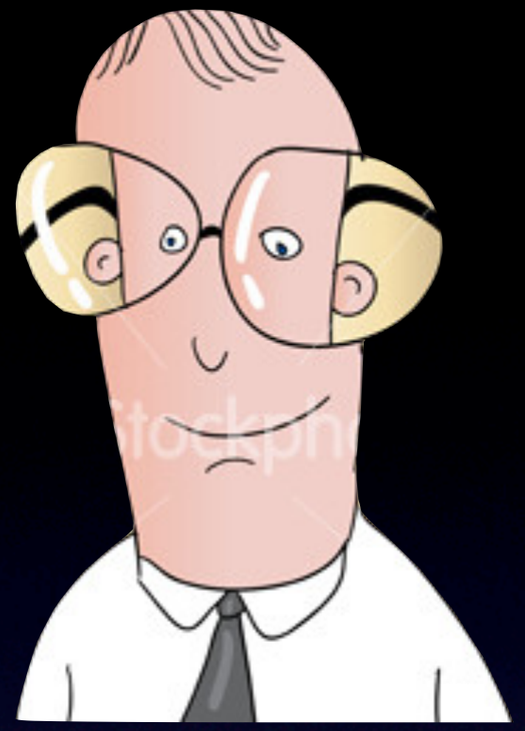

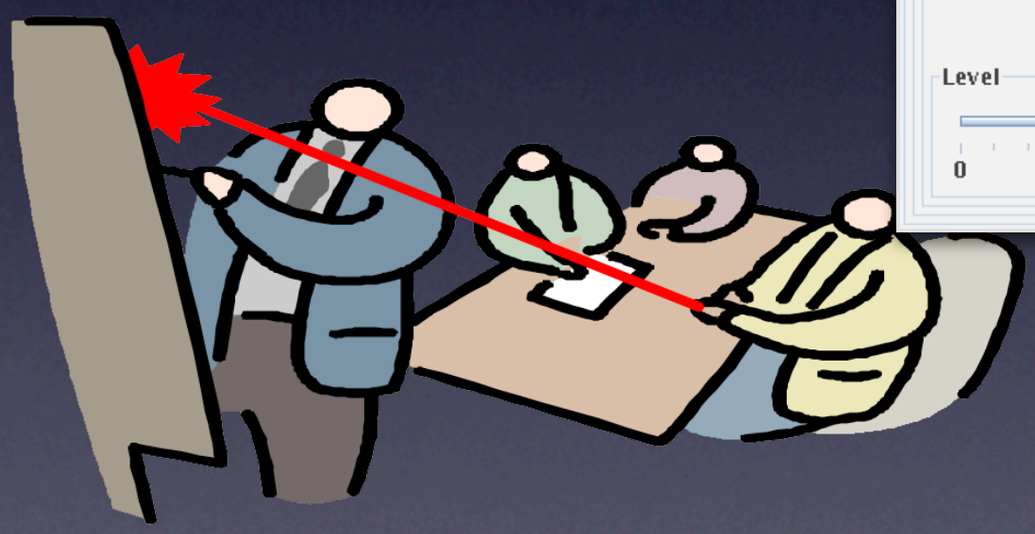

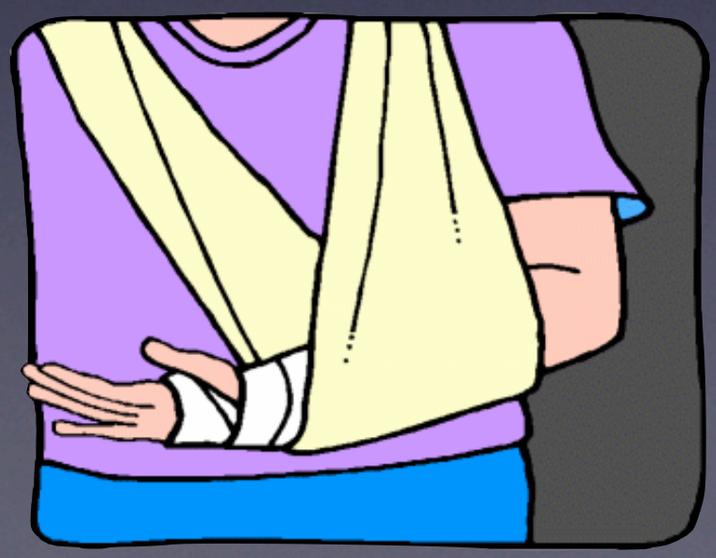

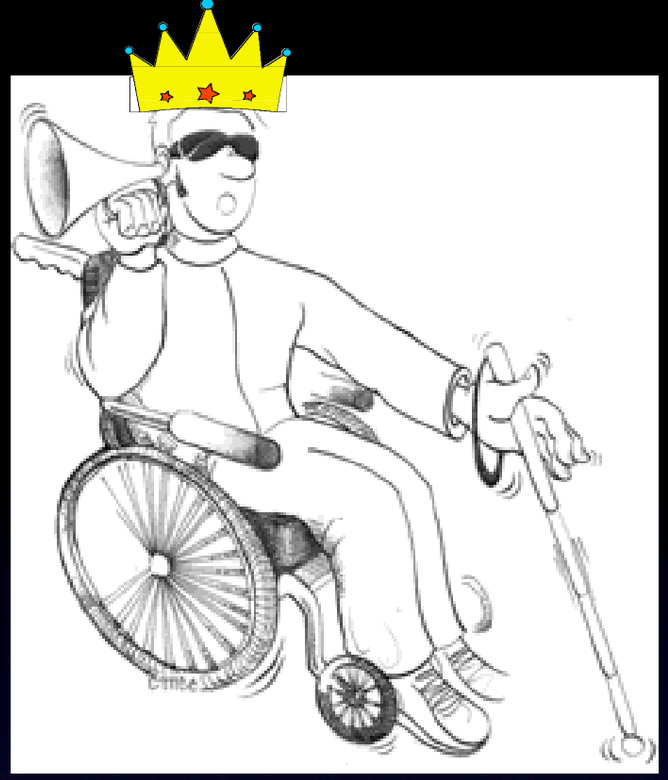

Classroom

Light Bank

Left

Light

Level

0 5 10

Center

Light

Level

0 5 10

Right

Light

Level

0 5 10

A/V Controls

Projector

Power

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Computer 1

Computer2

Video

Screen

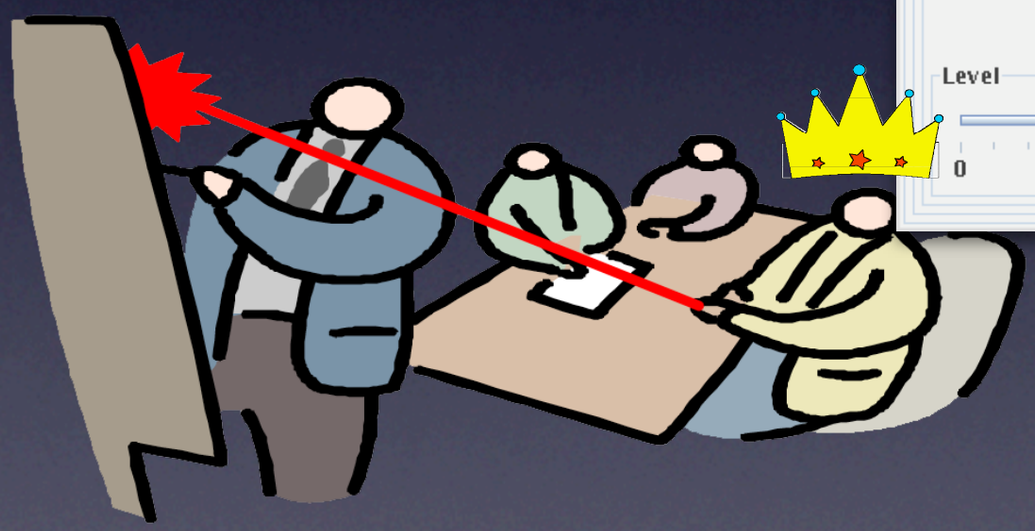
Vent

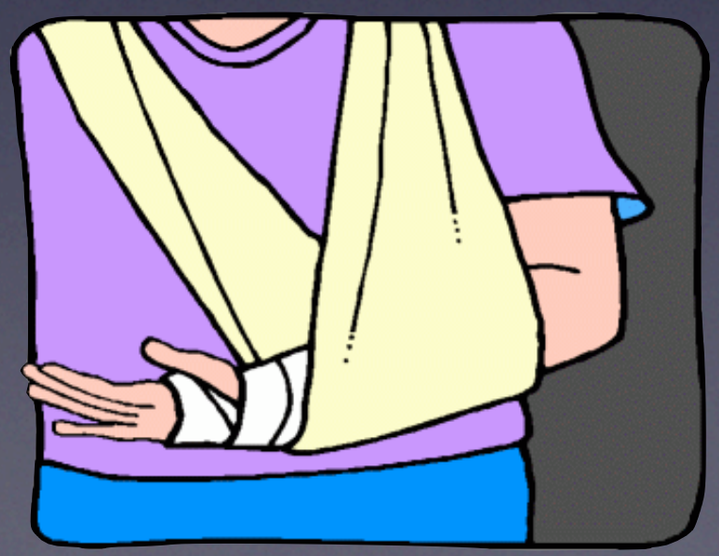
Off

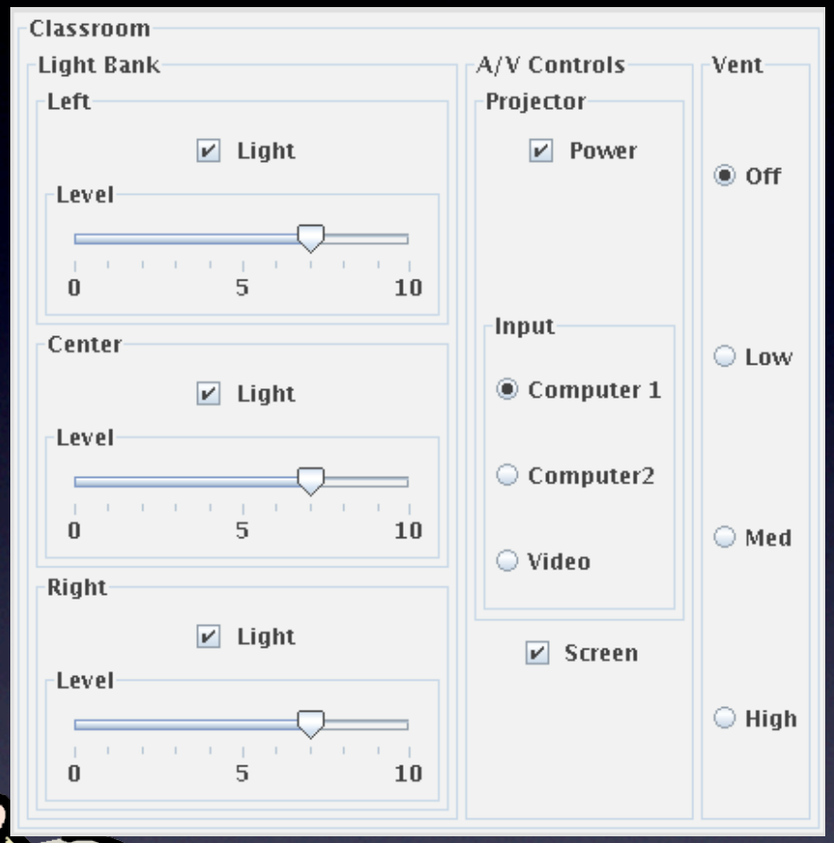
Low

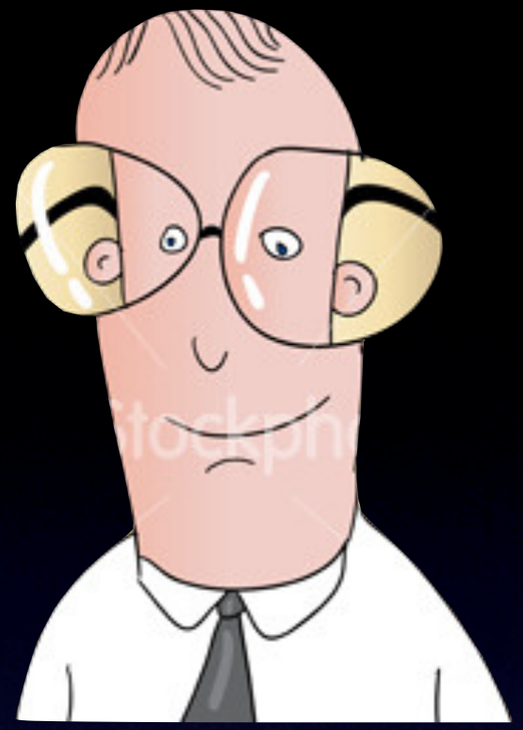
Med

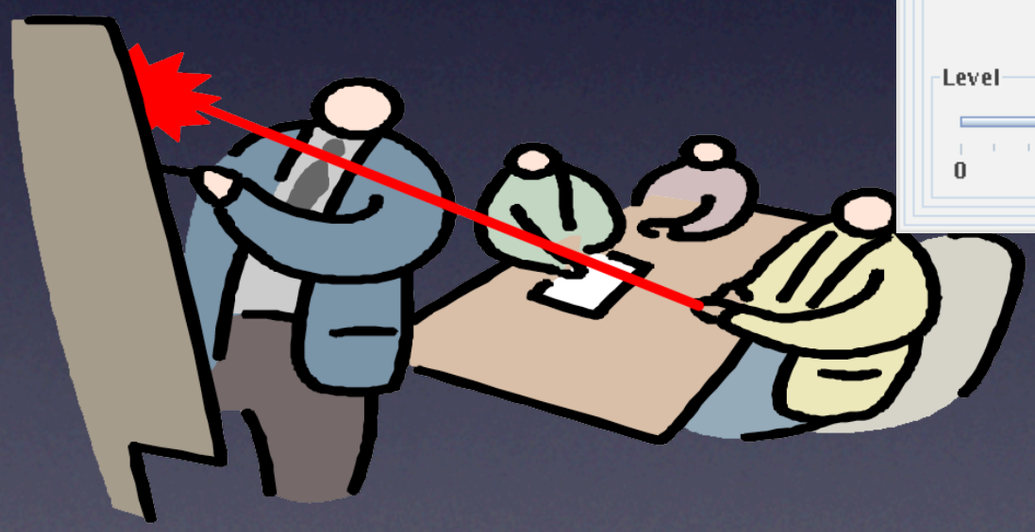
High

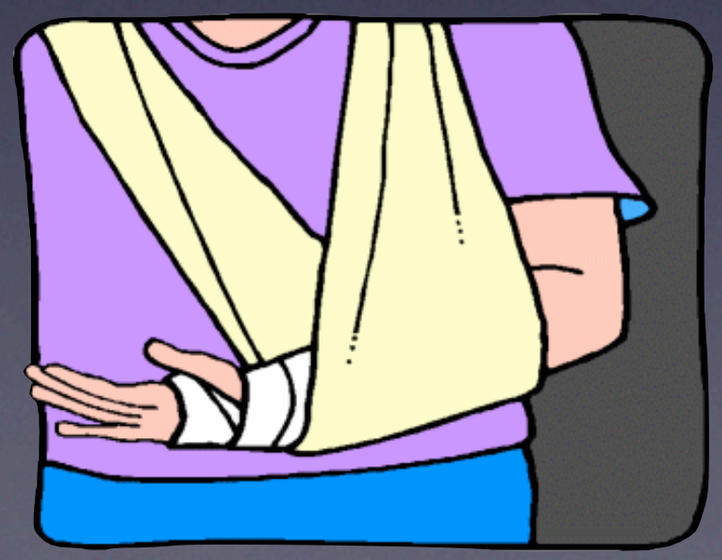




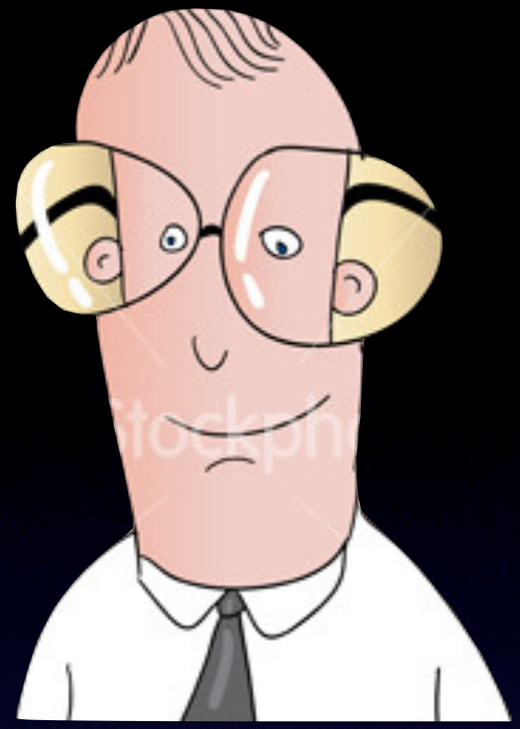

Classroom
Light Bank
Left
Light
Level
0
5
10
Center
Light
Level
0
5
10
Right
Light
Level
0
5
10
A/V Controls
Projector
Power
Input
Computer 1
Computer2
Video
Screen
Vent
Off
Low
Med
High

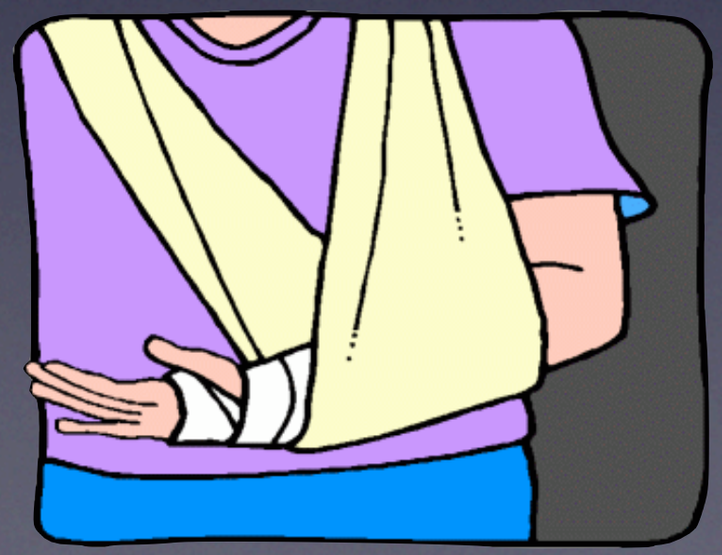







SCHOOL BUS
21






SCHOOL BUS
21

Classroom

Light Bank

Left

Light: On

Level

0 | 1 | 2 | 3 | 4 | 5 | 6 | 7 | 8 | 9 | 10

Center

Light: On

Level

0 | 1 | 2 | 3 | 4 | 5 | 6 | 7 | 8 | 9 | 10

Right

Light: On

Level

0 | 1 | 2 | 3 | 4 | 5 | 6 | 7 | 8 | 9 | 10

A/V Controls

Projector

Power

Input

Computer 1

Computer2

Video

Screen

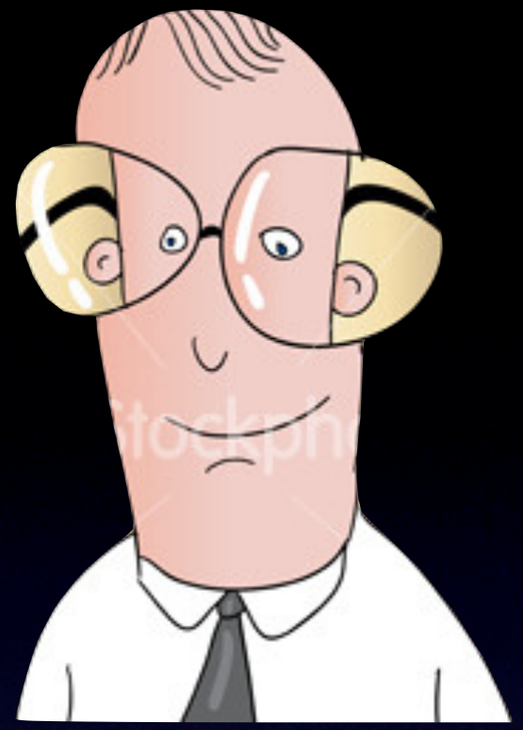
Vent

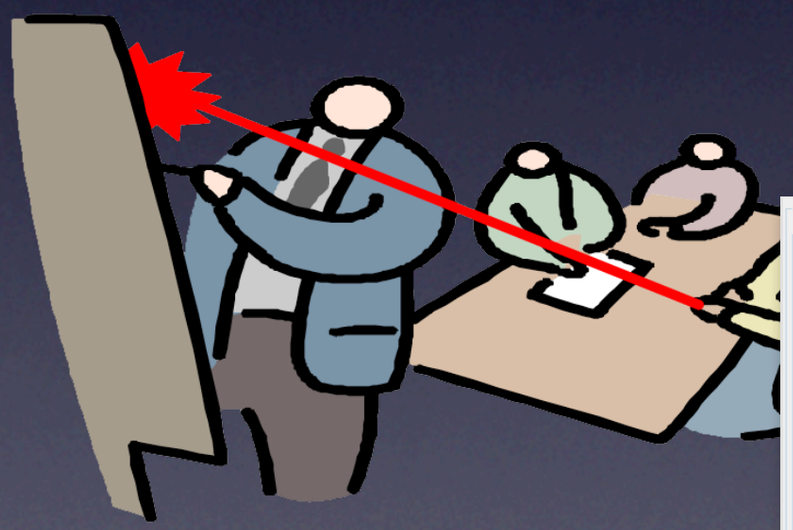
Off

Low

Med

High





Classroom

Light Bank

Left

Light: On

Level

0 1 2 3 4 5 6 7 8 9 10

Center

Light: On

Level

0 1 2 3 4 5 6 7 8 9 10

Right

Light: On

Level

0 1 2 3 4 5 6 7 8 9 10

A/V Controls

Projector

Power

Input

Computer 1

Computer2

Video

Screen

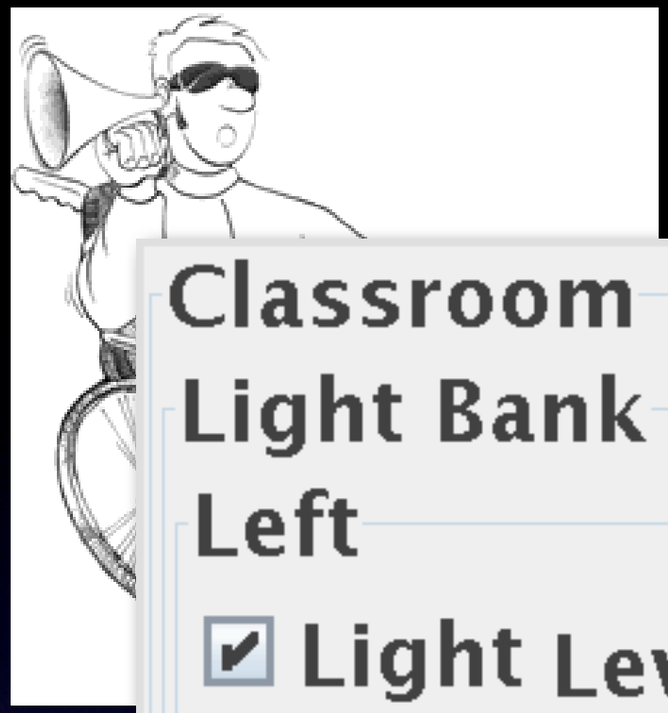
Vent

Off

Low

Med

High



Classroom

Light Bank

Left

Light Level 7

Center

Light Level 7

Right

Light Level 7

A/V Controls

Projector

Power

Input

Computer 1

Computer2

Video

Screen

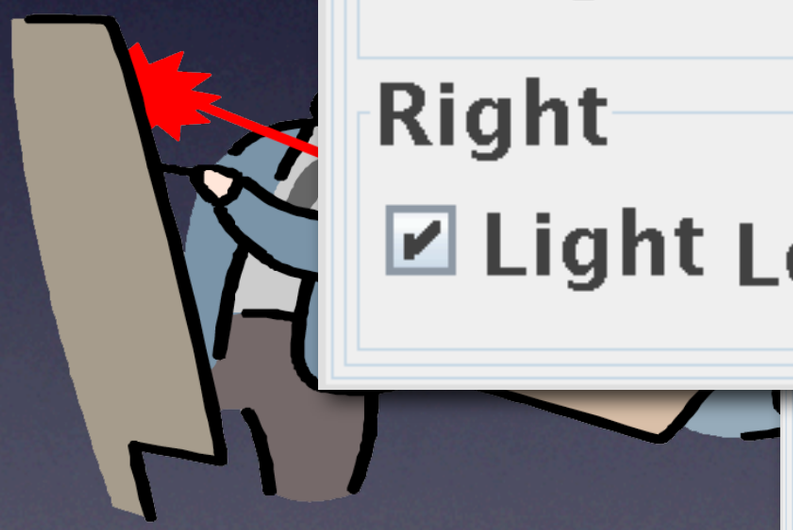
Vent

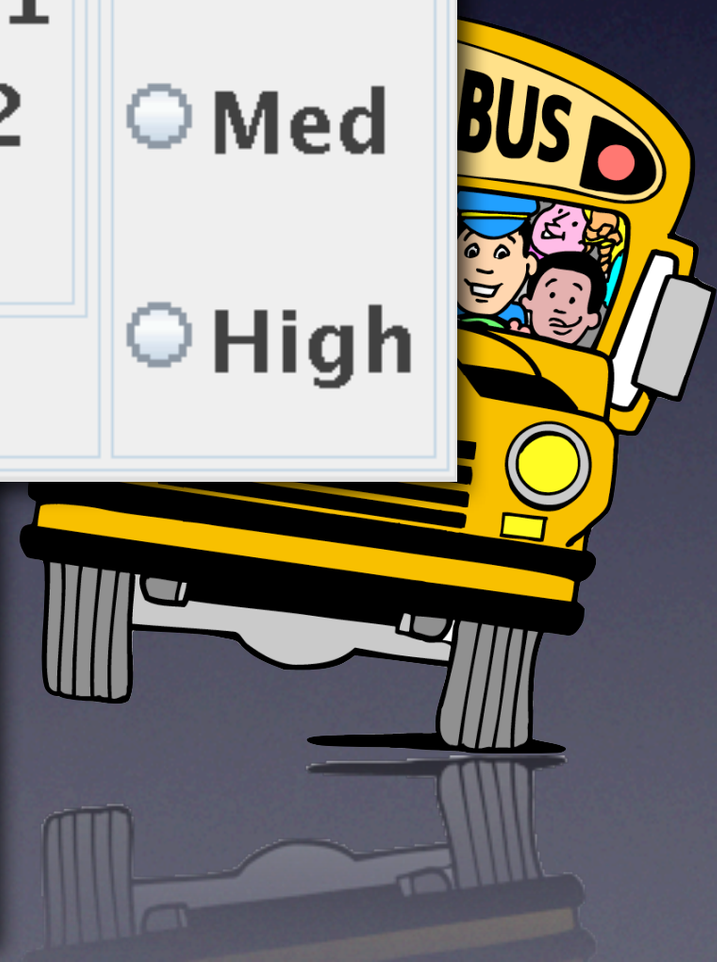
Off

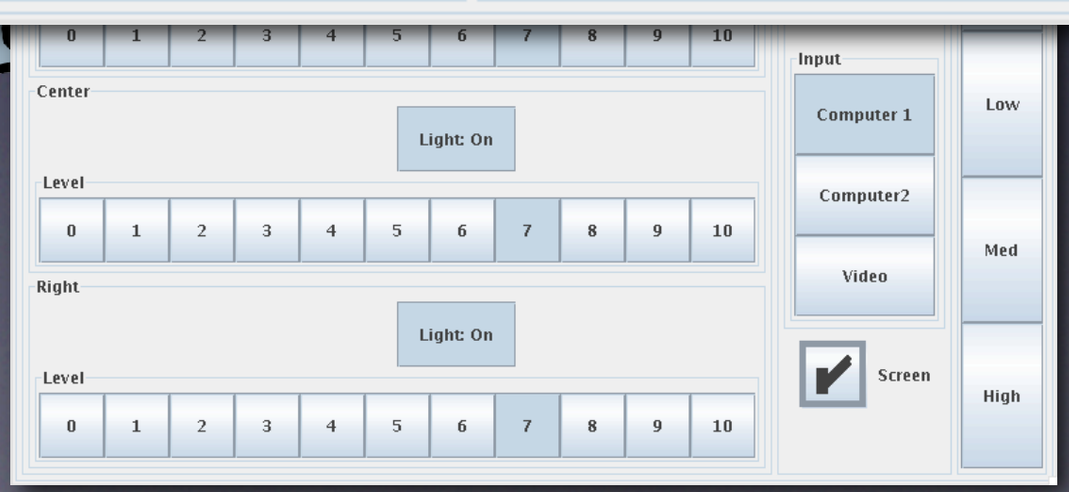
Low

Med

High







Classroom

Light Bank

Left

Light Level 7

Center

Light Level 7

Right

Light Level 7

A/V Controls

Projector

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Input

Computer 1

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Video

Screen

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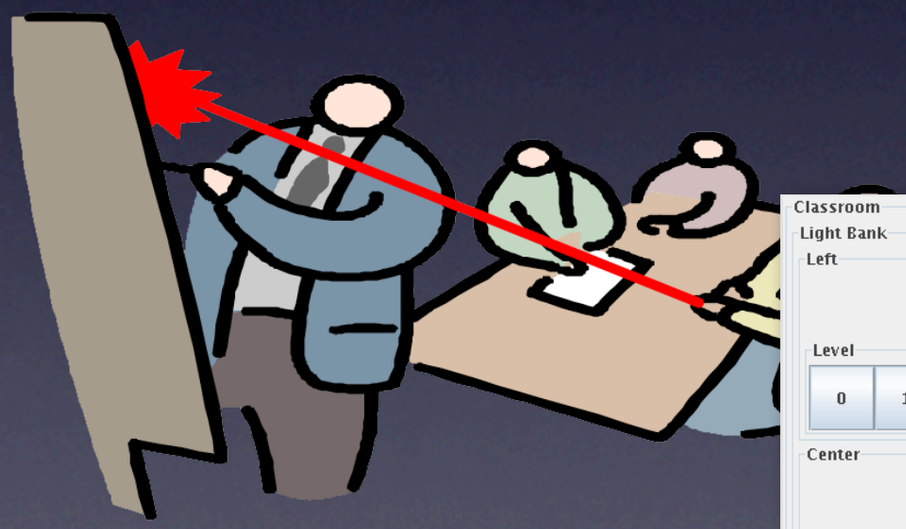

Classroom

Light Bank

Left

Light: On

Level

0 1 2 3 4 5 6 7 8 9 10

Center

Light: On

Level

0 1 2 3 4 5 6 7 8 9 10

Right

Light: On

Level

0 1 2 3 4 5 6 7 8 9 10

A/V Controls

Projector

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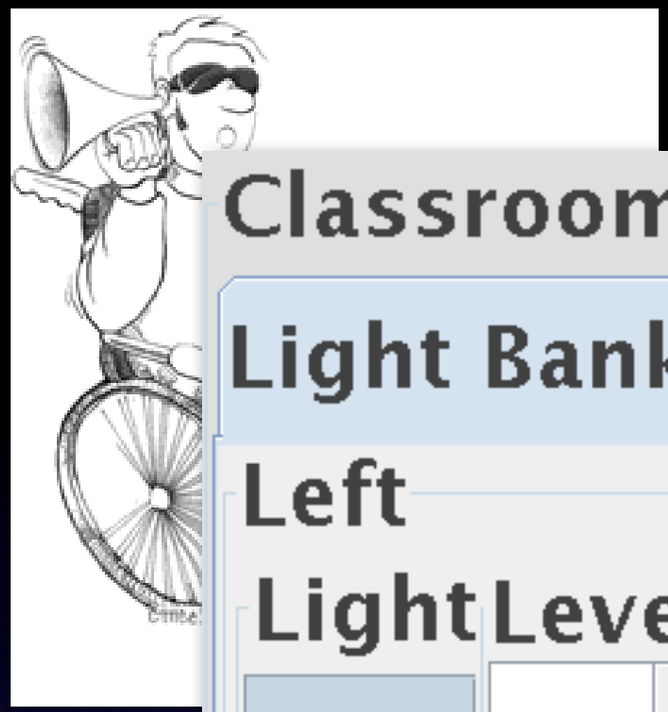
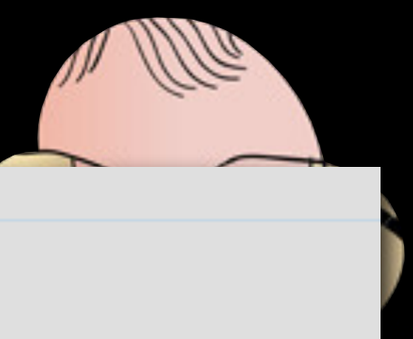
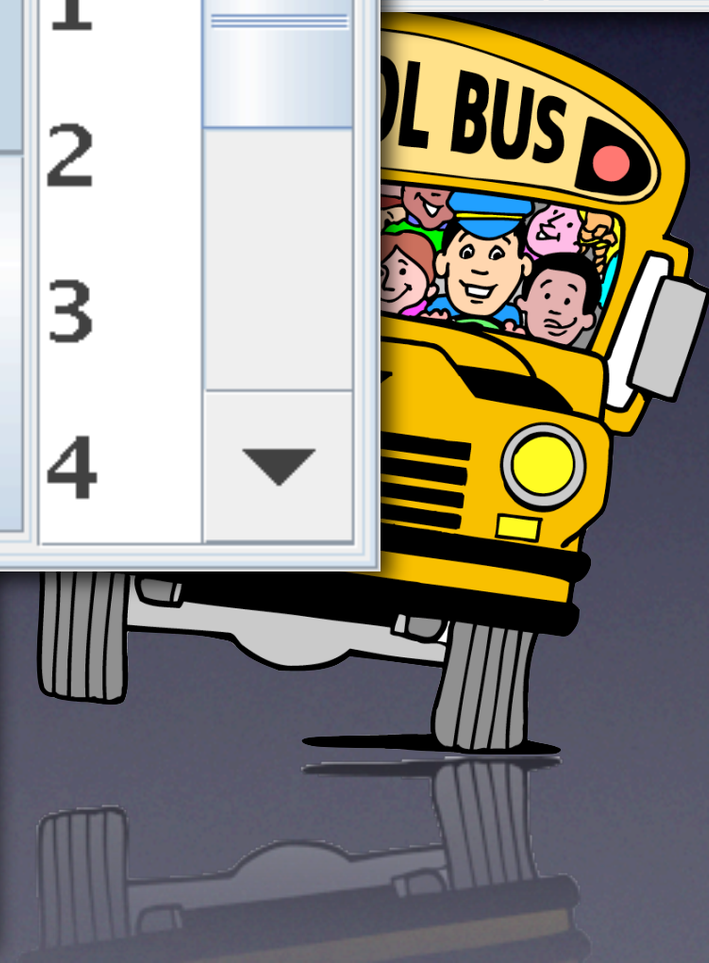


Classroom

Light Bank | A/V Controls | Vent

Left Light	Left Level	Center Light	Center Level	Right Light	Right Level
On	0	On	0	On	0
	1		1		1
	2		2		2
Off	3	Off	3	Off	3
	4		4		4





Light: On

Level

0 1 2 3 4 5 6 7 8 9 10

Right

Light: On

Level

0 1 2 3 4 5 6 7 8 9 10

Computer2

Video

Screen

Med

High

Classroom

Light Bank | A/V Controls | Vent

Left Light

On / Off

Level: 0 1 2 3 4

Center Light

On / Off

Level: 0 1 2 3 4

Right Light

On / Off

Level: 0 1 2 3 4

Classroom

Light Bank

Left

Light Level 7

Center

Light Level 7

Right

Light Level 7

A/V Controls

Projector

Power

Input

Computer 1

Computer2

Video

Screen

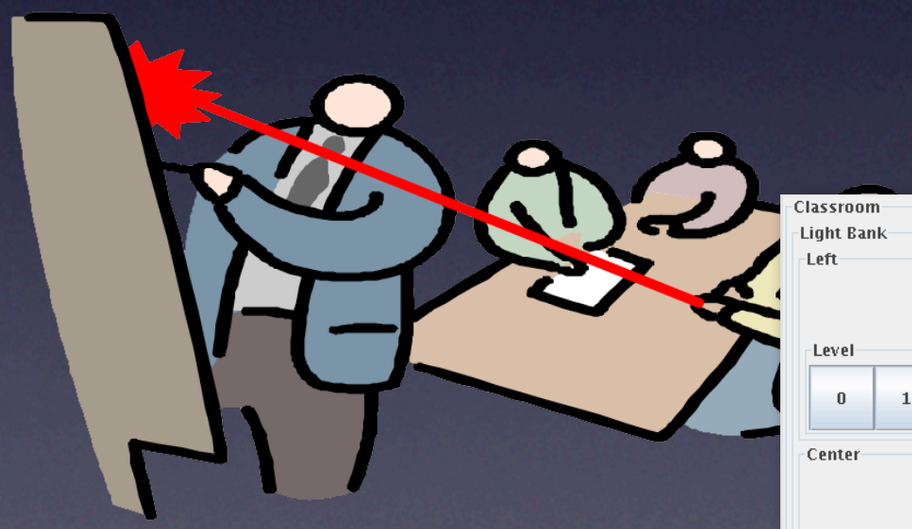
Vent

Off

Low

Med

High



Classroom

Light Bank

Left

Light: On

Level: 0 1 2 3 4 5 6 7 8 9 10

Center

Light: On

Level: 0 1 2 3 4 5 6 7 8 9 10

Right

Light: On

Level: 0 1 2 3 4 5 6 7 8 9 10

A/V Controls

Projector

Power

Input

Computer 1

Computer2

Video

Screen

Vent

Off

Low

Med

High

Road Map

- ✓ Introduction
- > Interface generation as optimization
- ☐ Modeling motor capabilities
- ☐ Adapting to motor capabilities
- ☐ Adapting to vision capabilities
- ☐ Adapting to motor and vision capabilities together
- ☐ Pilot User Study
- ☐ Lessons learned

Automatic Interface Generation

- Manually capture design knowledge as rules
- Automatically apply rules to generate new interfaces

Automatic Interface Generation

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- **Problems:**

Automatic Interface Generation

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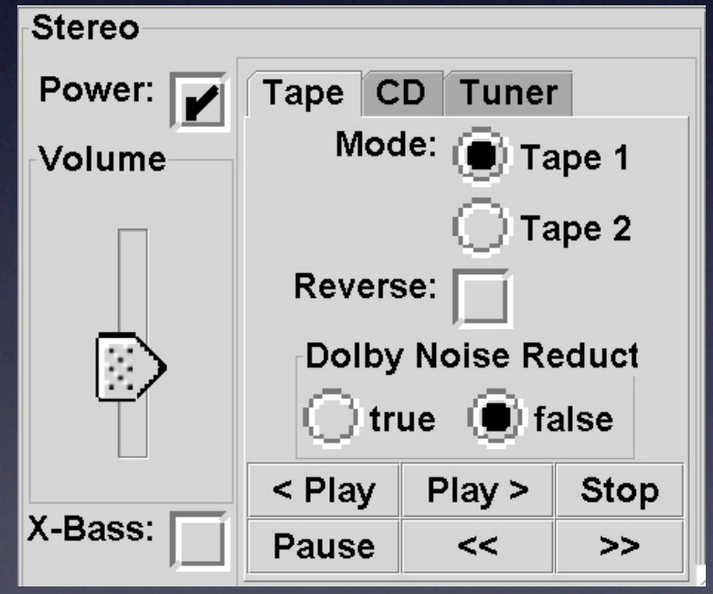
- **Problems:**
- New rule sets necessary for every device type, interaction style or even screen size

Automatic Interface Generation

- Manually capture design knowledge as rules
- Automatically apply rules to generate new interfaces
- **Problems:**
- New rule sets necessary for every device type, interaction style or even screen size
- No good way to adapt to individual preferences or needs

Our Approach: User Interface Generation as Optimization

Driven by a "cost function":

$() = ...

and constraints

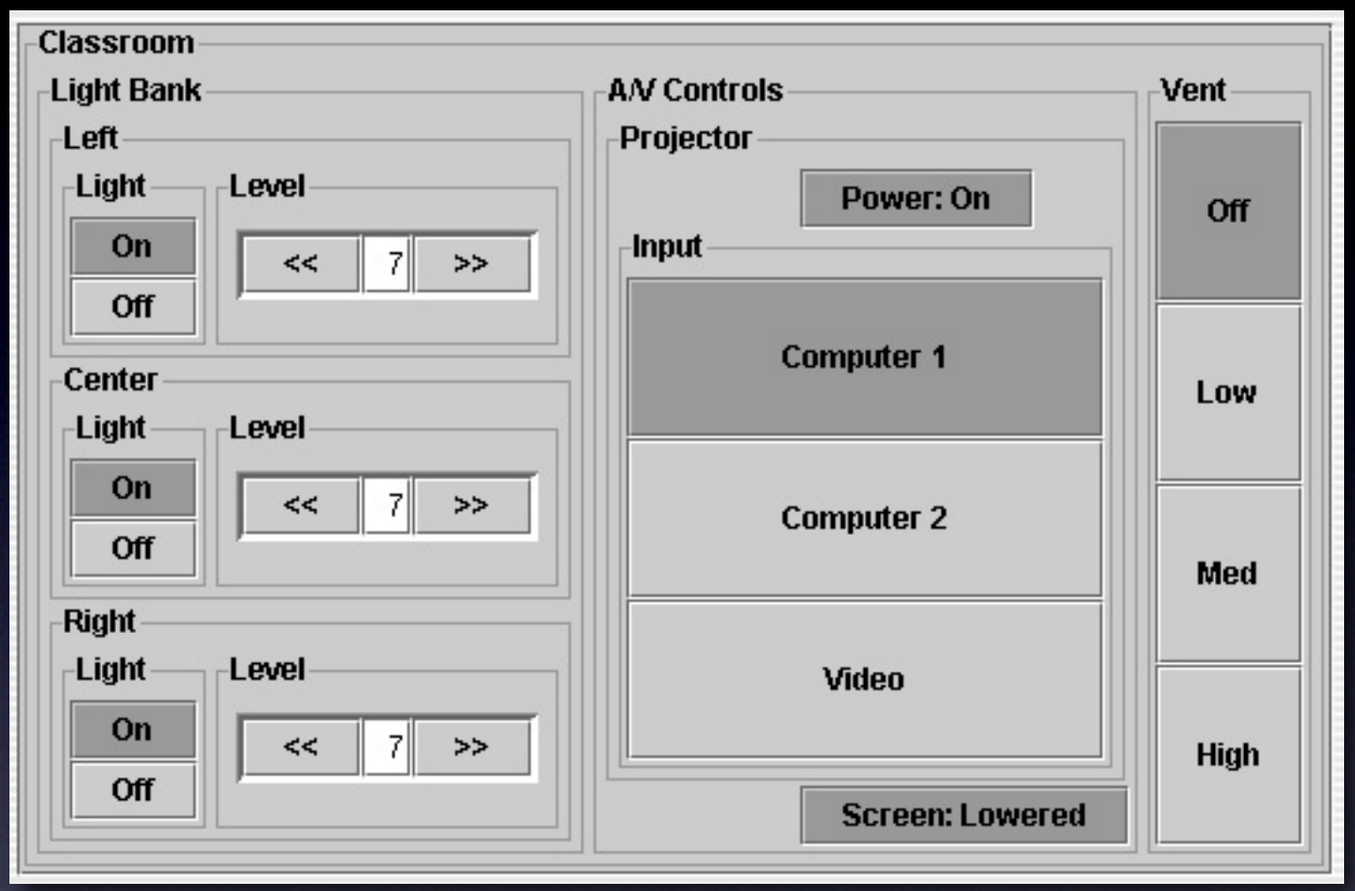
[Gajos and Weld, IUI'05]

Find the interface that minimizes

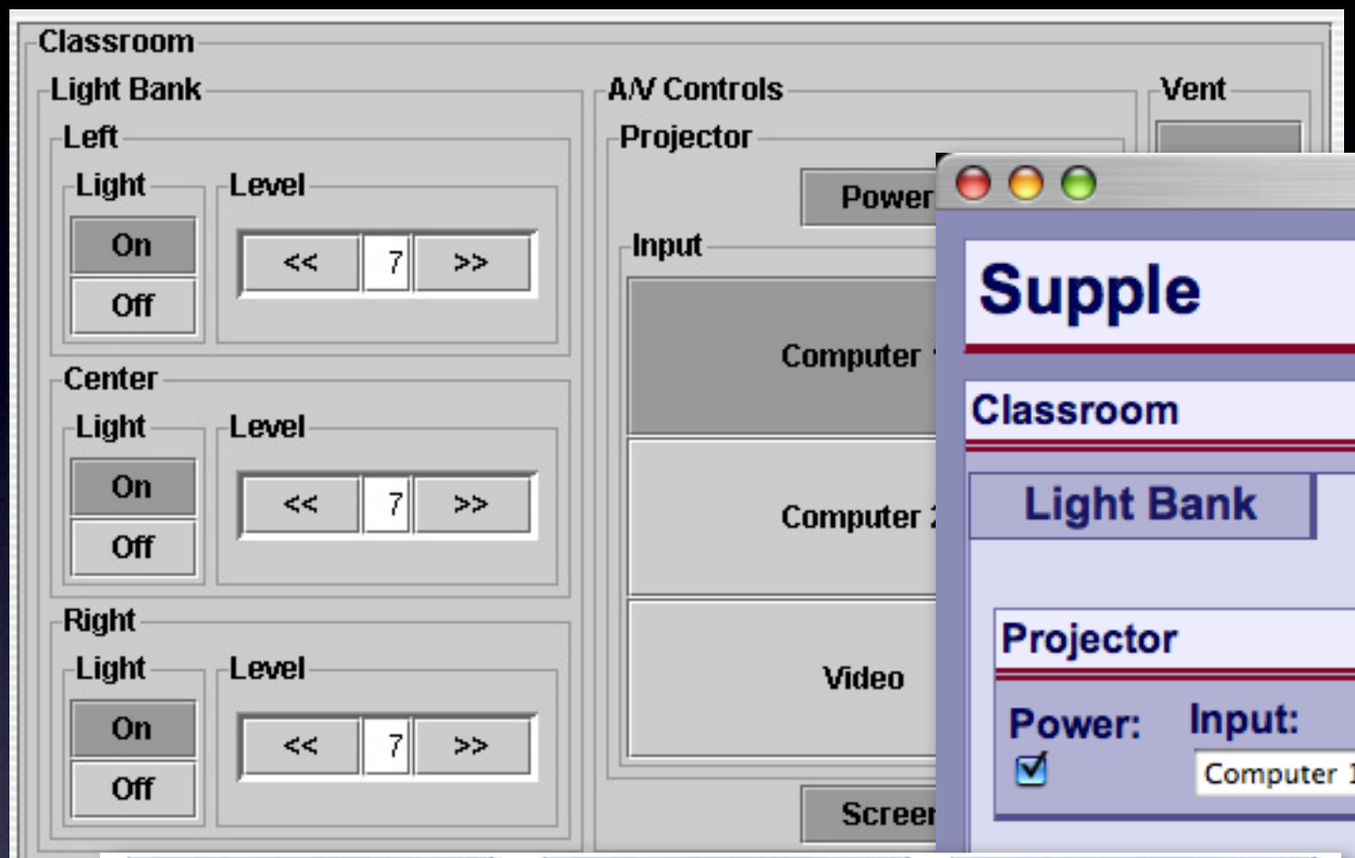
without violating constraints

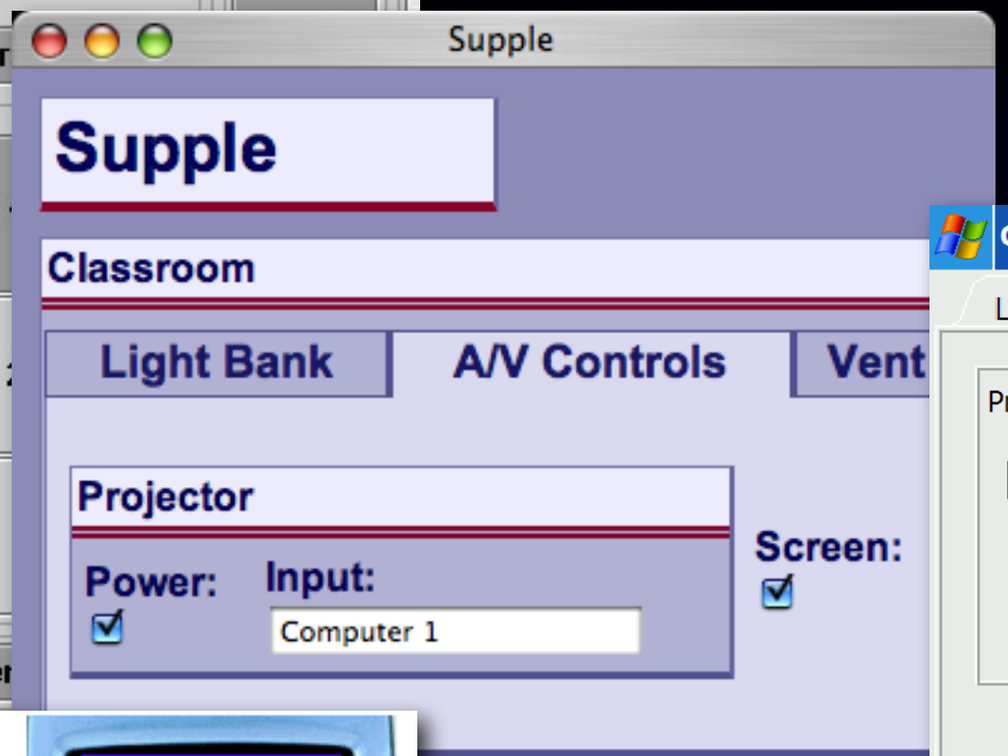
[Gajos and Weld, IUI'05]

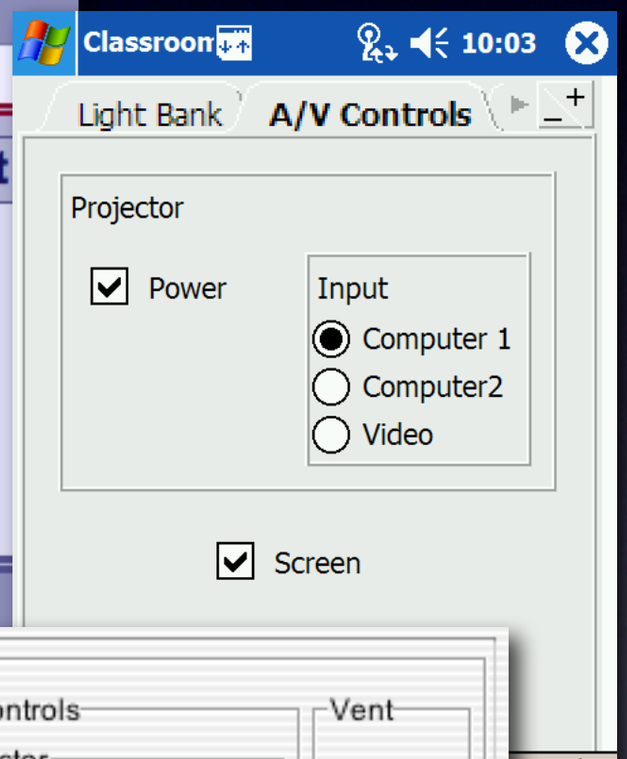
Single Algorithm -- Many Devices

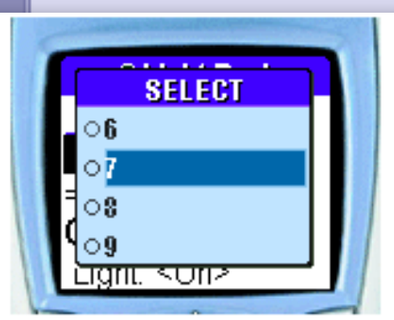


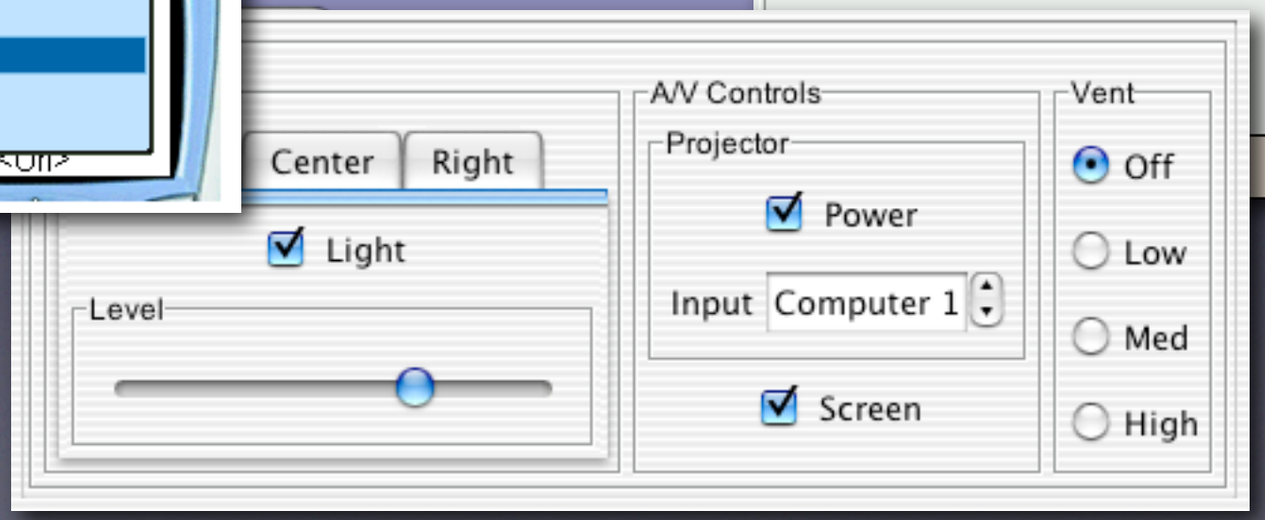
Single Algorithm -- Many Devices





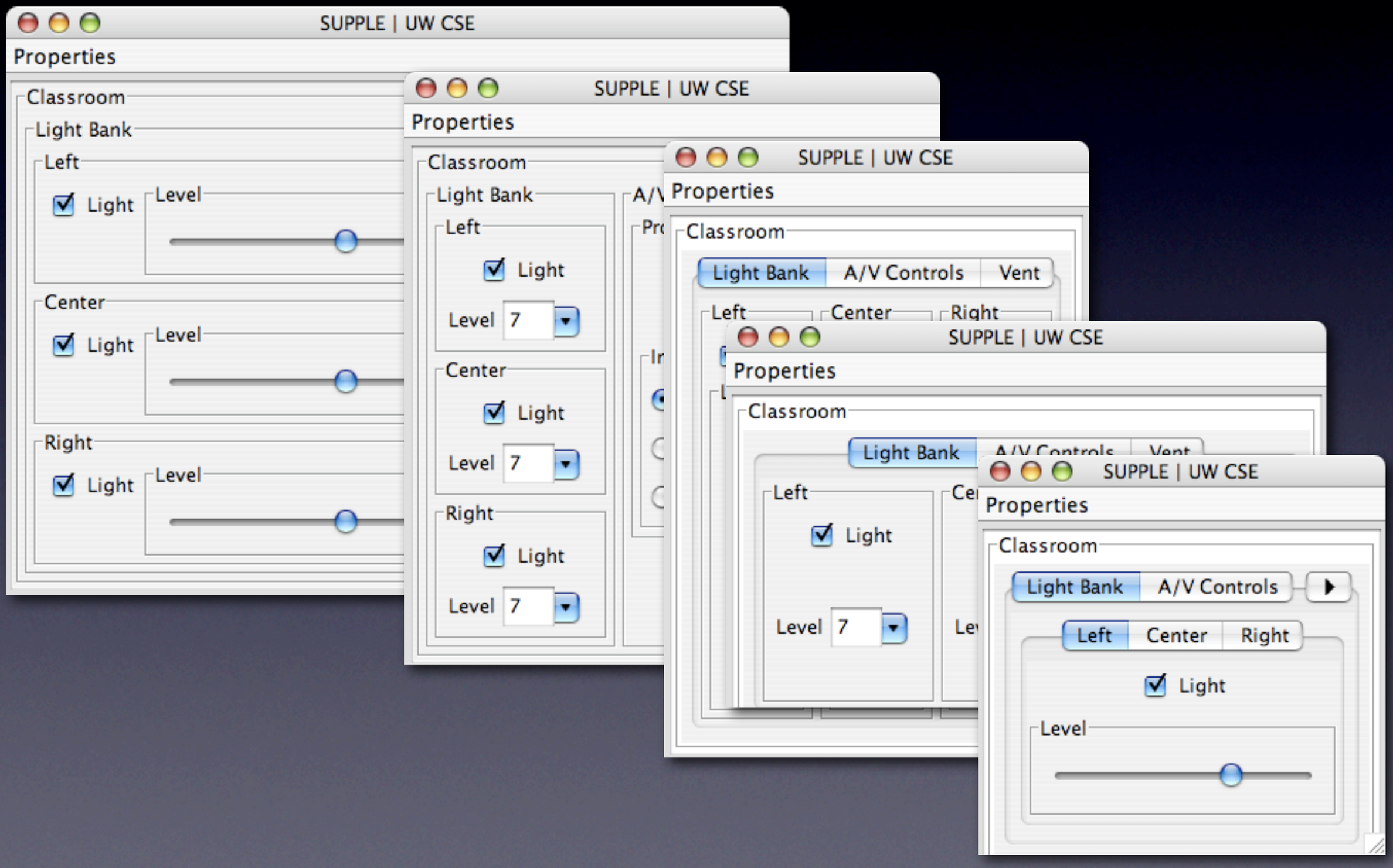






Robustly Adapting to Different Screen Sizes

Robustly Adapting to Different Screen Sizes



Supple: Email Example

Properties

Folders

New
Rename
Delete
Expunge

New Folder
Junk-E-Mail
New Folder 1
New Folder 2
Unerwünscht
Unbekannt
INBOX
Entwurf
Papierkorb
Gesendet
Postausgang

Messages

	25.04 05:36 AM	Suzette Schulz <CHWIZOKAIVQ@ADSVISION.COM>	Sandy, check it out
*	25.04 05:25 AM	Elsie Bassett <BECEZKRWRTH@ACCESSIBLEINFO.COM>	No Obliiii gation
*	24.04 10:00 PM	Fred Pace <jbibktyesnamt@beveragebooks.com>	Professional Loans w
*	24.04 02:36 PM	OEM on Sale <zvrjjhn@hurting.com>	Get 96% Dis.counted OEM Microsc
	24.04 06:01 AM	Stephen Hood <Vern@be-lax.com>	What do you think
	24.04 04:35 AM	Vito Aguirre <Guidry@ilovethemovies.com>	Lose it
	24.04 03:19 AM	Meghan <hwdwysowbypek@jornaldiario.com>	Swiss meds
	24.04 02:42 AM	Perdue <HMHTV@merseymail.com>	, who do u want 2 win?
	23.04 04:42 PM	Thekla Upchurch <mira53.mcclimons@freemail.com.ua>	Heisse News

Details

New
Reply
Forward
Delete
Move

Details

Senders: Thekla Upchurch <mira53.mcclimons@freemail.com.ua>
Date: 23.04 04:42 PM
Recipients: Olaf <supple@web.de>
Subject: Heisse News

Content

Flatratesex, für nur 14,99 Euro kannst Du Dir einen monat lang über 200
Private Livecams
anschaun, dazu noch unzählige Bilder und Videos, ohne 0190 ohne versteckte
Kosten.
Der absolute Hammer !

http://www.sexania.com

Kein Bock mehr auf unsere Mails? Dann einfach hier austragen lassen:
http://www.netporni.com/unsubscribe.php?841034746010487564387 4087

Configuration

Status:

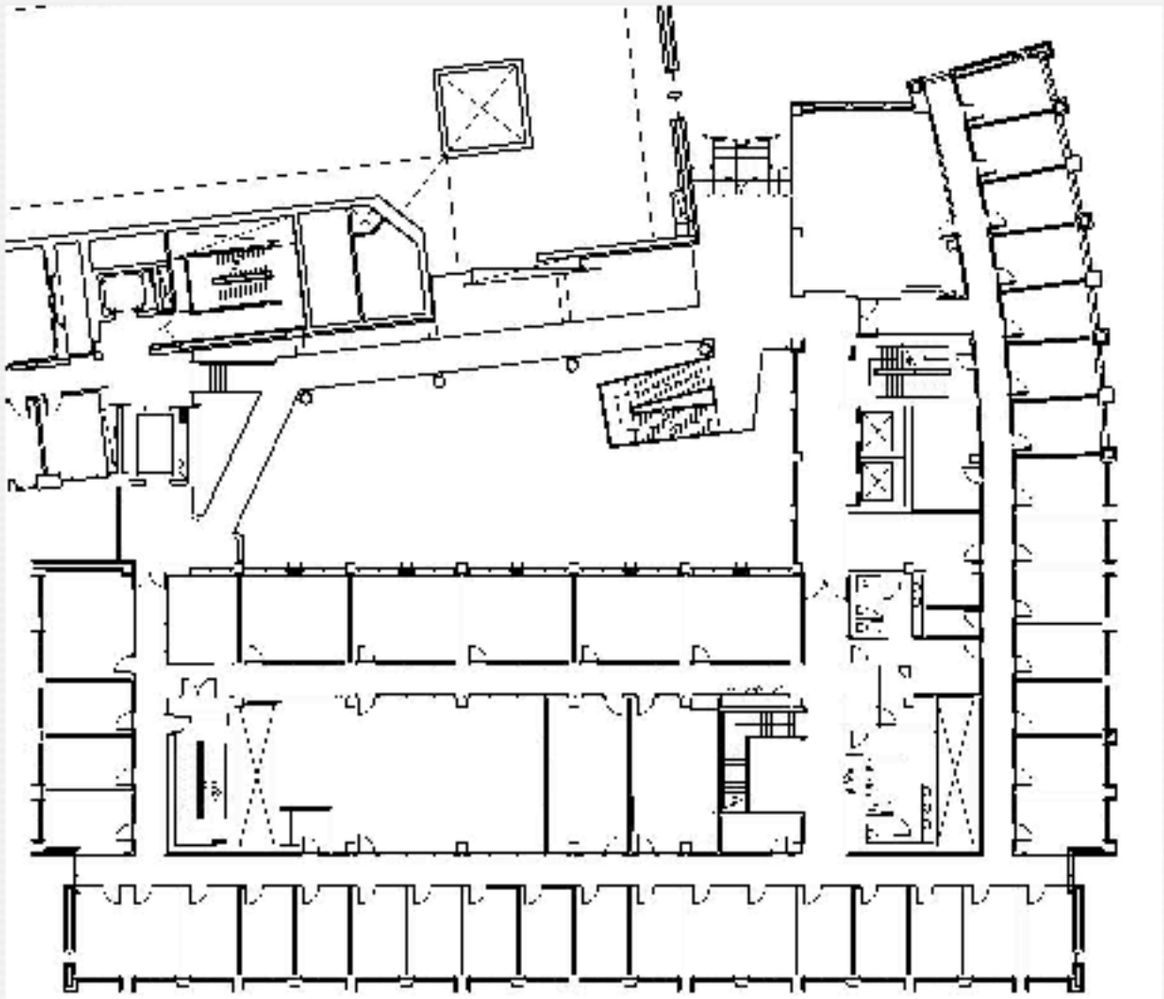
Supple: Map Demo

Properties

Map Demo

Pick a location

The Map



Location: (847.0,240.0)

Info

Photo

Name: Dan

Office: 588

Highly Personalizable!

$(

) == ??

Adapting to Preferences

$(

) = = Preference estimate

[Gajos and Weld, UIST'05]

Adapting to Motor Capabilities

Estimated

$(

) = = task completion time

Road Map

- ✓ Introduction
- ✓ Interface generation as optimization
- > Modeling motor capabilities
- ☐ Adapting to motor capabilities
- ☐ Adapting to vision capabilities
- ☐ Adapting to motor and vision capabilities together

Participants

	Device used	Impairment
Motor-impaired	Mouse	Muscular Dystrophy
	Trackball	Spinal cord injury
	Head Mouse	Spinal cord injury
Unusual device	Eye Tracker	*none*
	Vocal Joystick	*none*
	Vocal Joystick	*none*
	Mouse	*none*
	Track Pad	*none*

Participants

	Device used	Impairment
Motor-impaired	Mouse	Muscular Dystrophy
	Trackball	Spinal cord injury
	Head Mouse	Spinal cord injury
Unusual device	Eye Tracker	*none*
	Vocal Joystick	*none*
	Vocal Joystick	*none*
	Mouse	*none*
	Track Pad	*none*

Participants

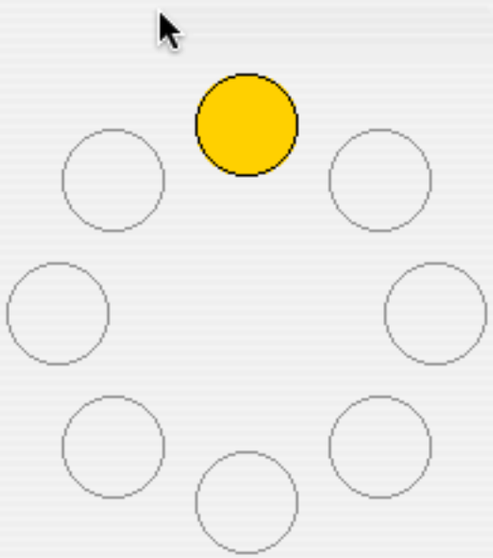
	Device used	Impairment
Motor-impaired	Mouse	Muscular Dystrophy
	Trackball	Spinal cord injury
Unusual device	Head Mouse	Spinal cord injury
	Eye Tracker	*none*
	Vocal Joystick	*none*
	Vocal Joystick	*none*
	Mouse	*none*
	Track Pad	*none*

Participants

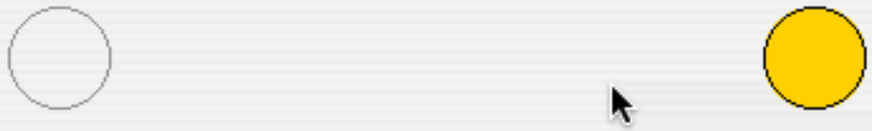
	Device used	Impairment
Motor-impaired	Mouse	Muscular Dystrophy
	Trackball	Spinal cord injury
	Head Mouse	Spinal cord injury
Unusual device	Eye Tracker	*none*
	Vocal Joystick	*none*
	Vocal Joystick	*none*
	Mouse	*none*
	Track Pad	*none*

Elicit a Person's Motor Abilities Model

Pointing

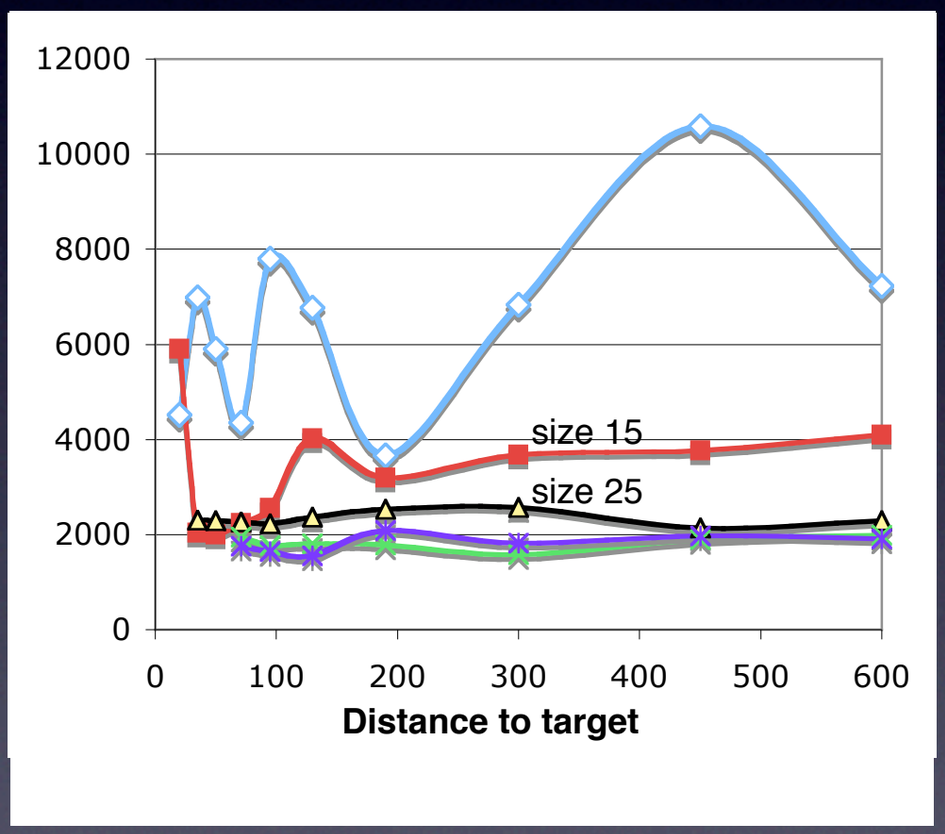


Dragging



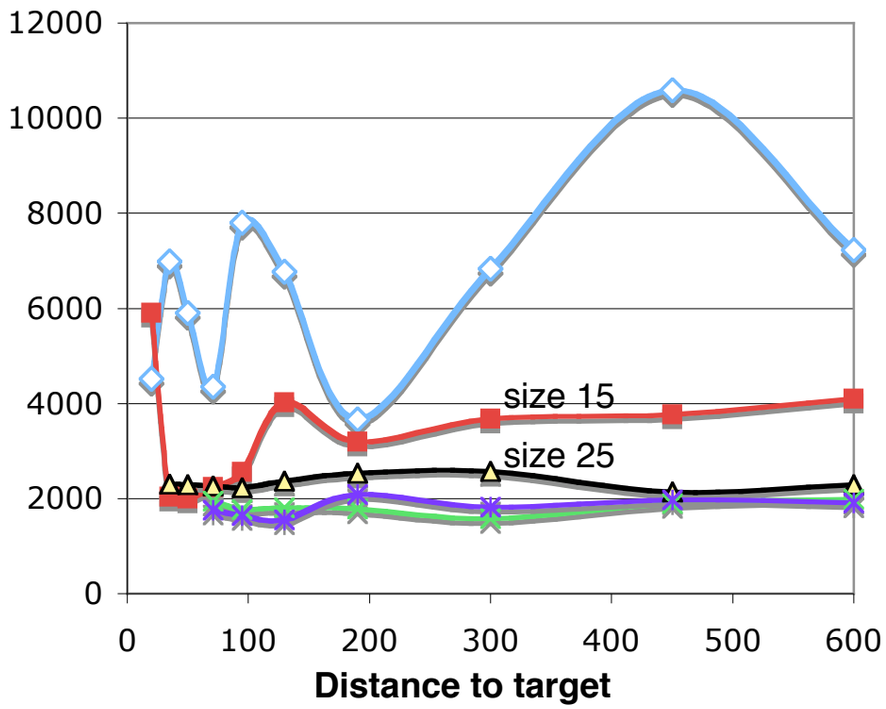
Predicting Movement Time

Actual Data

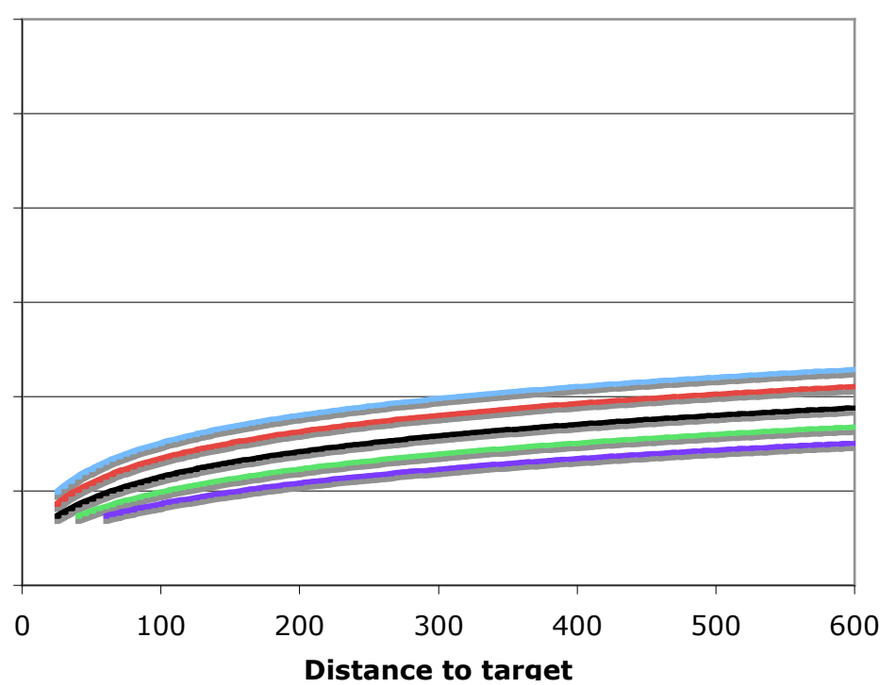


Predicting Movement Time

Actual Data

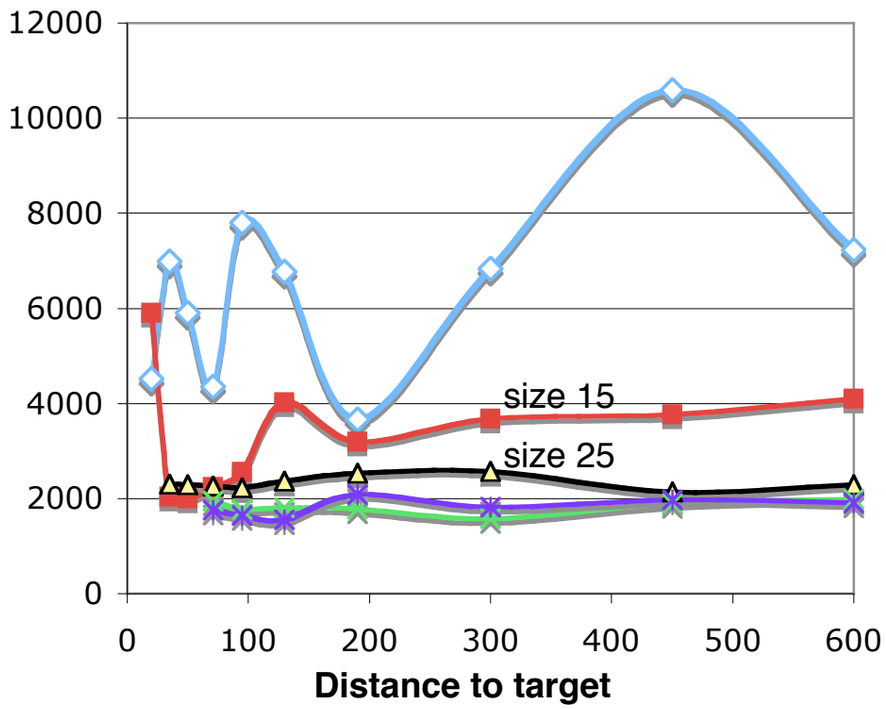


Fitts' Law Prediction

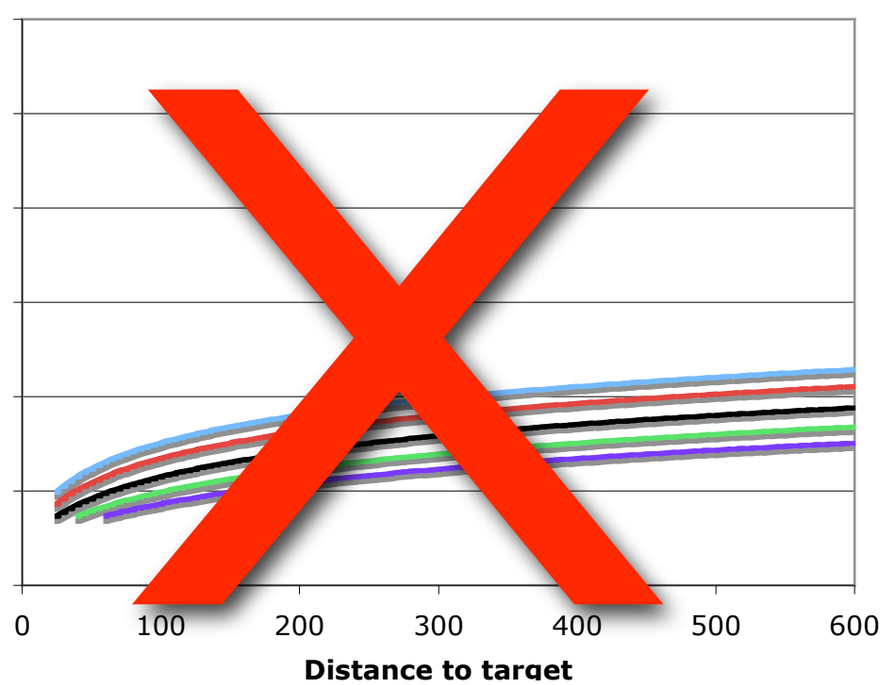


Predicting Movement Time

Actual Data



Fitts' Law Prediction

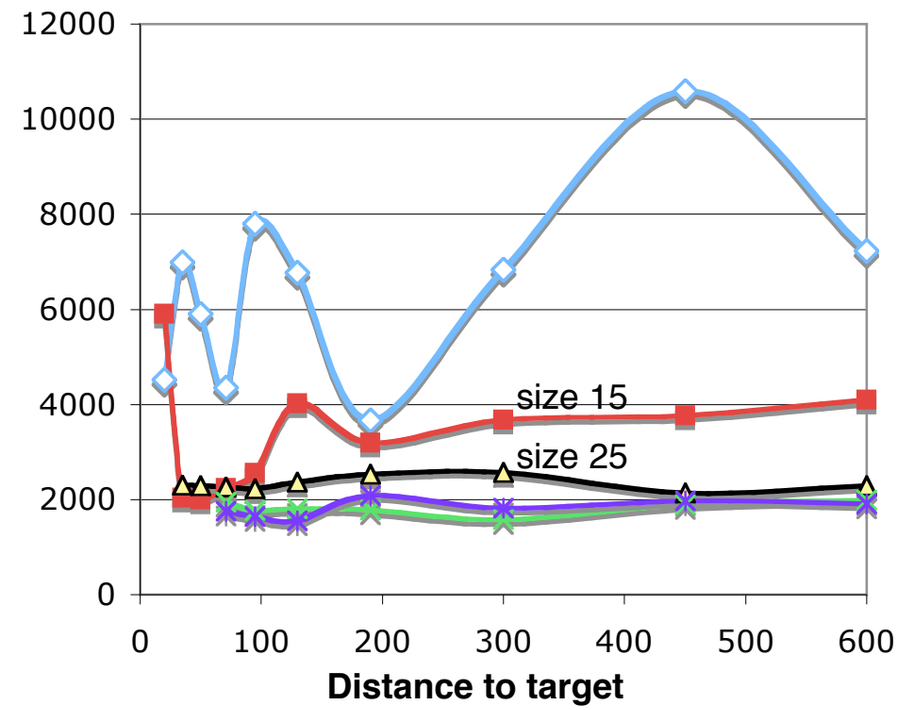


Custom Motor Capability Models

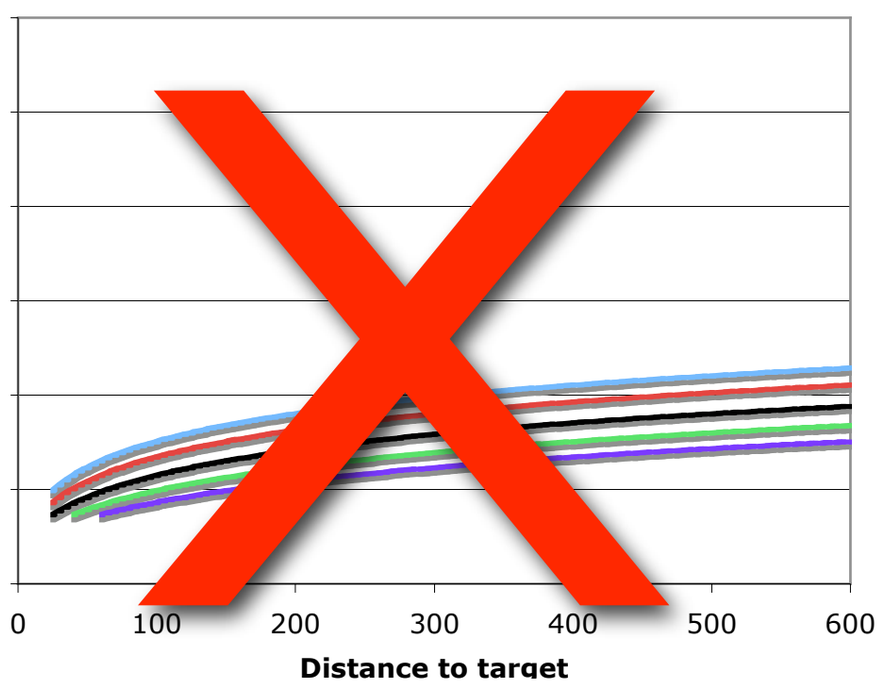
- Supple++
  - Automatically selects the best set of features for a custom regression model for each participant from:
    ID, 1, log(D), log(W), D, 1/W, W
- Trains the models

Predicting Movement Time

Actual Data

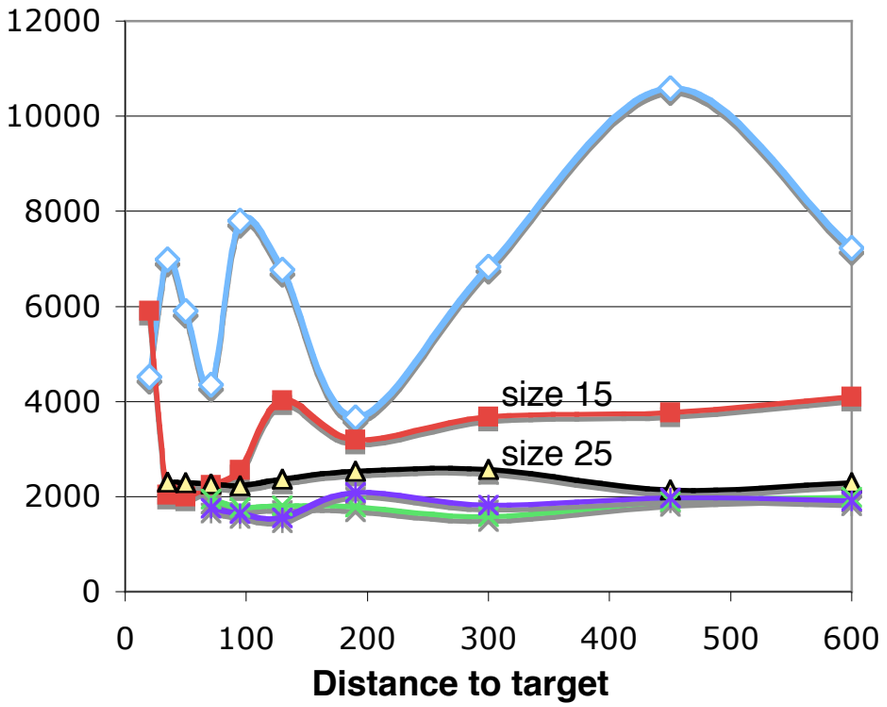


Fitts' Law Prediction

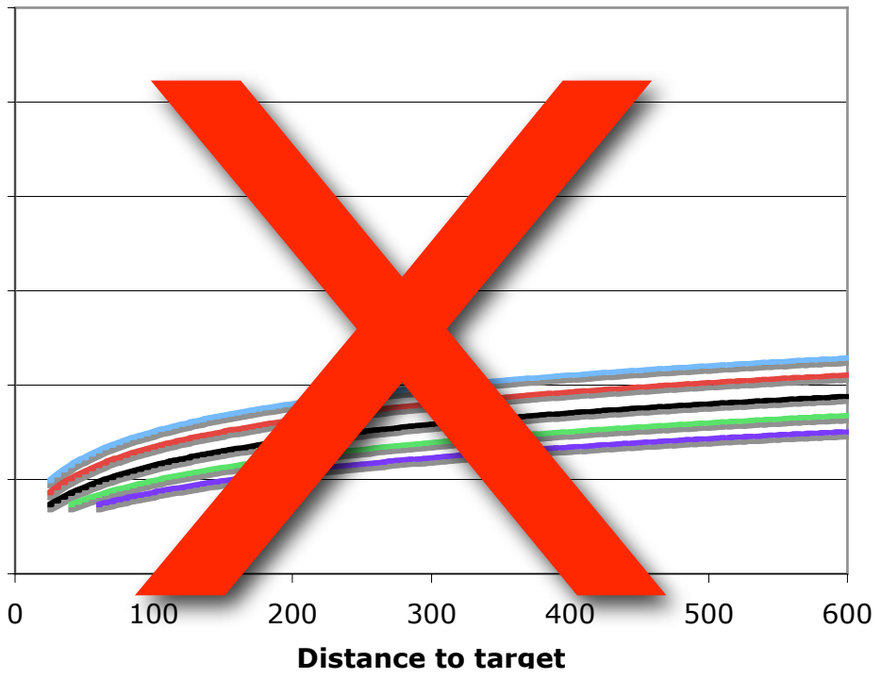


Predicting Movement Time

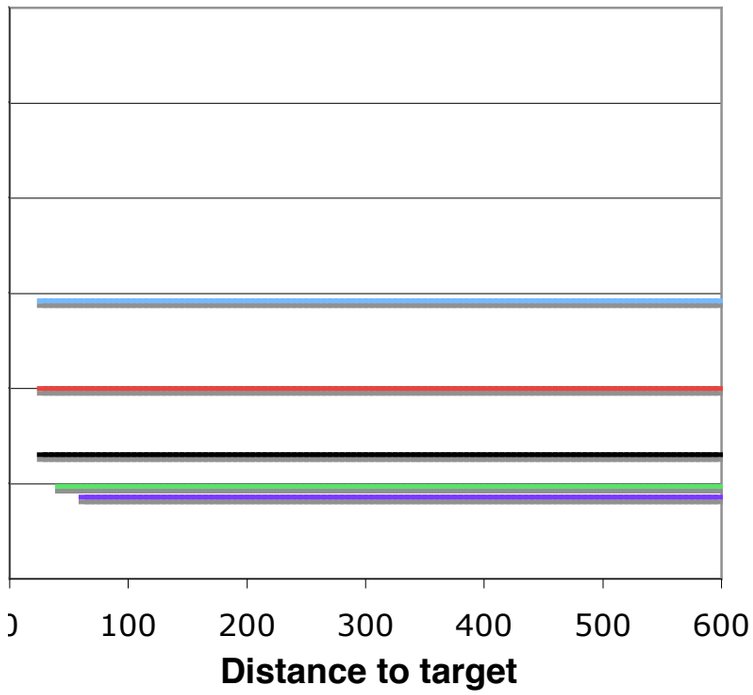
Actual Data



Fitts' Law Prediction



Custom Model



Road Map

- ✓ Introduction
- ✓ Interface generation as optimization
- ✓ Modeling motor capabilities
- > Adapting to motor capabilities
- ☐ Adapting to vision capabilities
- ☐ Adapting to motor and vision capabilities together
- ☐ Pilot User Study
- ☐ Lessons learned

UI Building Blocks

- Widgets

UI Building Blocks

- Widgets
- Layout

UI Building Blocks

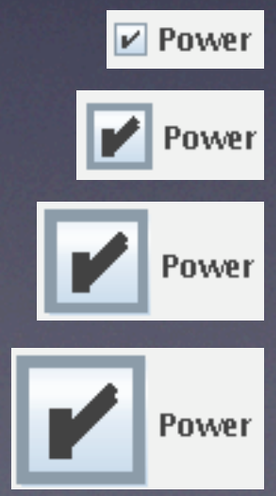
- Widgets
- Layout
- Structure (divide into windows, pop-ups, tabs)

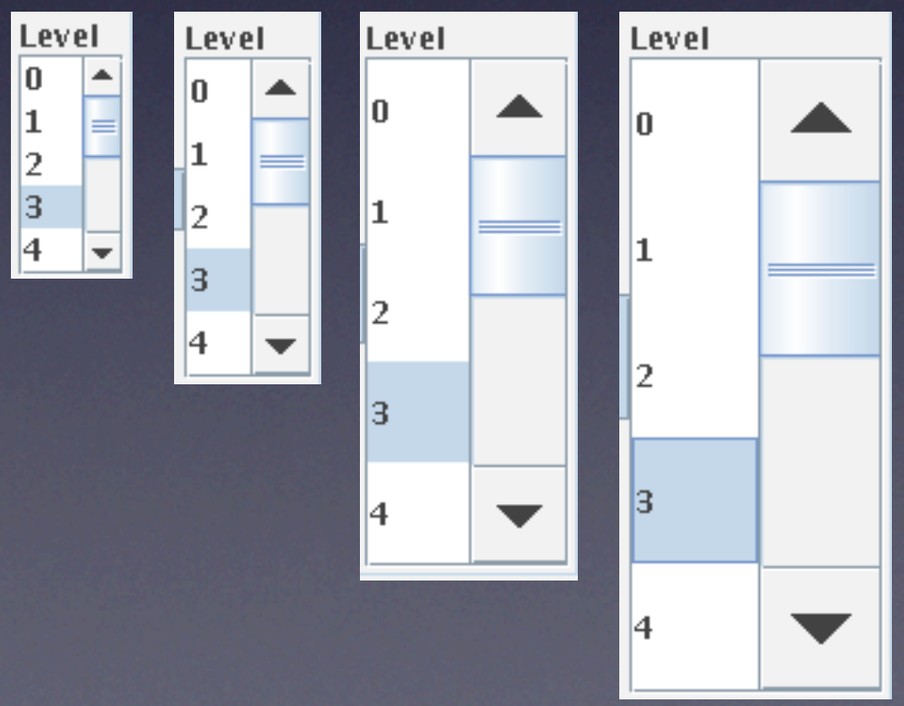
UI Building Blocks

- Widgets
- Layout
- Structure (divide into windows, pop-ups, tabs)
- Size of interactors

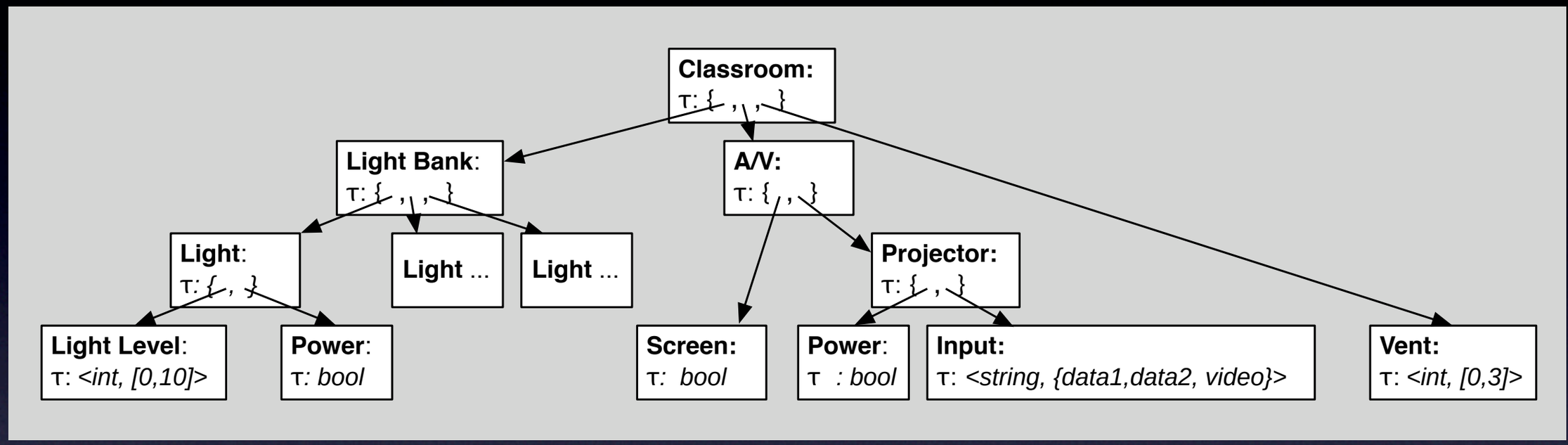
UI Building Blocks

- Widgets
- Layout
- Structure (divide into windows, pop-ups, tabs)
- Size of interactors

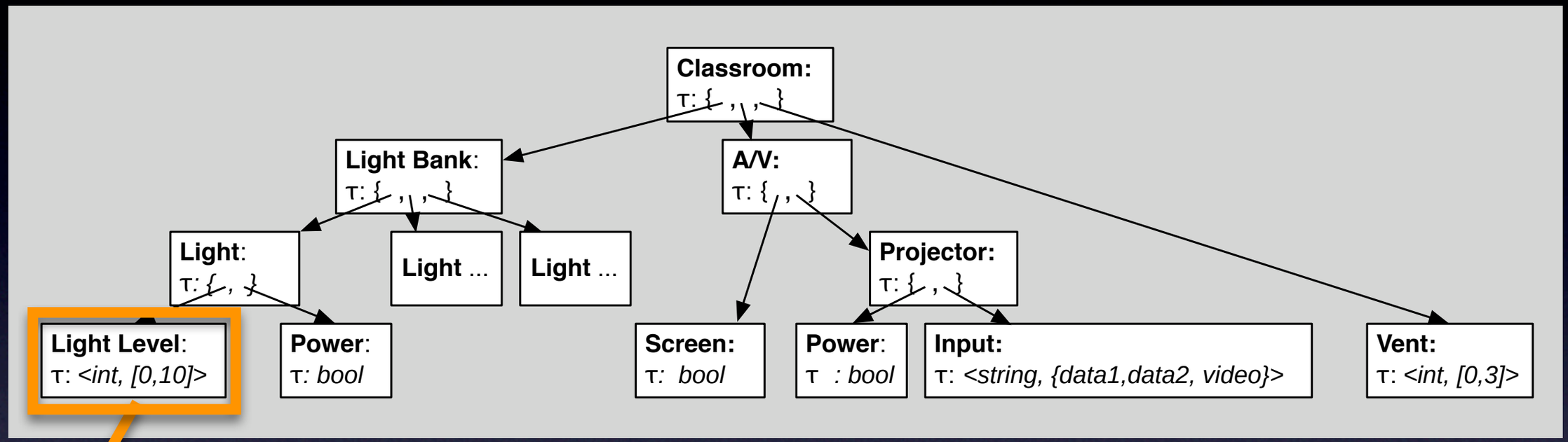


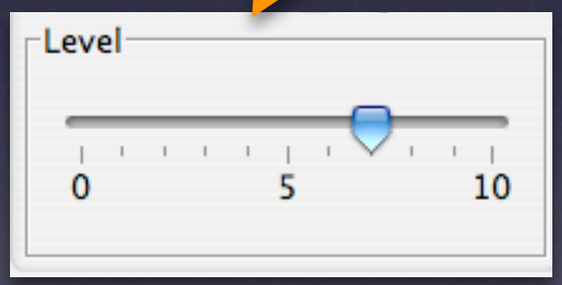


Optimization as Search

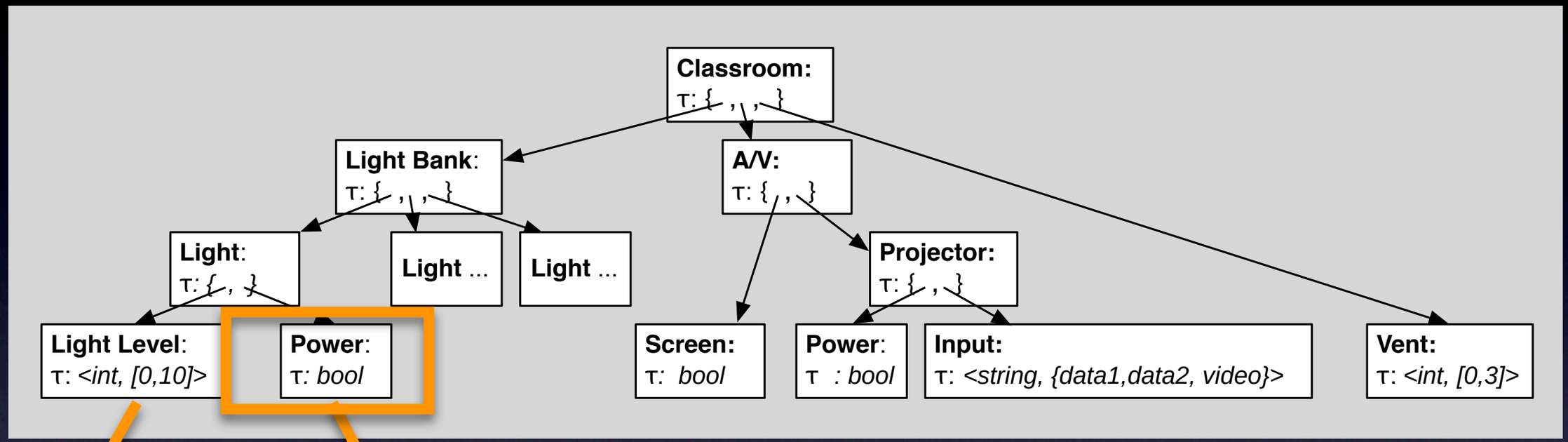


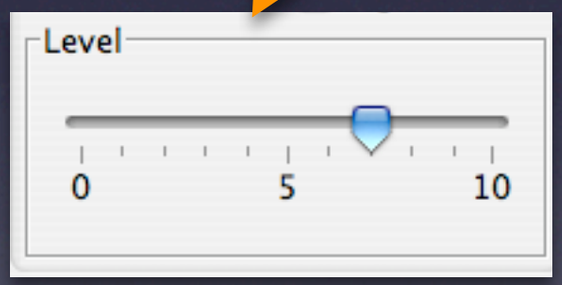
Optimization as Search



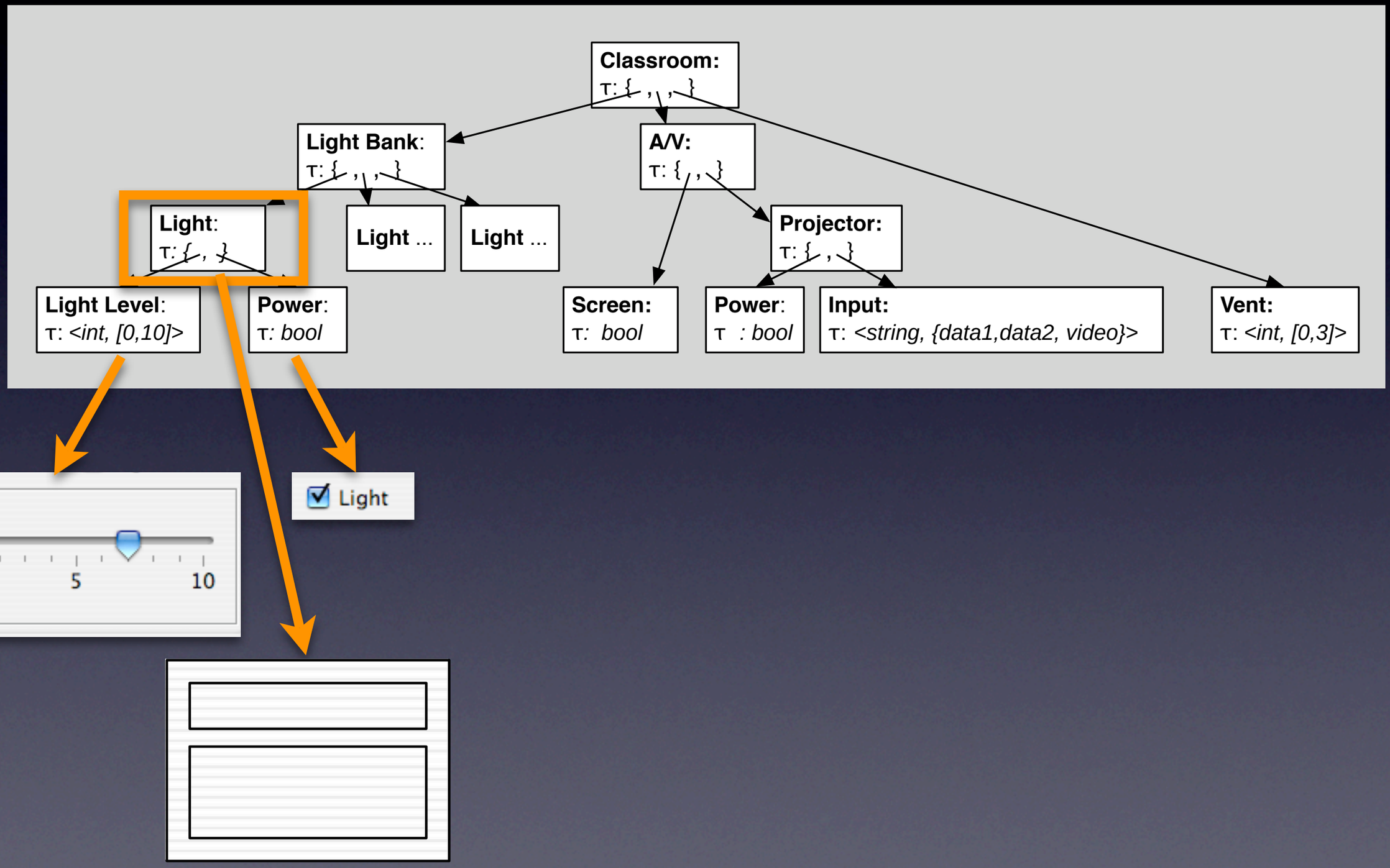


Optimization as Search

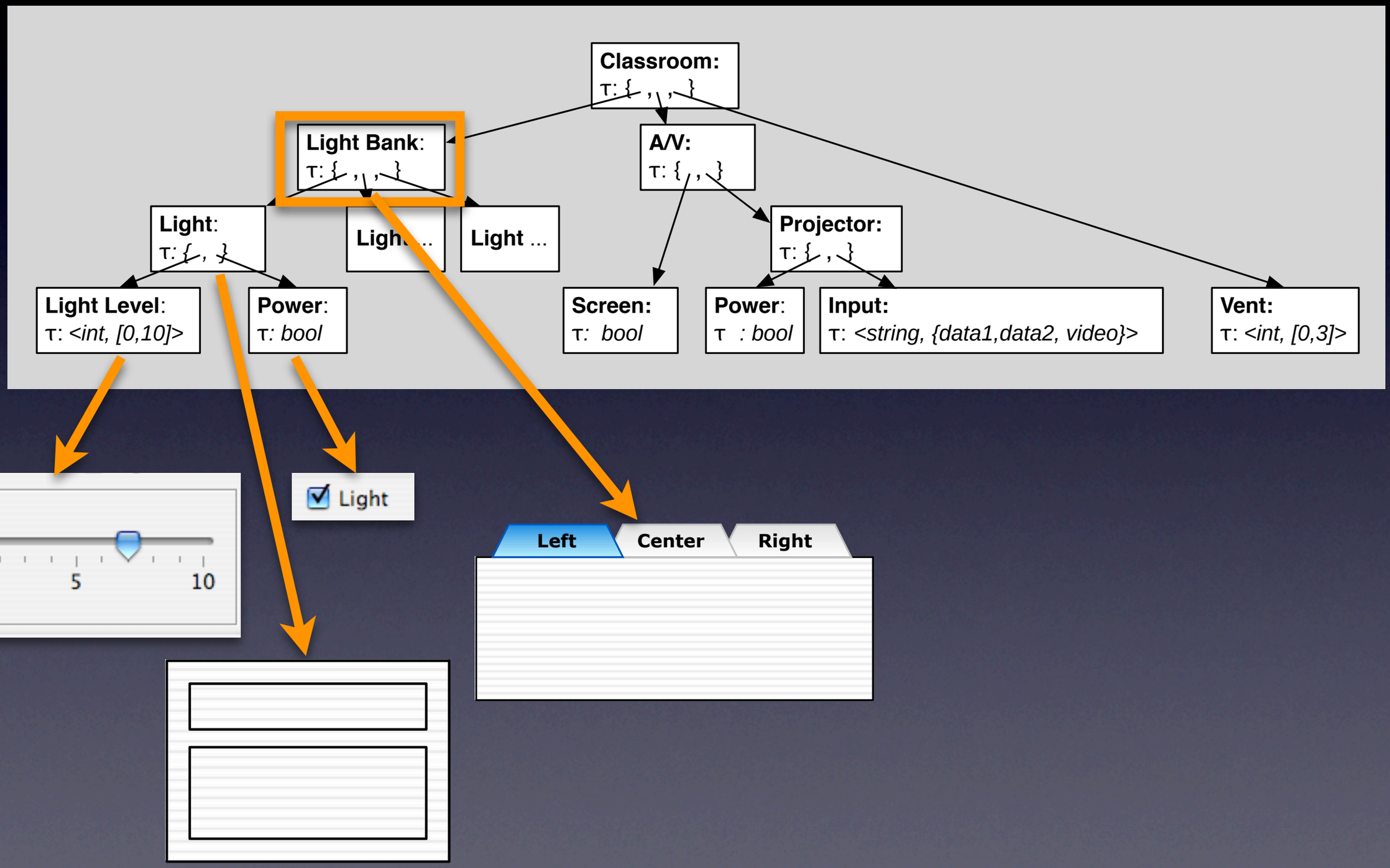




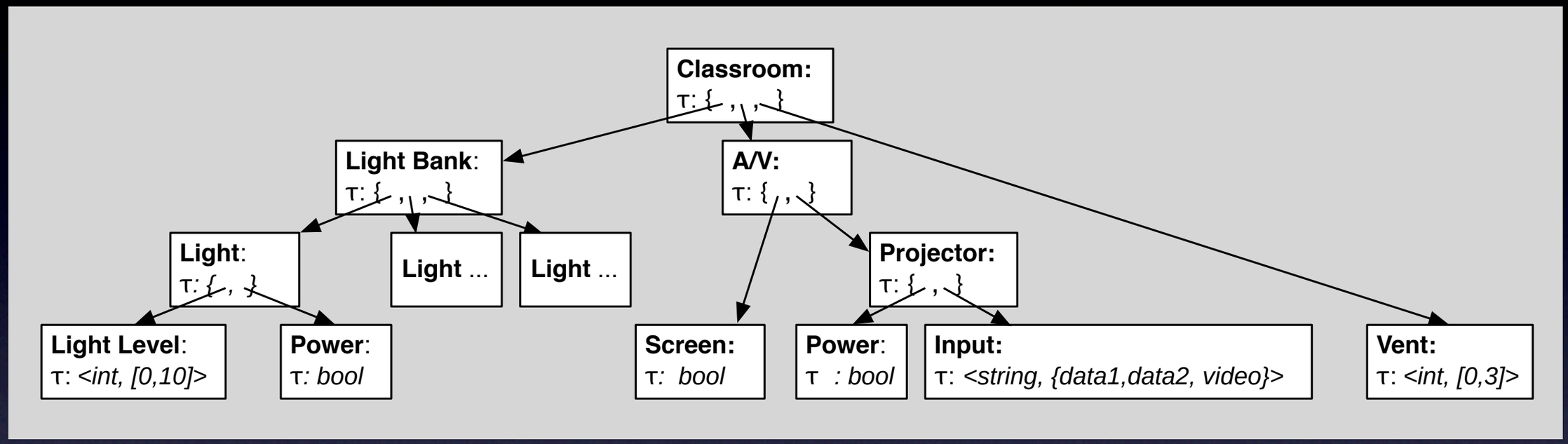
Optimization as Search

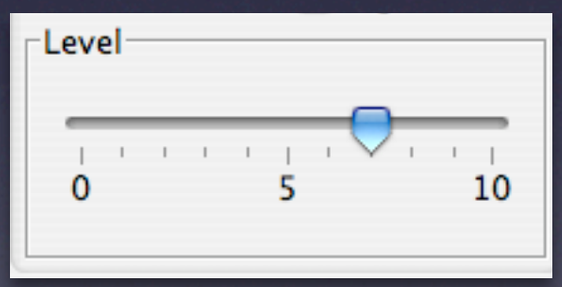


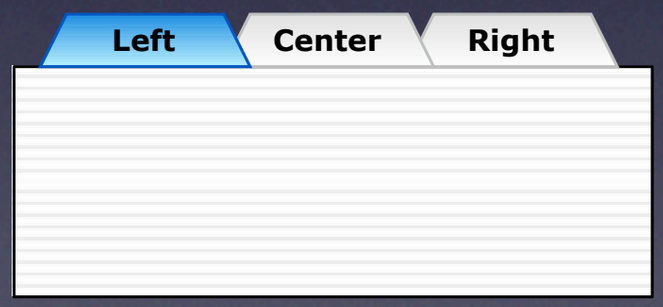
Optimization as Search



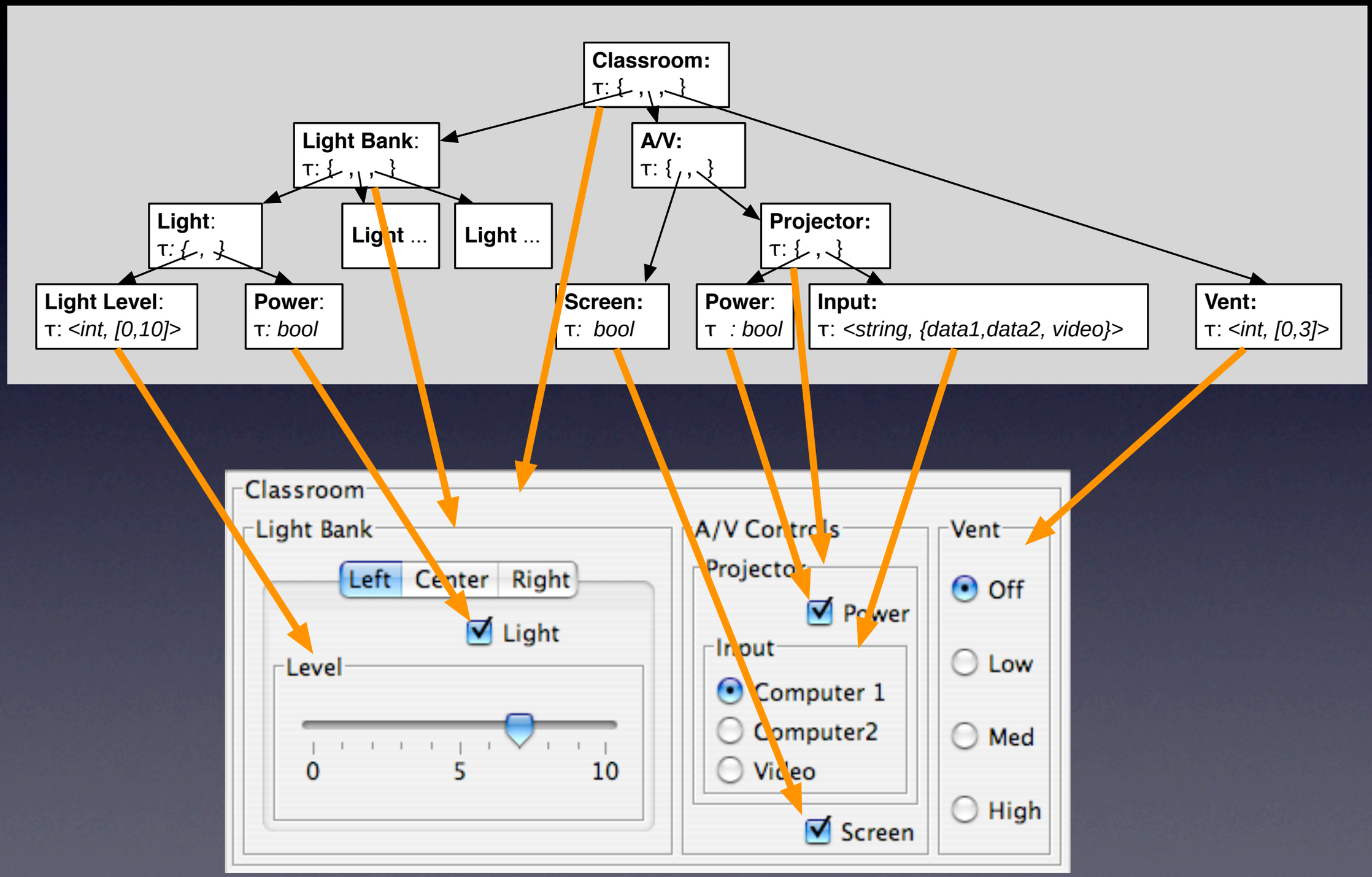
Optimization as Search



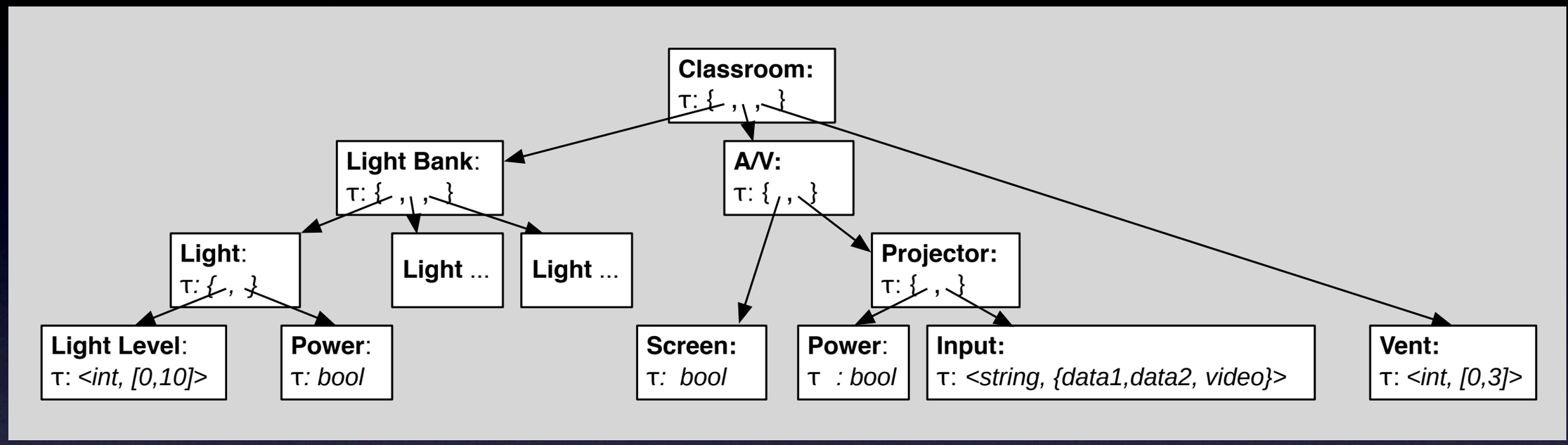




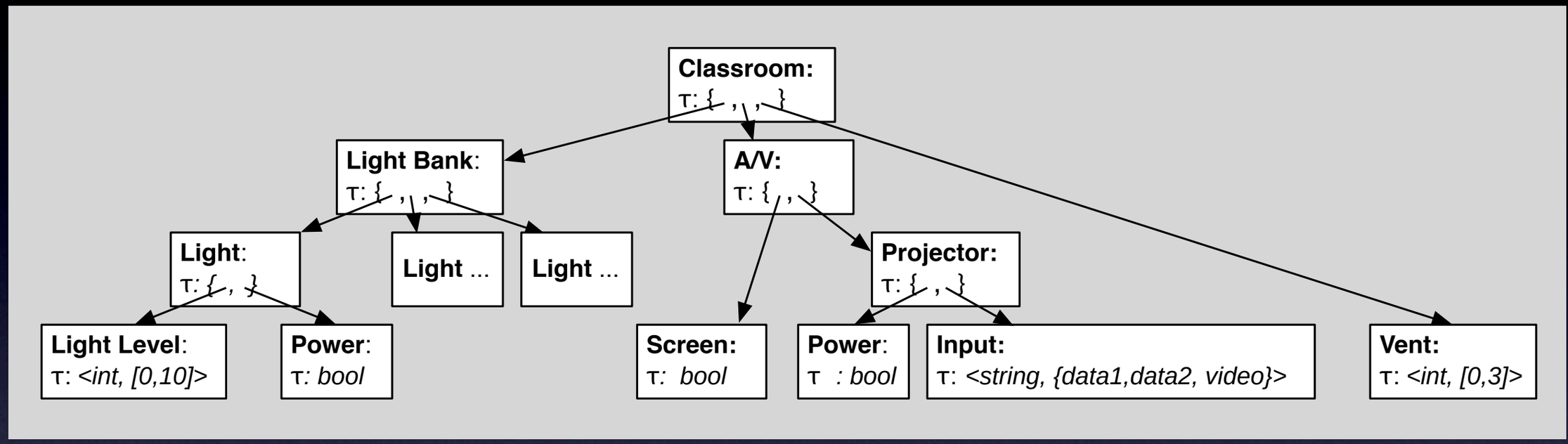
Optimization as Search

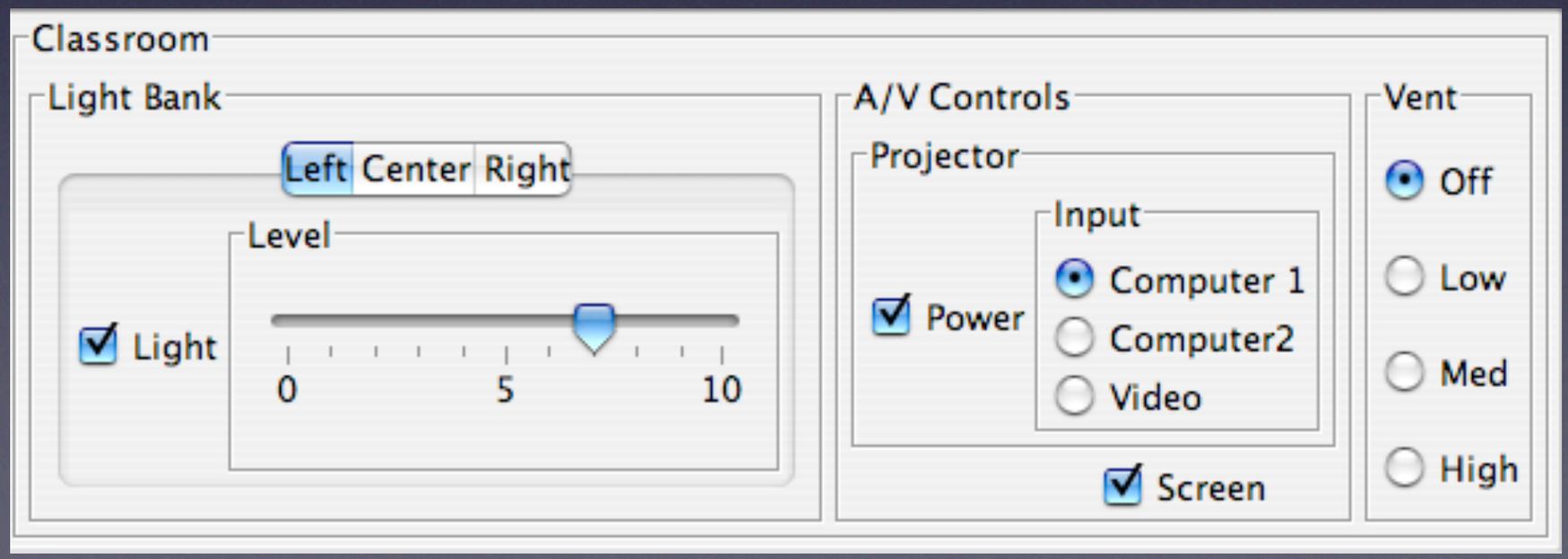


Optimization as Search

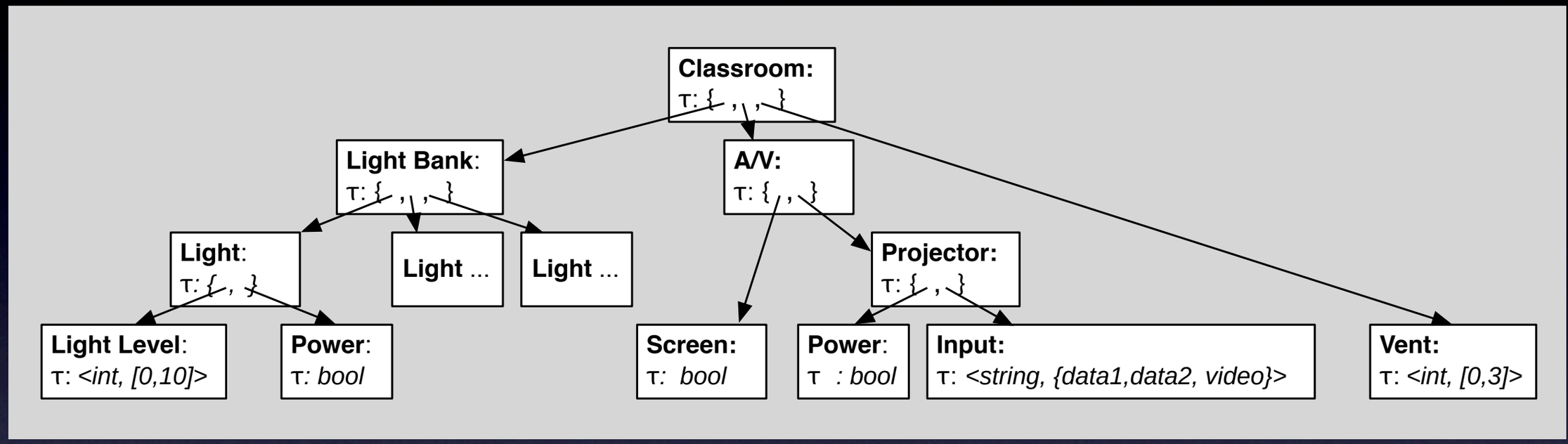


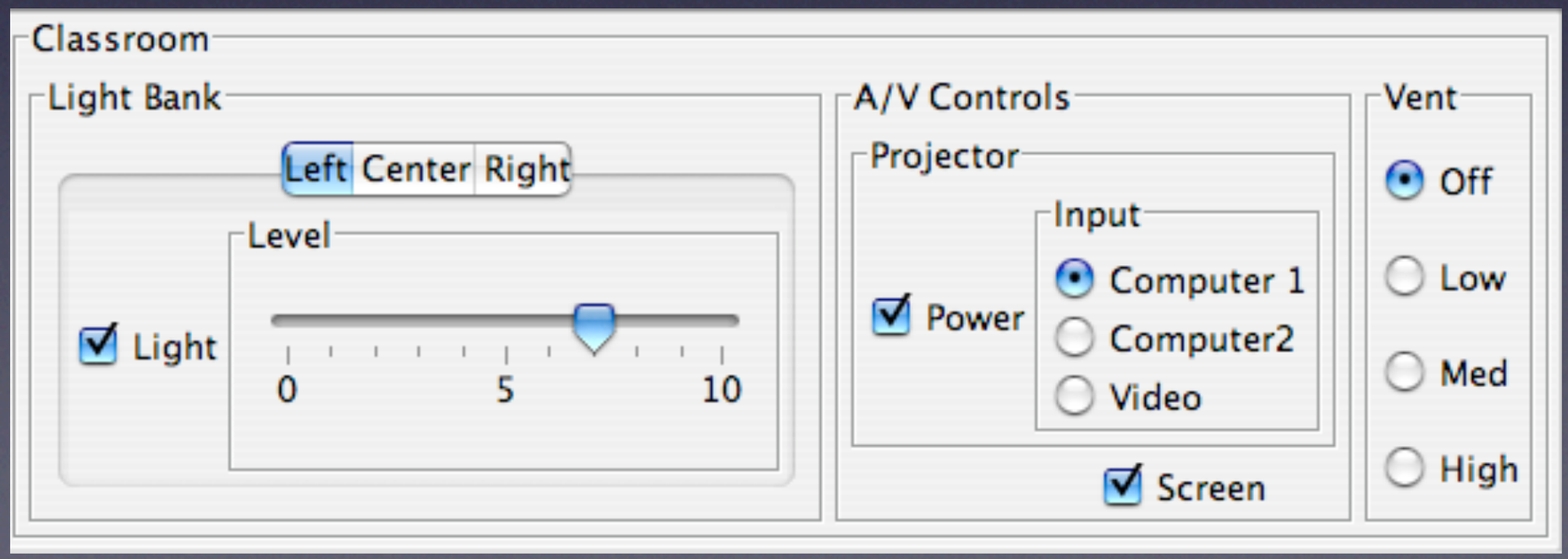
Optimization as Search





Optimization as Search





Optimization as Search

Enumerate all the options: **~370 years**

Light Level:
τ: <*int, [0,10]*>

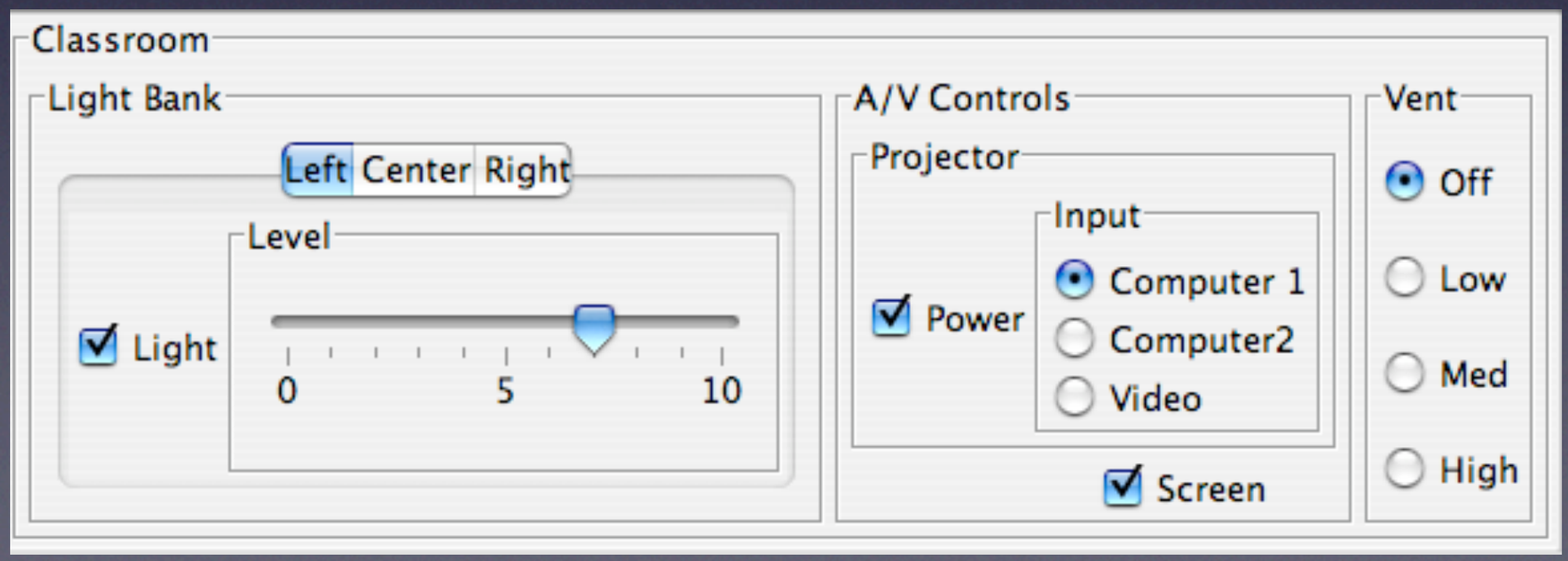
Power:
τ: *bool*

Screen:
τ: *bool*

Power:
τ : *bool*

Input:
τ: <*string, {data1,data2, video}*>

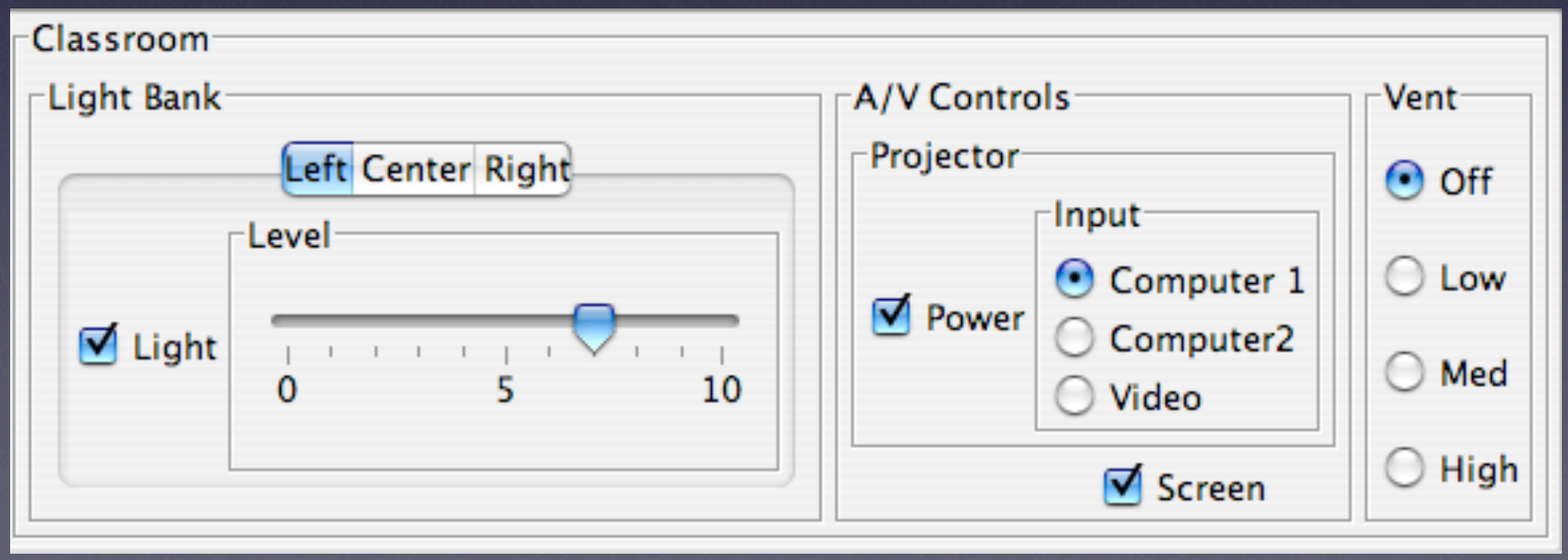
Vent:
τ: <*int, [0,3]*>



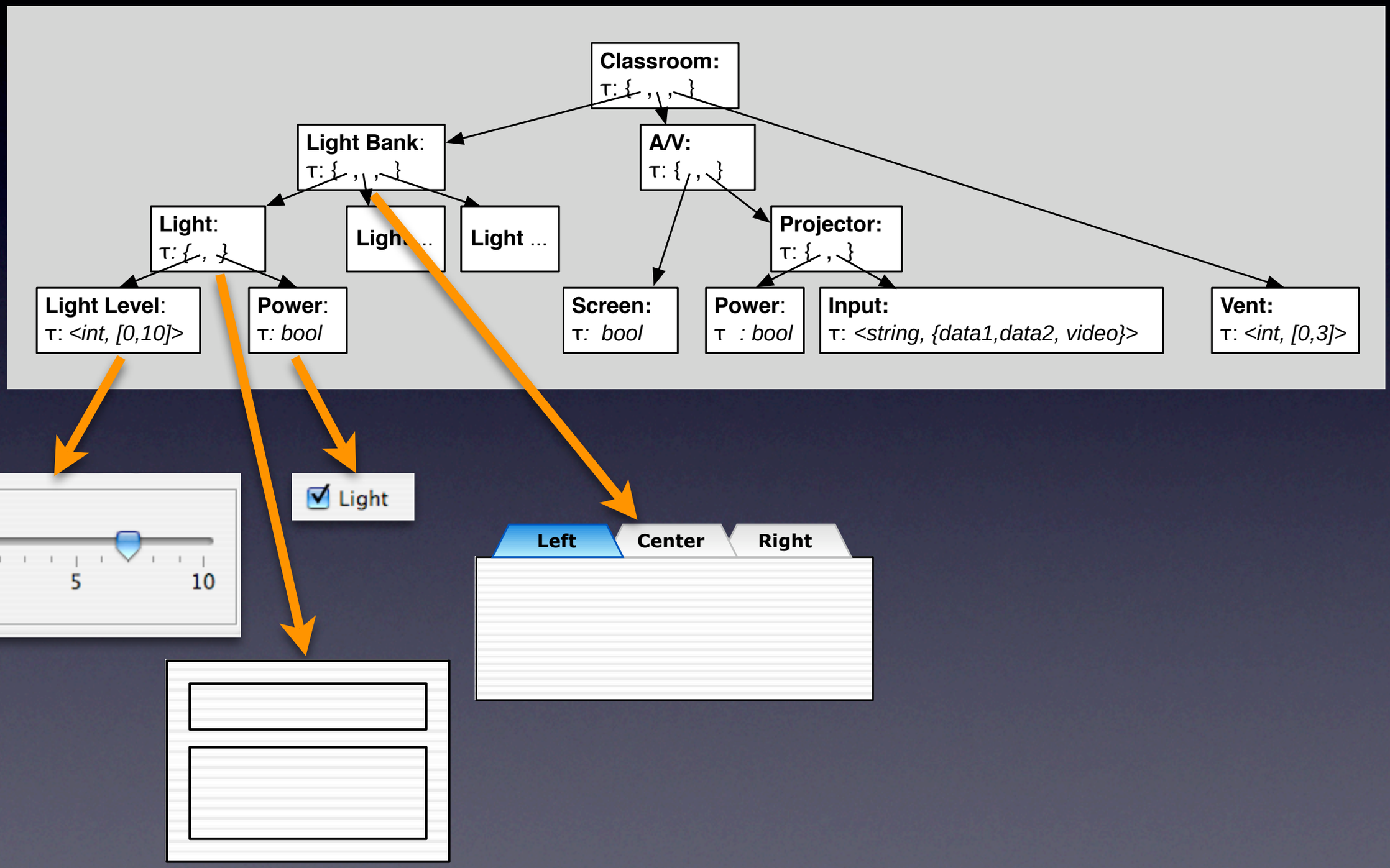
Optimization as Search

Enumerate all the options: **~370 years**

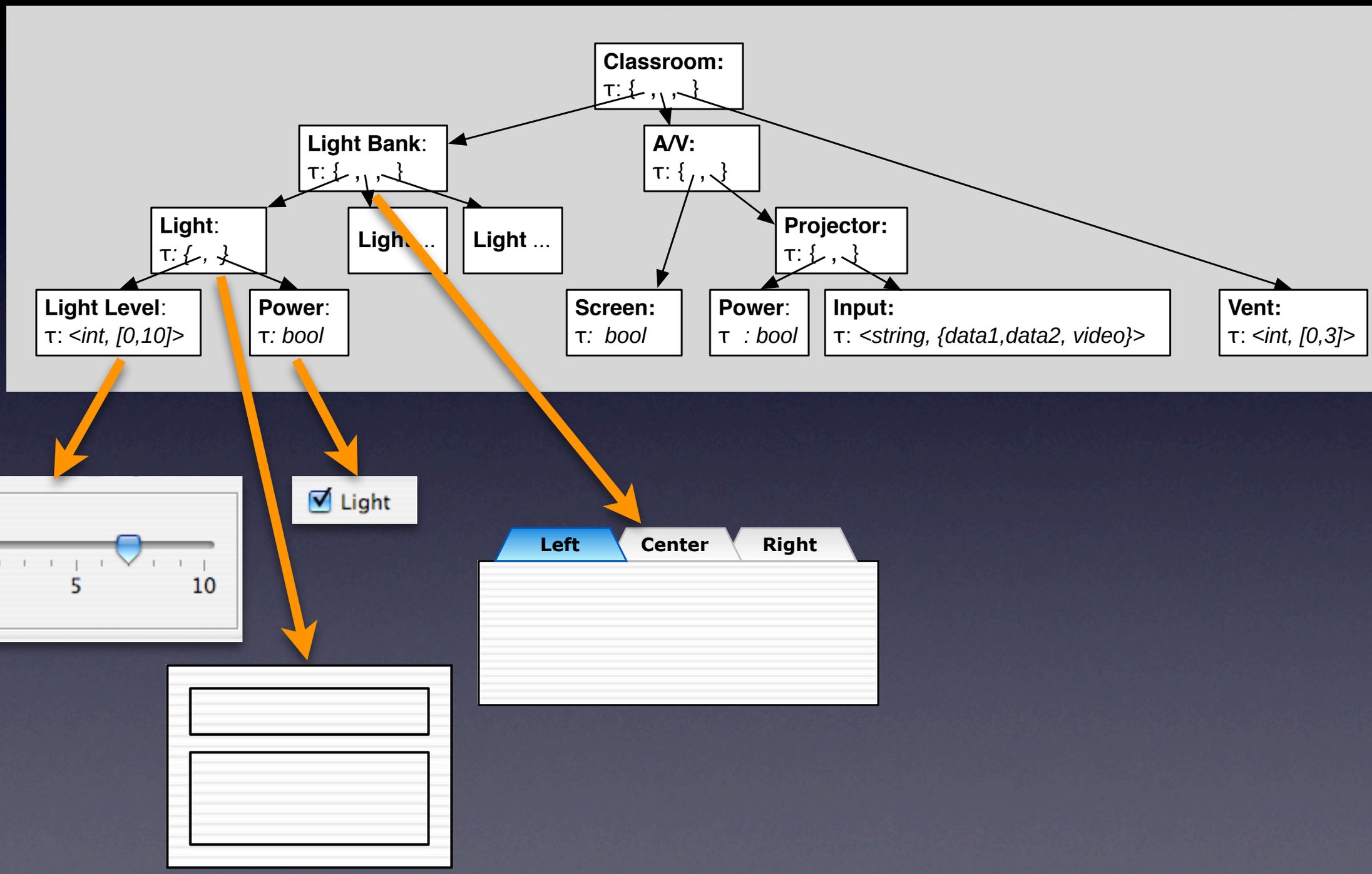
Supple: **~2 seconds**



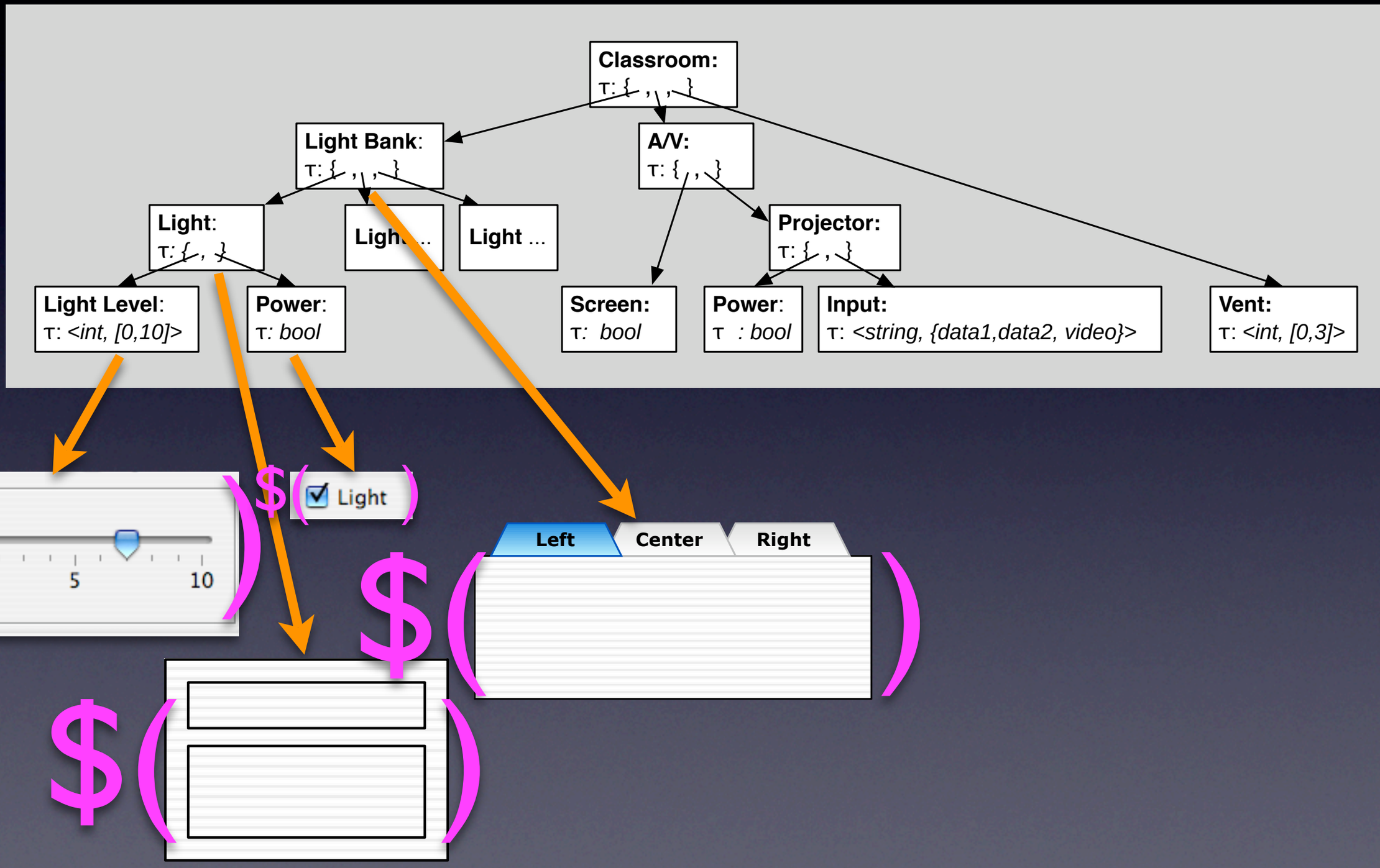
Optimization as Search



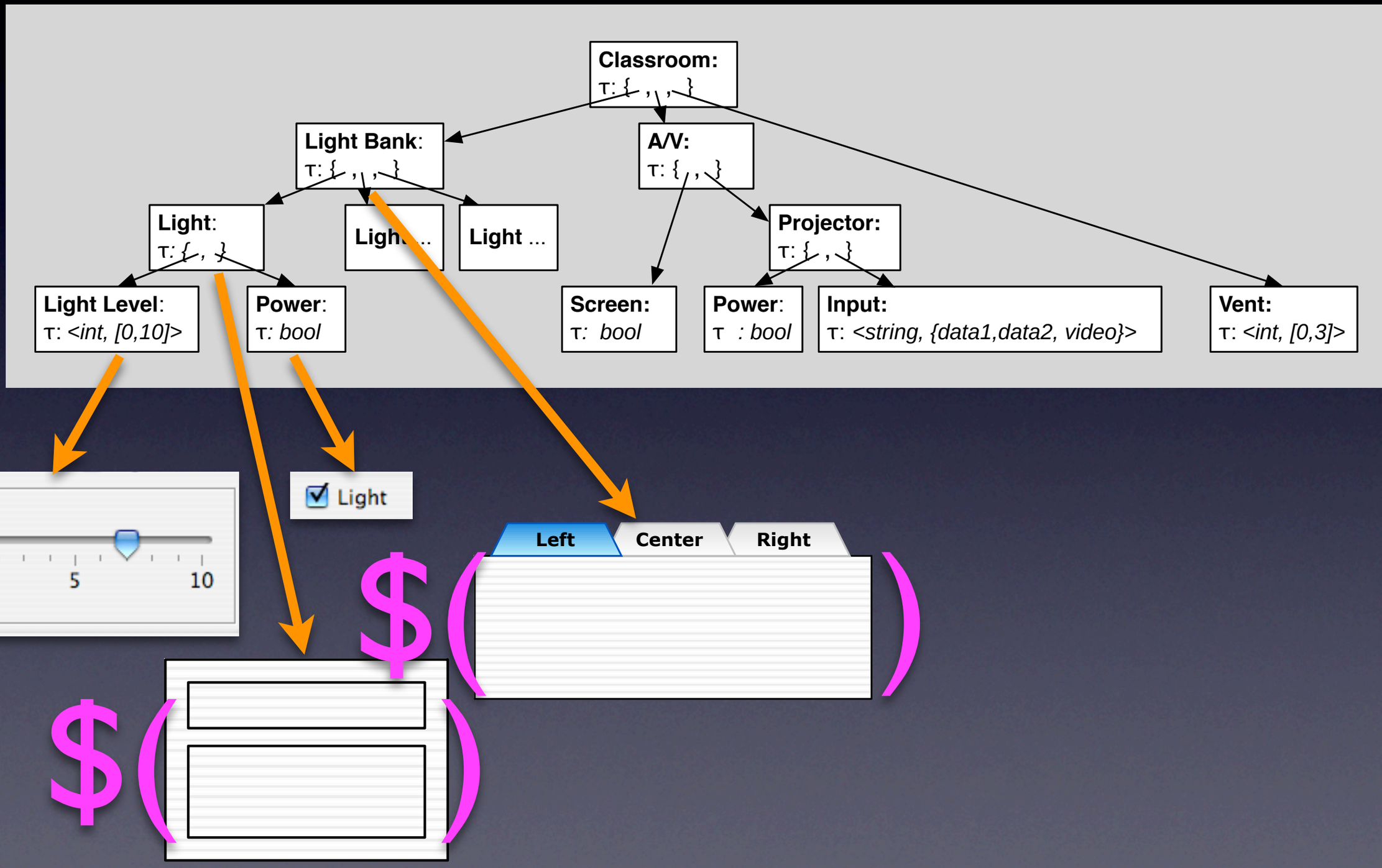
Optimization as Search



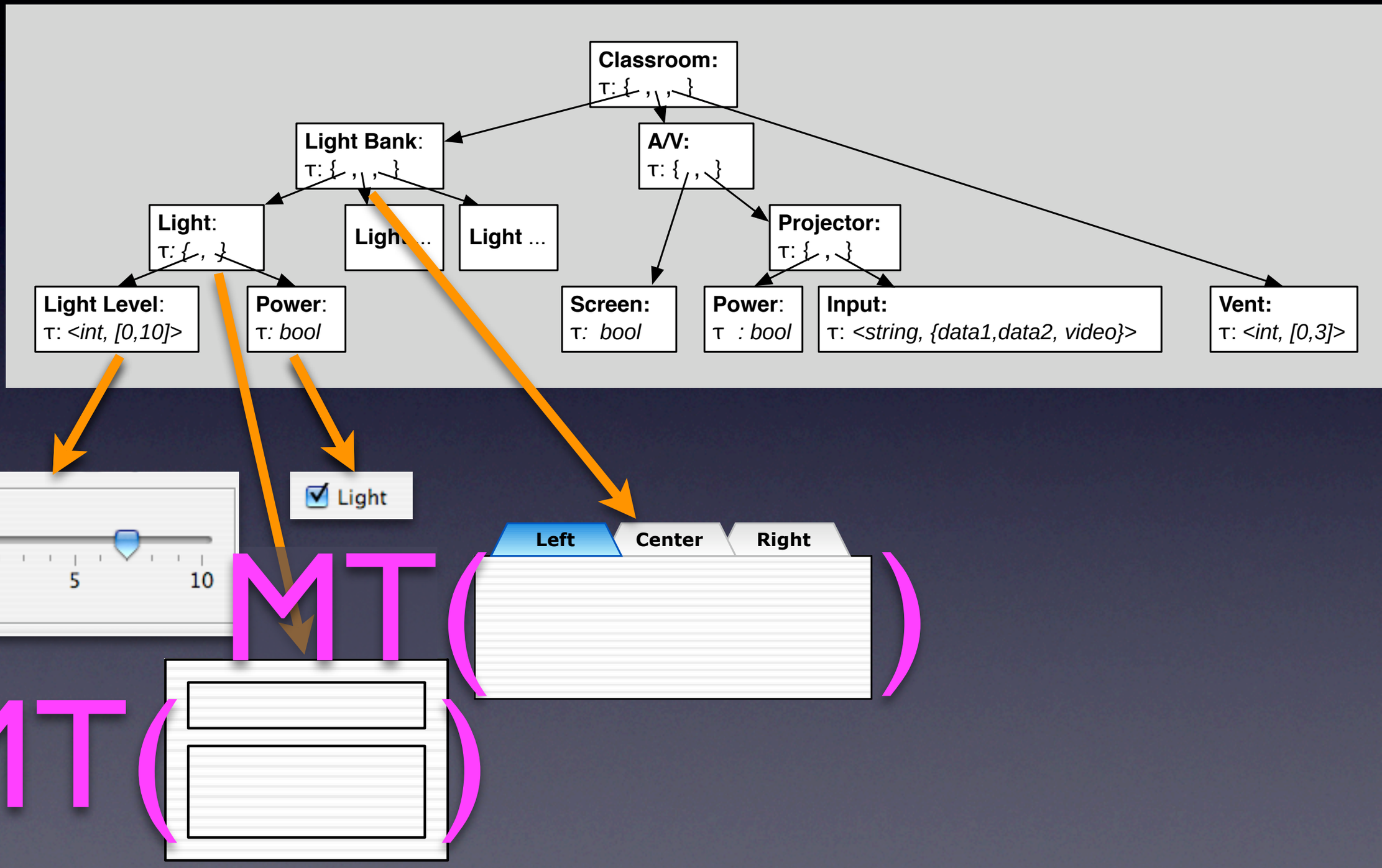
Optimization as Search



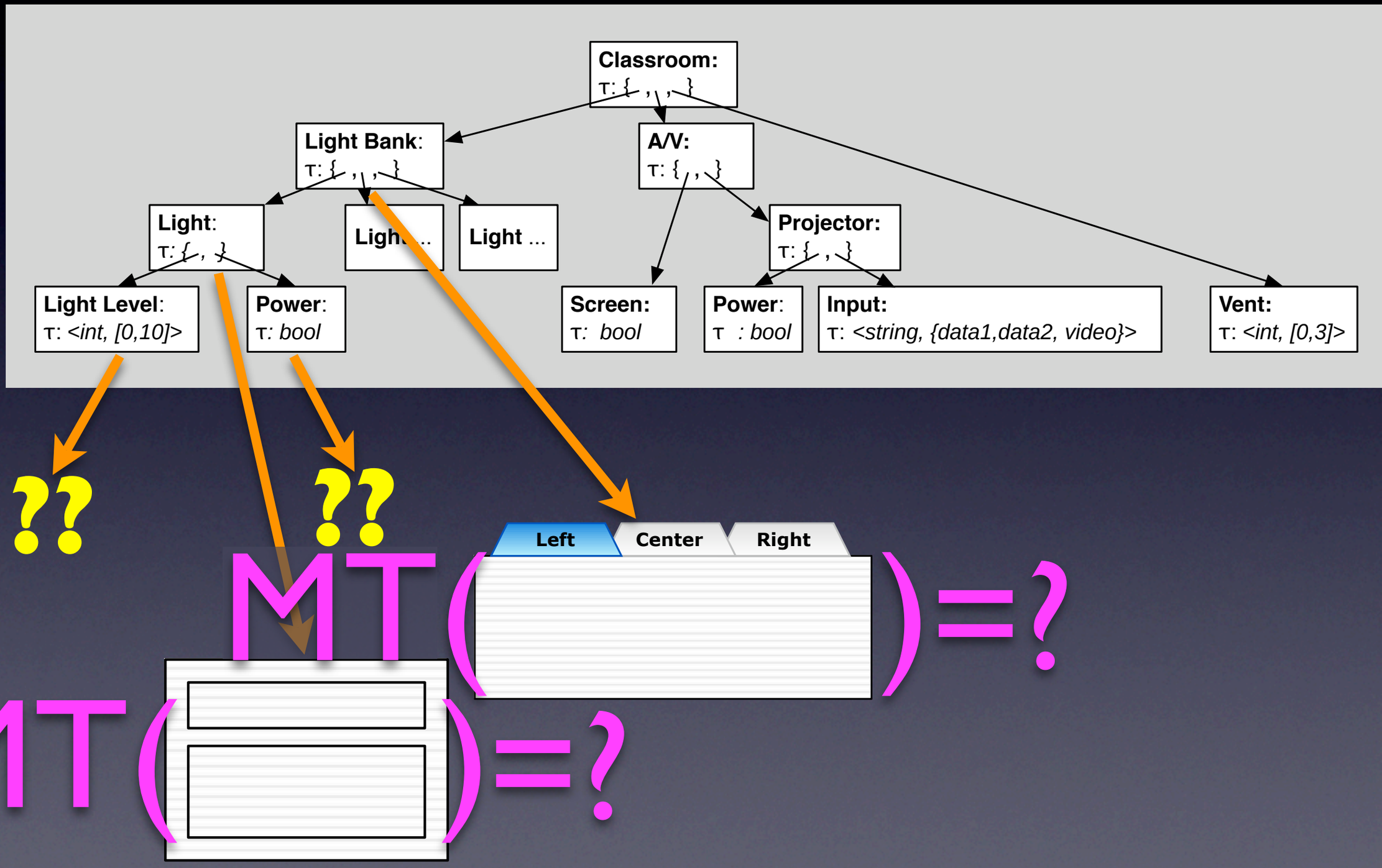
Optimization as Search



Optimization as Search



Optimization as Search



Optimization as Search

Use Supple to optimize for motor abilities:

hours or days

Vent:
τ: *<int, [0,3]>*

??

??

MT( )=?

MT( )=?

Left | Center | Right

Supple++

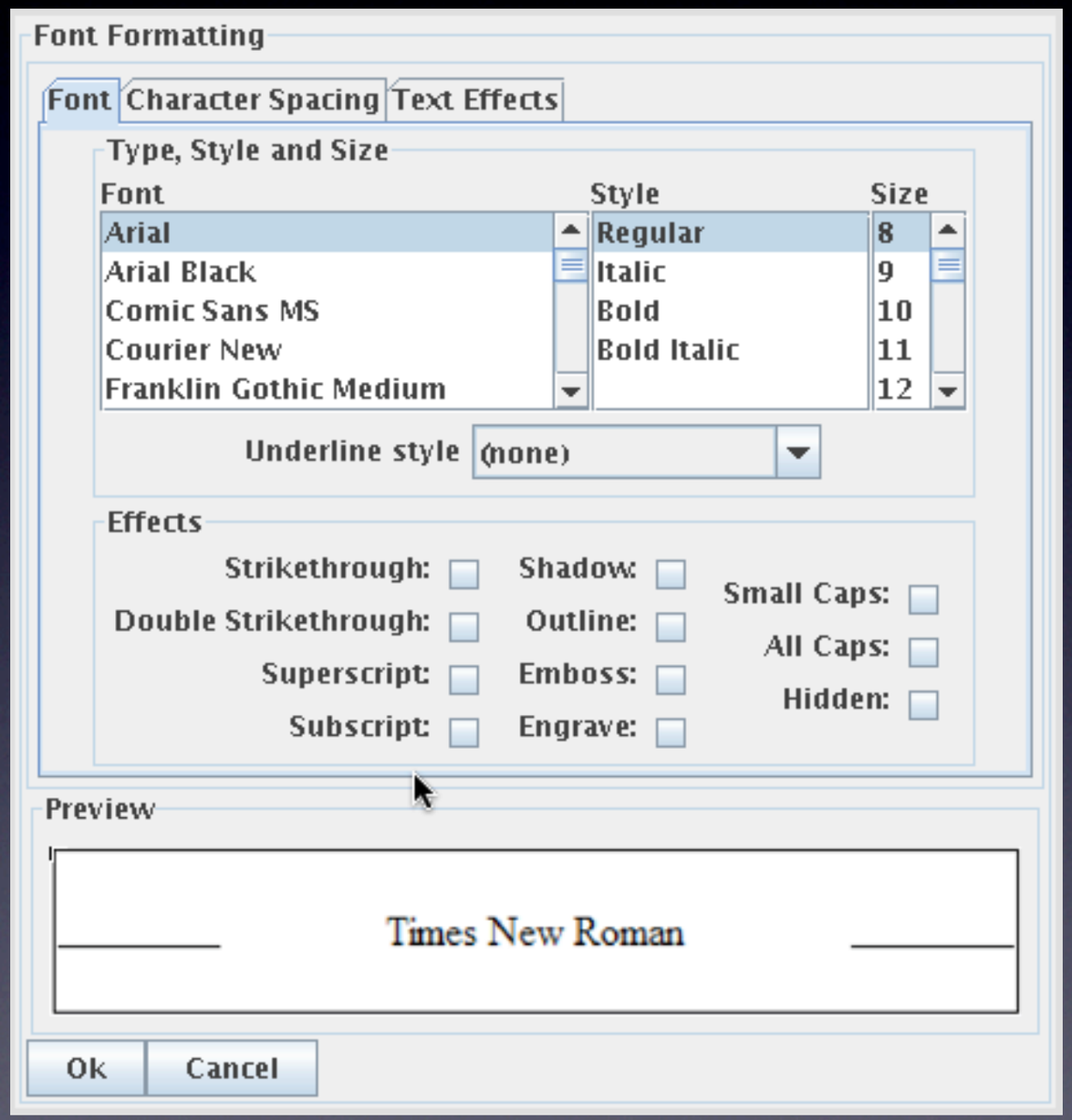
- Novel optimization-based algorithm computes a lower bound on movement time through a layout even before all the widgets are chosen

Supple++

- Novel optimization-based algorithm computes a lower bound on movement time through a layout even before all the widgets are chosen

Use **Supple++** to optimize for motor abilities:
seconds or minutes

Results


Font Formatting
Font
Character Spacing
Text Effects
Type, Style and Size
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Style
Size
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Arial Black
Comic Sans MS
Courier New
Franklin Gothic Medium
Regular
Italic
Bold
Bold Italic
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12
Underline style
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Effects
Strikethrough:
Double Strikethrough:
Superscript:
Subscript:
Shadow:
Outline:
Emboss:
Engrave:
Small Caps:
All Caps:
Hidden:
Preview
Times New Roman
Ok
Cancel

Font | Character Spacing | Text Effects

Type, Style and Size

Font	Style	Size
Arial	Regular	8
Arial Black	Italic	9
Comic Sans MS	Bold	10
Courier New	Bold Italic	11
Franklin Gothic Medium		12
Italic		13
Gautami		14
Georgia		15
Helvetica		16
Latha		17
Lucida Console		18
Lucida Sans Unicode		19
Microsoft Sans Serif		20
Modern MS Sans Serif		21
MS Serif		22
My Boli		23
Palatino Linotype		24
Roman		25
Script		26
Small Fonts		27
Symbol		28
Tahoma		29
Times New Roman		30
Trebuchet MS		31
Tunga		32
Verdana		33
Webdings		34
WingDings		35
		36
		37

Underline style

- (none)
- Single solid
- Double solid
- Dotted
- Dashed
- Wavy

Effects

- Strikethrough
- Double Strikethrough
- Superscript
- Subscript
- Shadow
- Outline
- Emboss
- Engrave
- Small Caps
- All Caps
- Hidden

Ok

Cancel

Preview

Times New Roman

Font | Character Spacing | Text Effects

Type, Style and Size

Font	Style	Size
Arial	Regular	8
Arial Black	Italic	9
Comic Sans MS	Bold	10
Courier New	Bold Italic	11
Franklin Gothic Medium		12
Italic		13
Gautami		14
Georgia		15
Helvetica		16
Latha		17
Lucida Console		18
Lucida Sans Unicode		19
Microsoft Sans Serif		20
Modern MS Sans Serif		21
MS Serif		22
Mv Boli		23
Palatino Linotype		24
Roman		25
Script		26
Small Fonts		27

Underline style

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- Single solid
- Double solid
- Dotted
- Dashed
- Wavy

Effects

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- Double Strikethrough
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- Small Caps
- All Caps
- Hidden

Ok

Cancel

Preview

Times New Roman

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Underline style

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Single solid

Double solid

Dotted

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Wavy

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Double Strikethrough

Superscript

Subscript

Shadow

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All Caps

Hidden

Ok

Cancel

Times New Roman

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Underline style

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Double solid

Dotted

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Strikethrough

Double Strikethrough

Superscript

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Underline style

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Single solid
Double solid
Dotted
Dashed
Wavy

Effects

Strikethrough
Double Strikethrough
Superscript
Subscript
Shadow
Outline
Emboss
Engrave
Small Caps
All Caps
Hidden

Ok
Cancel

Times New Roman

Size

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Underline style

(none)
Single solid
Double solid
Dotted
Dashed
Wavy

Effects

Strikethrough
Double Strikethrough
Superscript
Subscript
Shadow
Outline
Emboss
Engrave
Small Caps
All Caps
Hidden

Times New Roman

Font | Character Spacing | Text Effects

Type, Style and Size

Font	Style	Size
Arial	Regular	8
Arial Black	Italic	9
Comic Sans MS	Bold	10
Courier New	Bold Italic	11
Franklin Gothic Medium		12
Italic		13
Gautami		14
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MS Serif		22
Mv Boli		23
Palatino Linotype		24
Roman		25
Script		26
Small Fonts		27

Underline style

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Single solid

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Font Formatting

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Type, Style and Size

Font	Style	Size
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Arial Black	Italic	9
Comic Sans MS	Bold	10
Courier New	Bold Italic	11
Franklin Gothic Medium		12
Italic		13
Gautami		14
Georgia		15
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Lucida Console		18
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Microsoft Sans Serif		20
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MS Serif		22
Mv Boli		23
Palatino Linotype		24
Roman		25
Script		26
Small Fonts		27
Symbol		28
Tahoma		20

Underline style

(none)
Single solid
Double solid
Dotted
Dashed
Wavy

Effects

- Strikethrough
- Double Strikethrough
- Superscript
- Subscript
- Shadow
- Outline
- Emboss
- Engrave
- Small Caps
- All Caps
- Hidden

Character Spacing

Scale

200%
150%
100%
90%
80%

Spacing

Normal
Expanded
Condensed

By

0
1
2
3
4
5
6
7
8
9

Position

Normal
Raised
Lowered

By

0
1
2
3
4

Kerning for fonts

Points and above

8
9
10
11
12
13
14
15
16
17

Text Effects

Animations

(none)
Blinking Background
Las Vegas Lights
Marching Black Ants
Marching Red Ants
Shimmer
Sparkle Text

Ok

Cancel

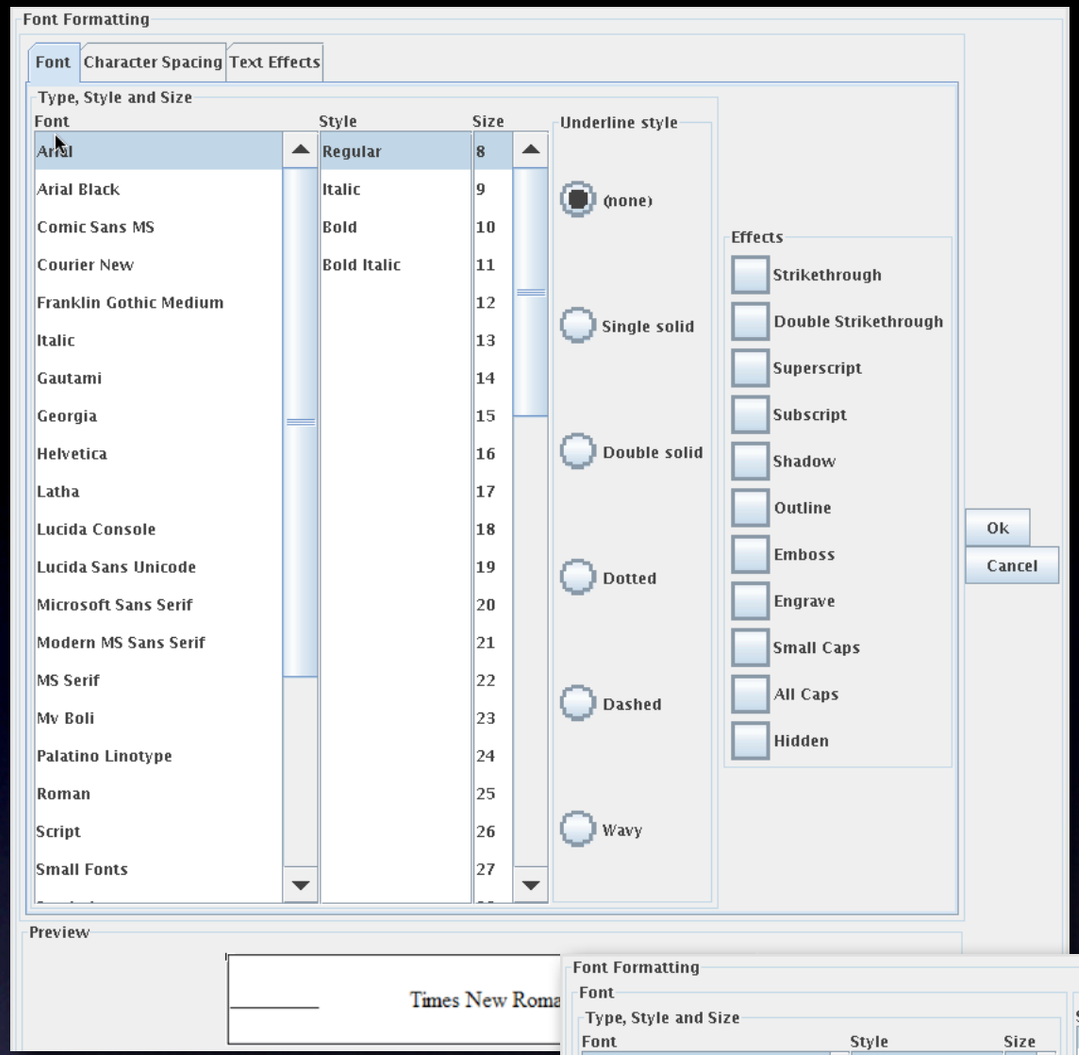
Preview

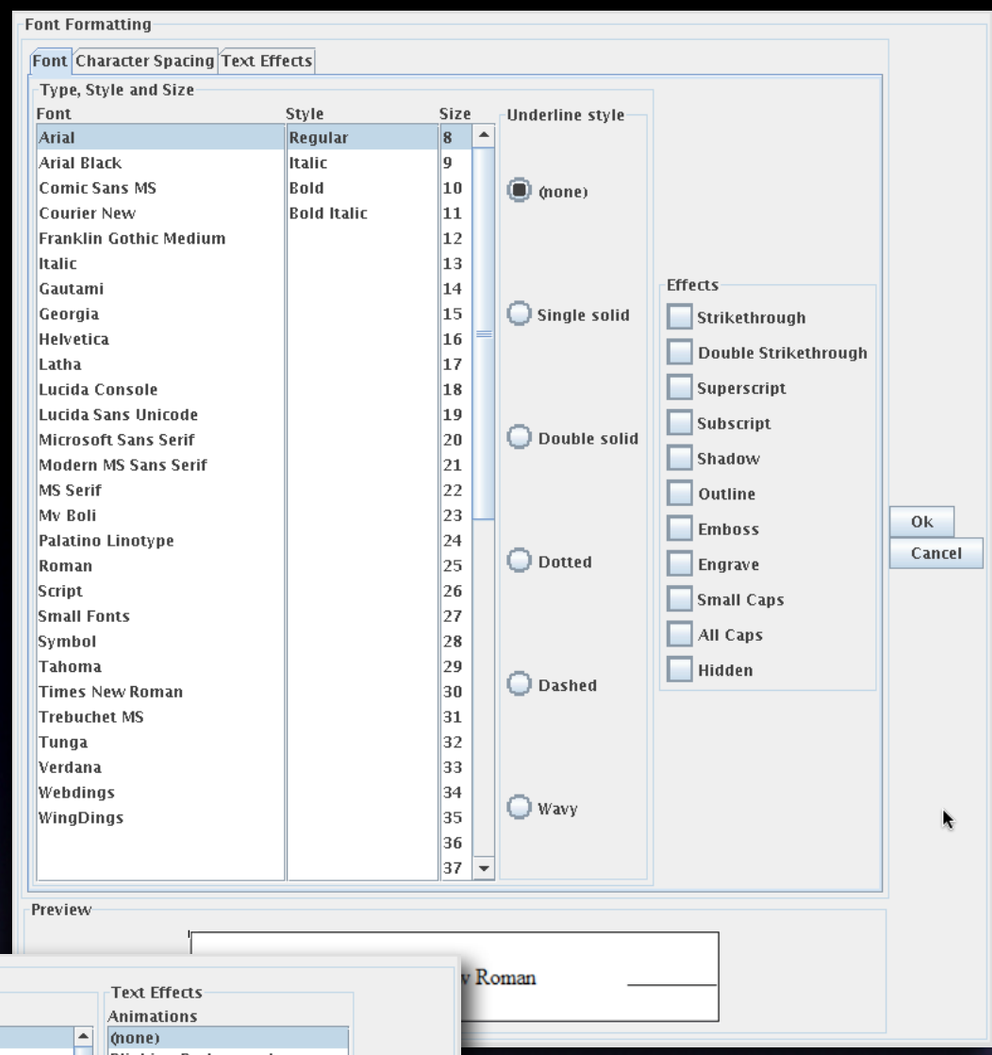
Times New Roman

Impaired dexterity

Able-bodied

Low strength





Road Map

- ✓ Introduction
- ✓ Interface generation as optimization
- ✓ Modeling motor capabilities
- ✓ Adapting to motor capabilities
- > Adapting to vision capabilities
- ☐ Adapting to motor and vision capabilities together
- ☐ Pilot User Study
- ☐ Lessons learned

Configuration

Rendering

Configuration

Accounts

- Web.de IMAP
- UW IMAP
- Web.de POP3
- Fastmail

Details

Details

Account Details

Account Name: Web.de IMAP

Reply Address: supple@web.de

From Address: supple@web.de

Incoming Server

Protocol: (•) imap ( ) pop3

Encrypted: [ ]

Server: imap.web.de

User: supple

Password: **********

Outgoing Server

Authentication: [✓]

Encrypted: [ ]

Server: smtp.web.de

User: supple

Password: **********

Add Account | Remove Account | Save | Switch to Account

Configuration

Accounts

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Encrypted: [ ]

Server: imap.web.de

User: supple

Password: **********

pop3

Encrypted:

Server: imap.web.de

User: supple

Password: **********

Outgoing Server

Authentication: ✔

Encrypted:

Server: smtp.web.de

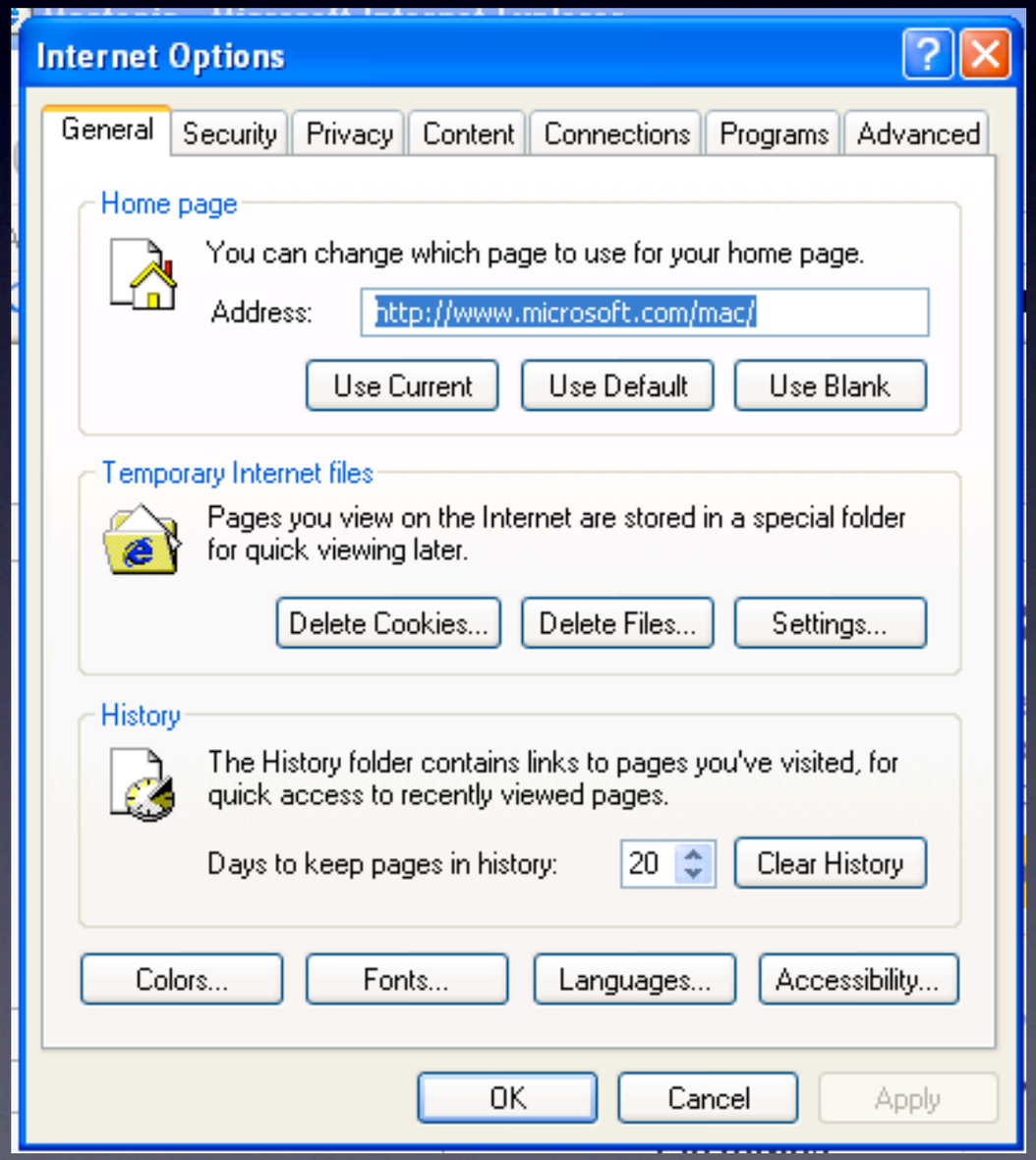
User: supple

Password: **********

Details

Account | Remove Account | Save | Switch to Accoun

Popular OS Solution: “Large Fonts”



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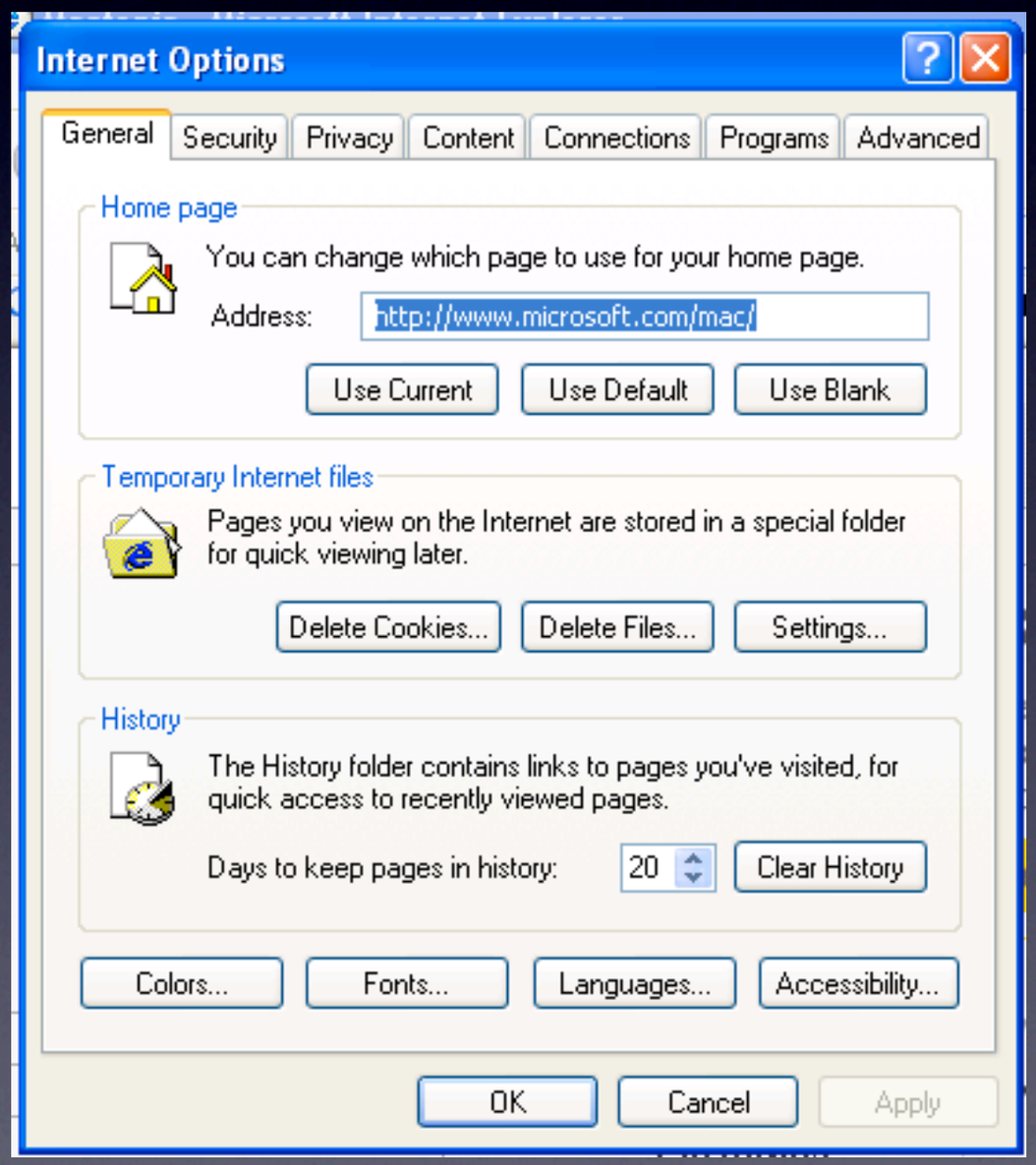
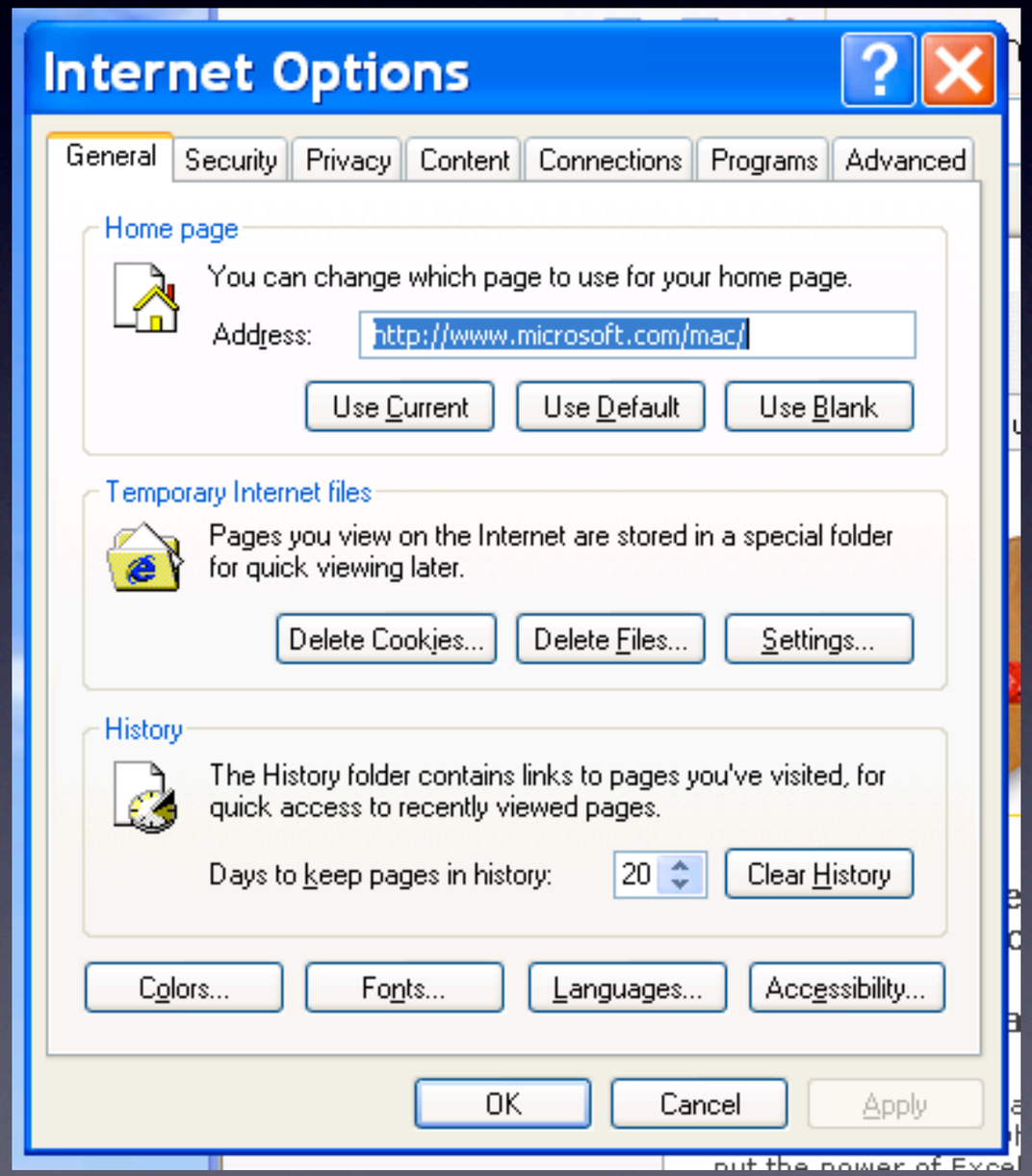
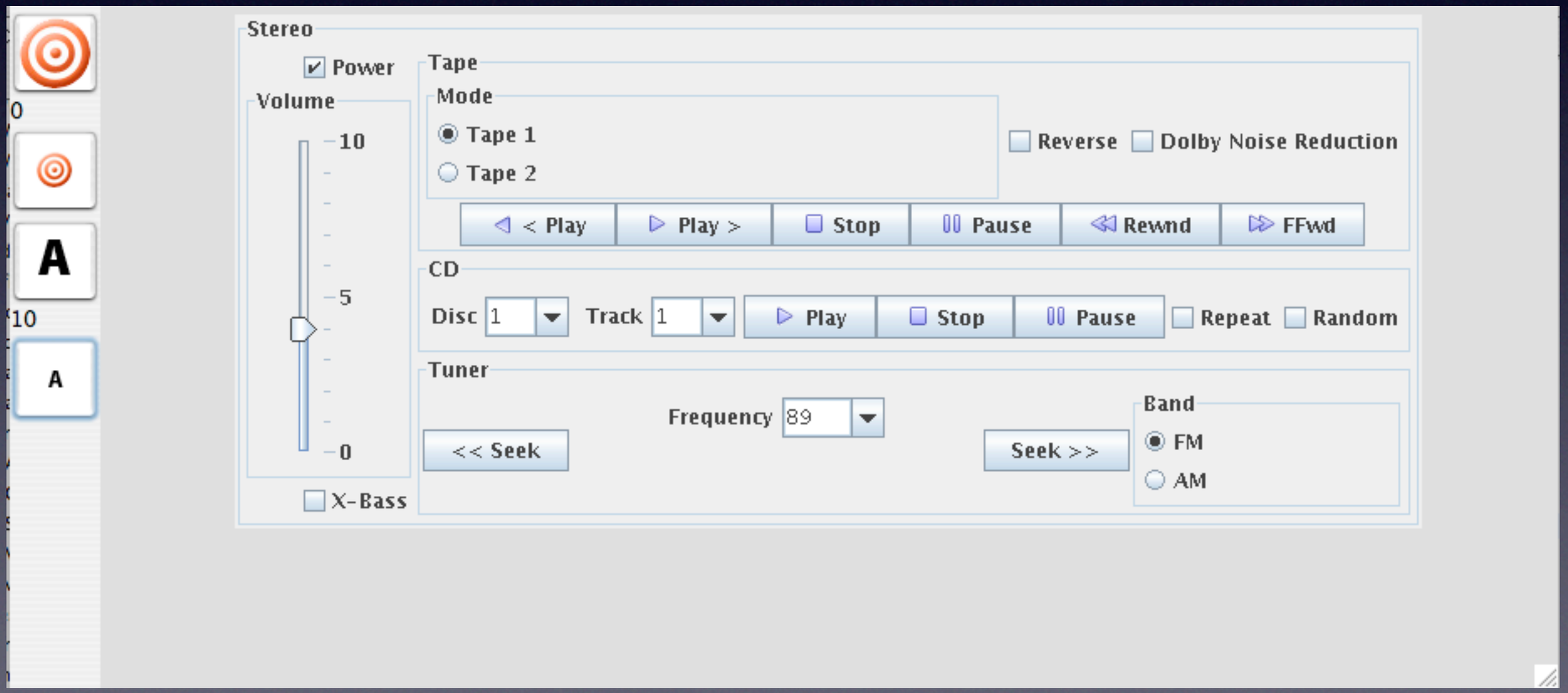
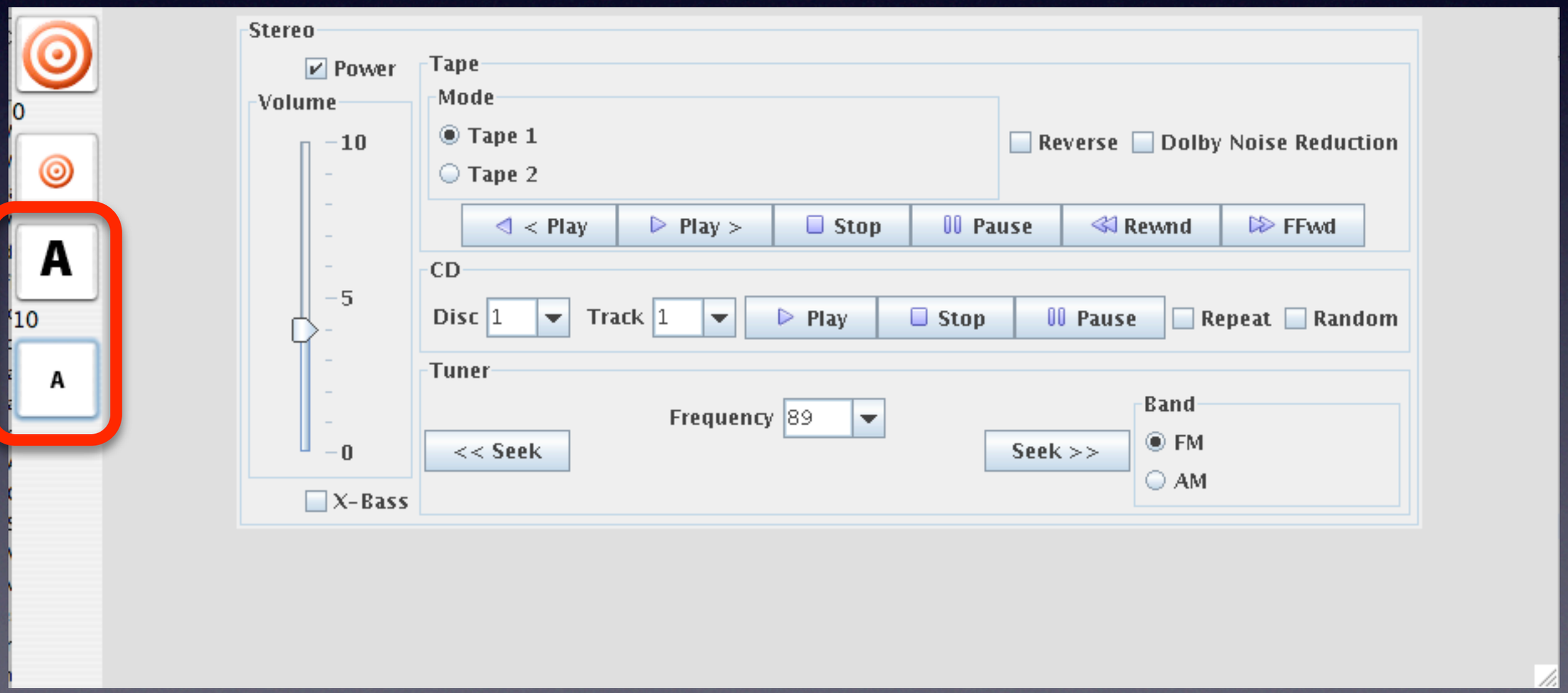




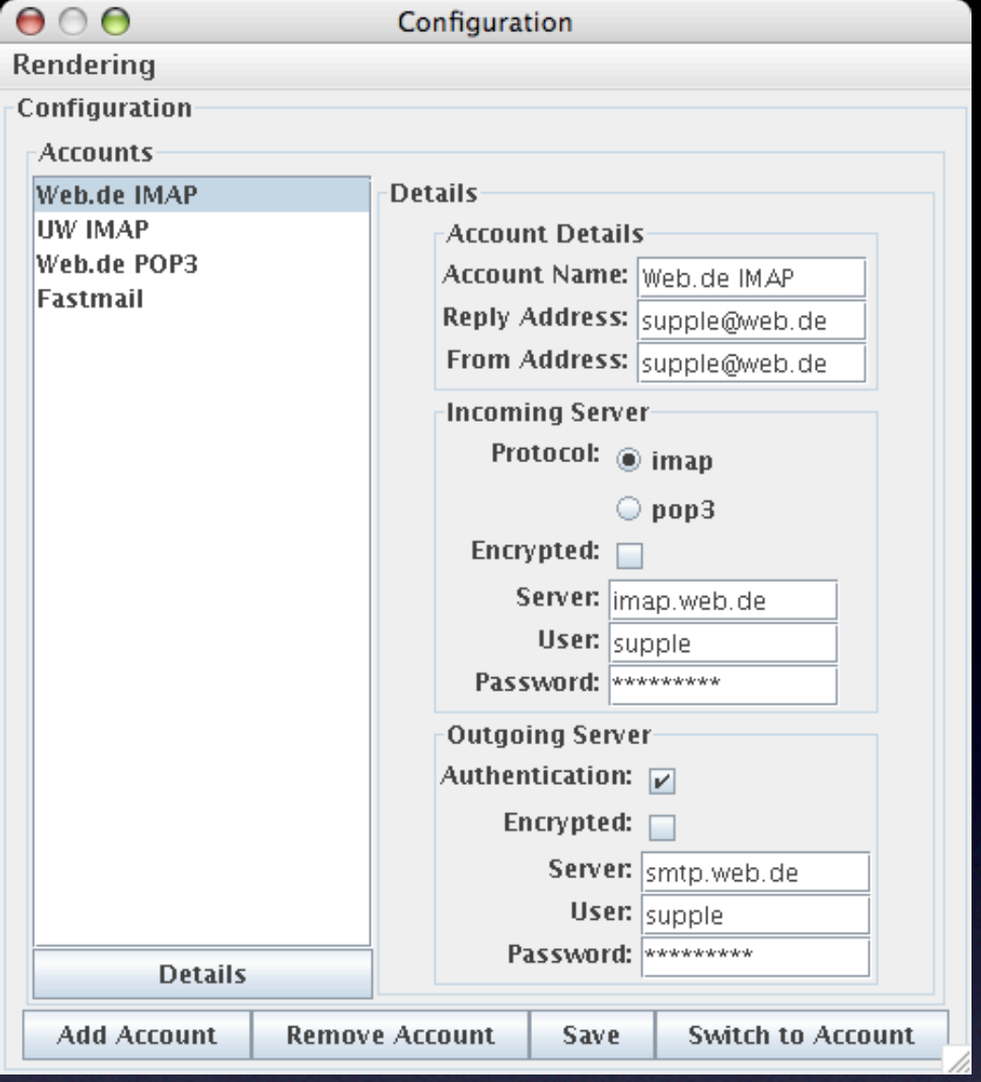
Supple++ Solution



Supple++ Solution

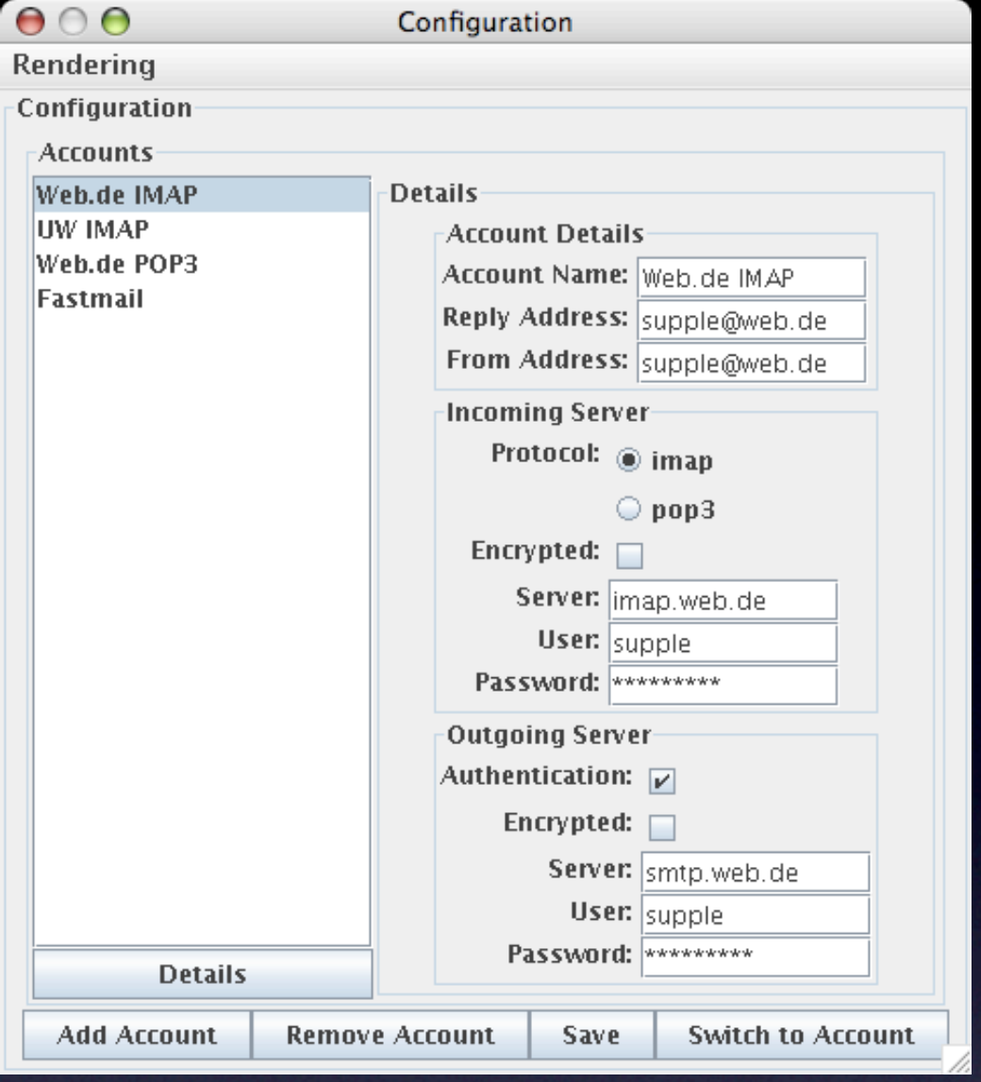


Supple++ Solution



Our Approach

- User selects desired minimum size for all visual cues
- User interface generation constrained to meet desired visual cue size
- Fast "resize and reflow"



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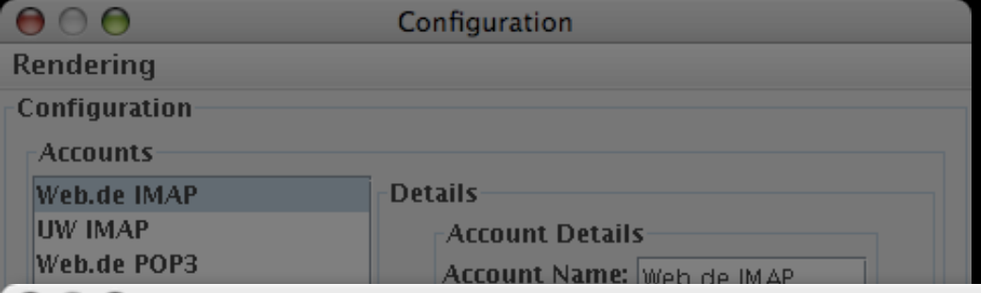

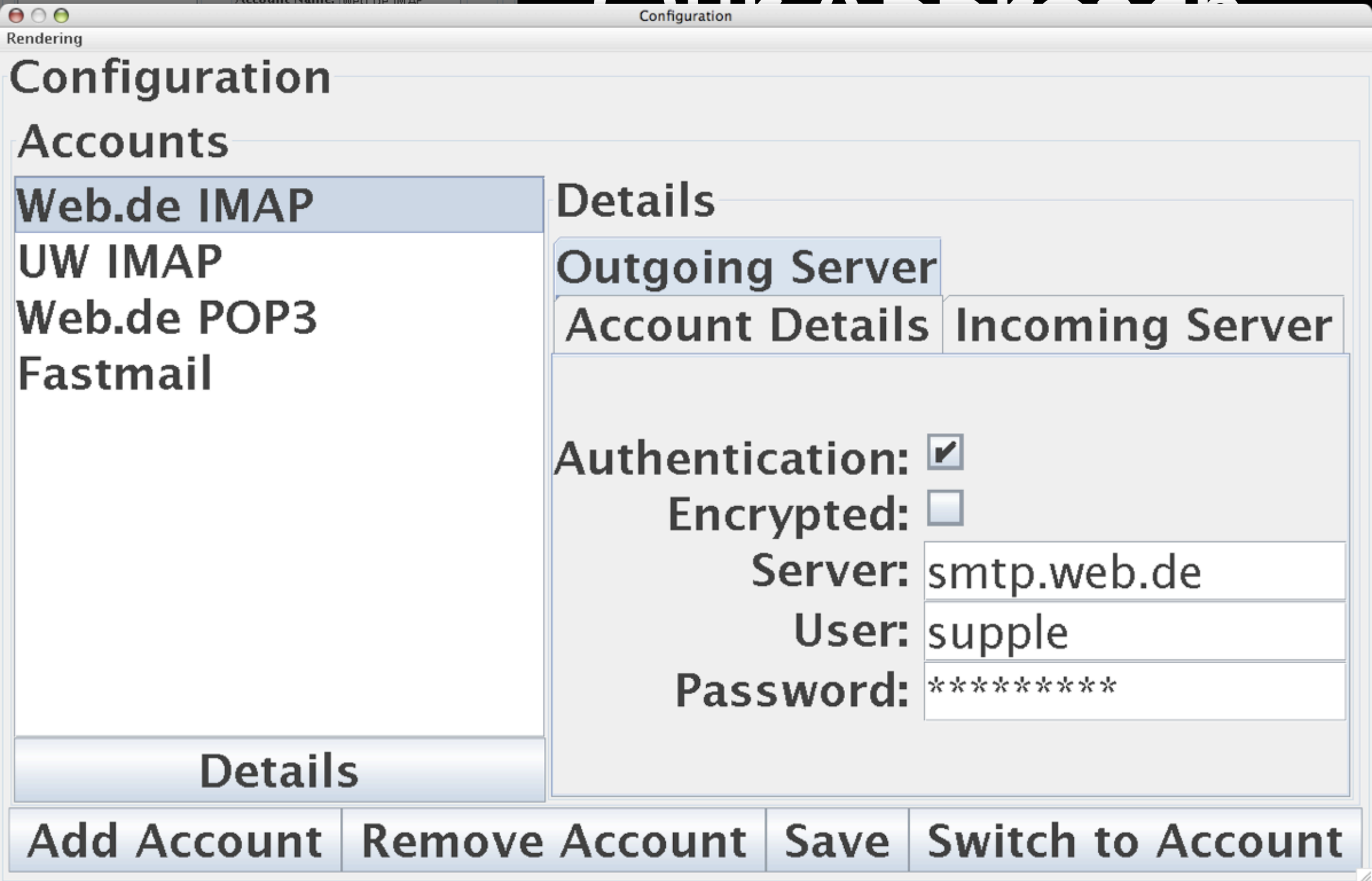

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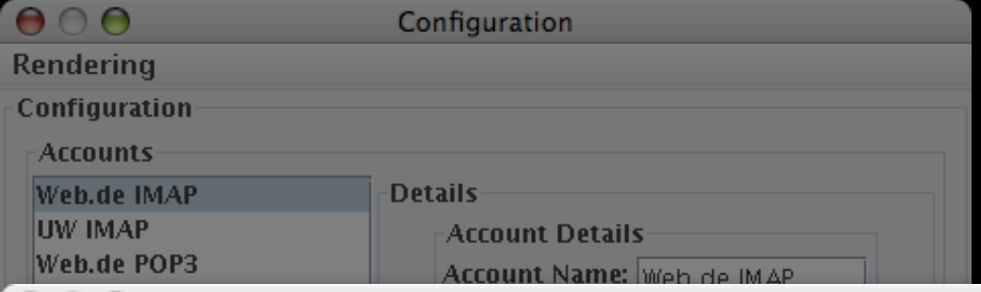

Configuration

Rendering

Configuration

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Web.de IMAP

UW IMAP

Web.de POP3

Fastmail

Details

Content arranged in tabs

Details

Outgoing Server

Account Details | Incoming Server

Authentication: ☑

Encrypted: ☐

Server: smtp.web.de

User: supple

Password: *********

Add Account | Remove Account | Save | Switch to Account

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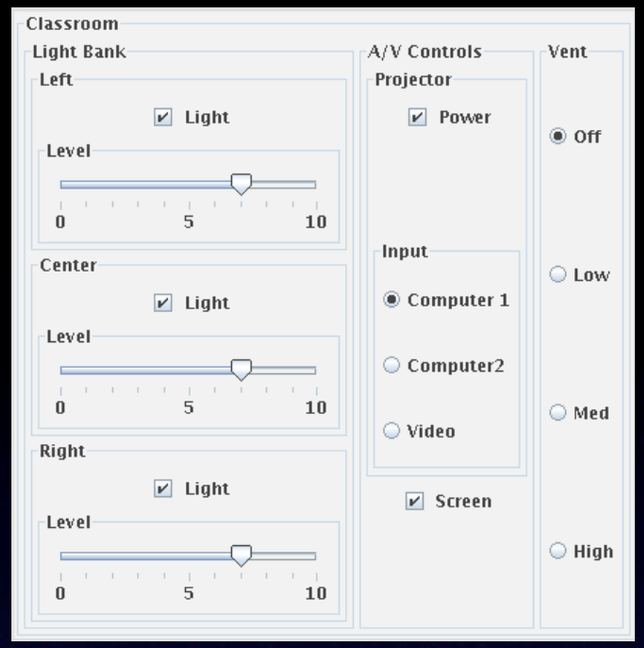
for “typical” users



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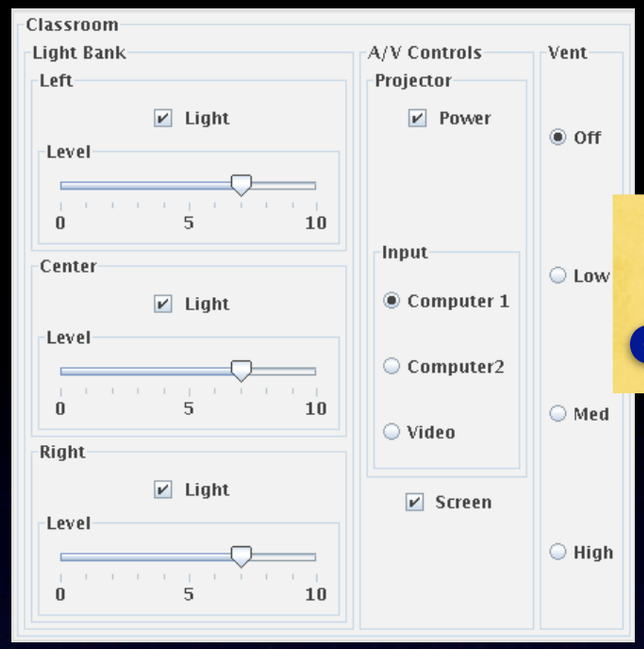
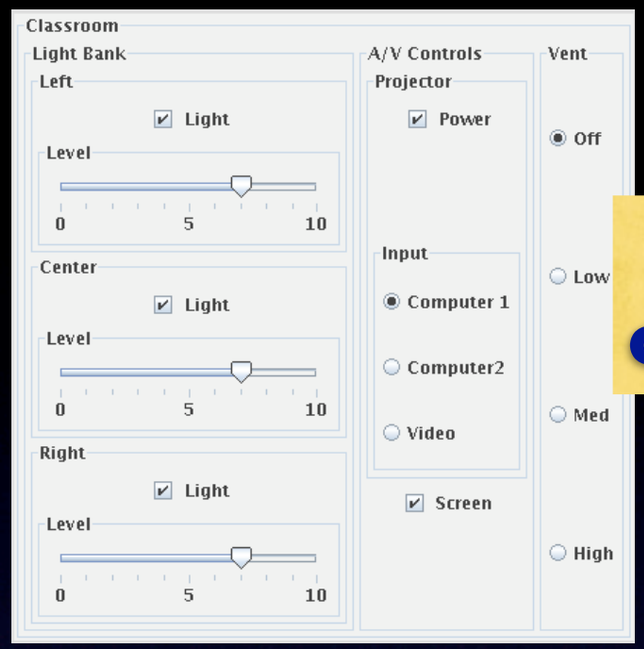


modified
cost function

impaired dexterity

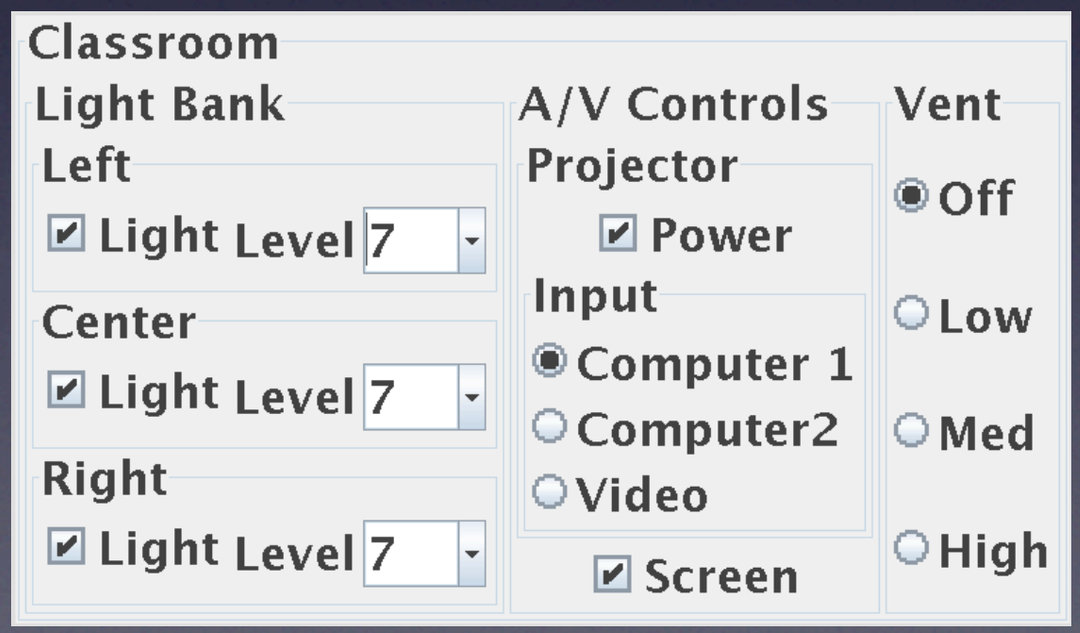
for “typical” users



modified
cost function

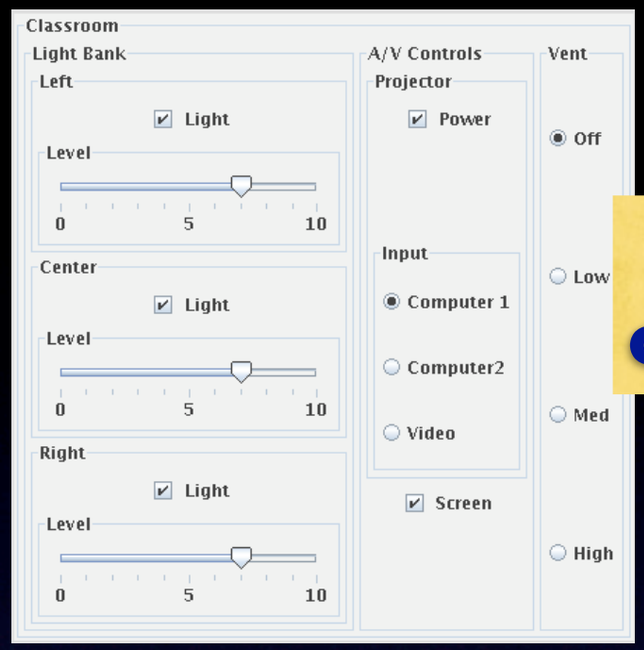
impaired dexterity

modified
constraints



low vision

for "typical" users



modified
cost function

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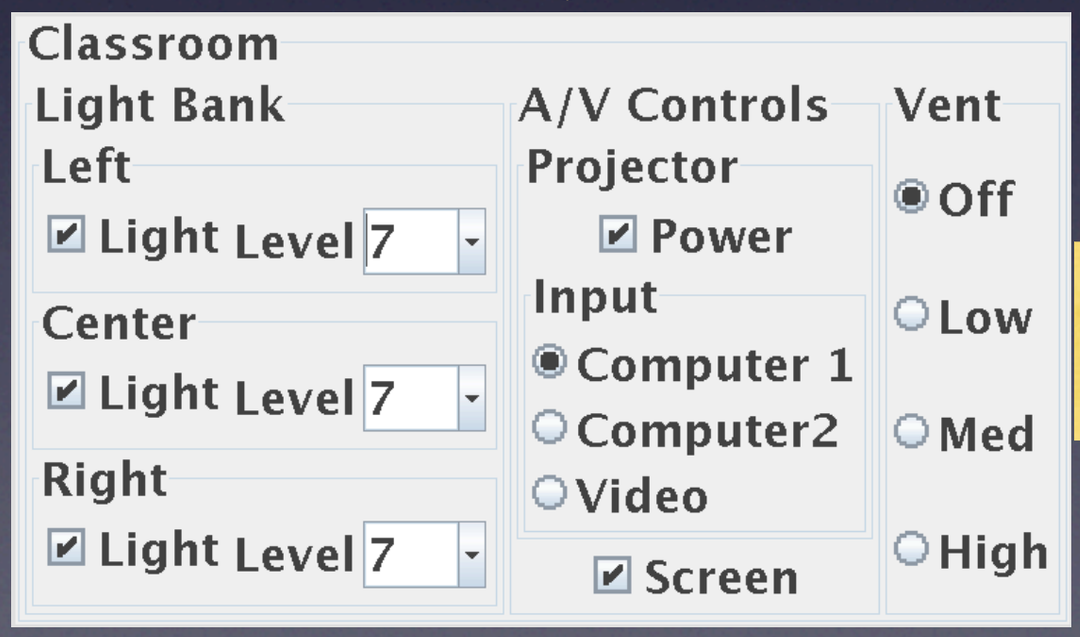
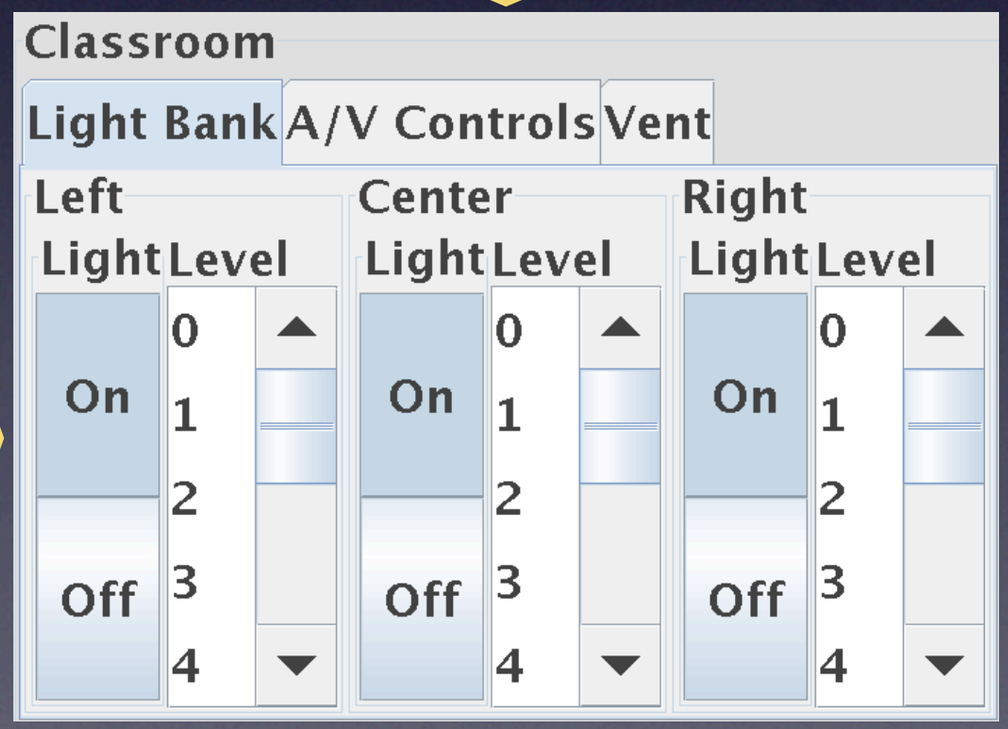
modified
constraints





low vision

low vision & impaired dexterity

Results of a Pilot Study

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- Enabled interaction for one participant

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- For others, personalized interfaces improved performance by 20%

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- Large variance

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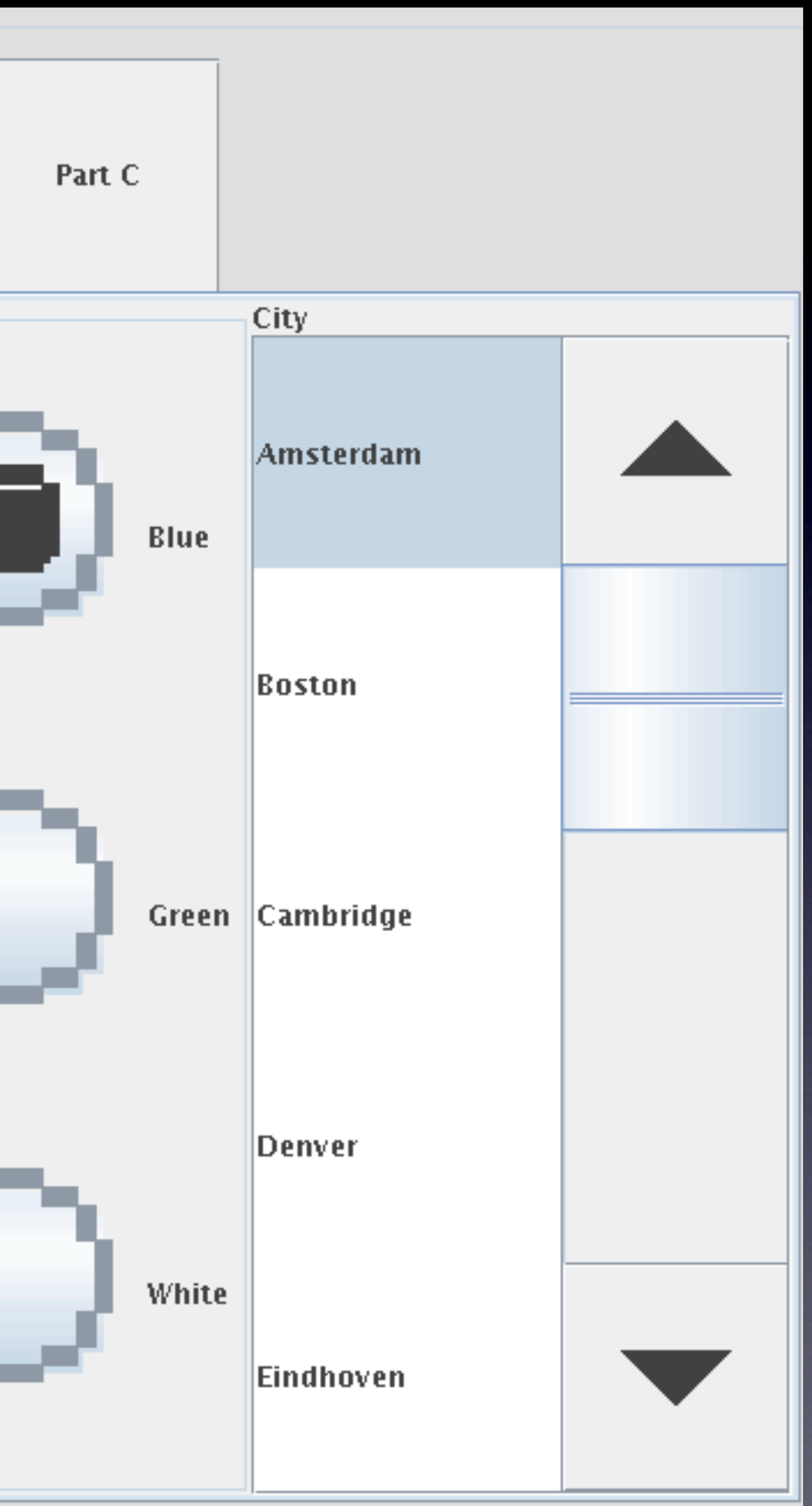
But

- Large variance
- Better but not best

Problems uncovered



- List selection ≠ drag + point

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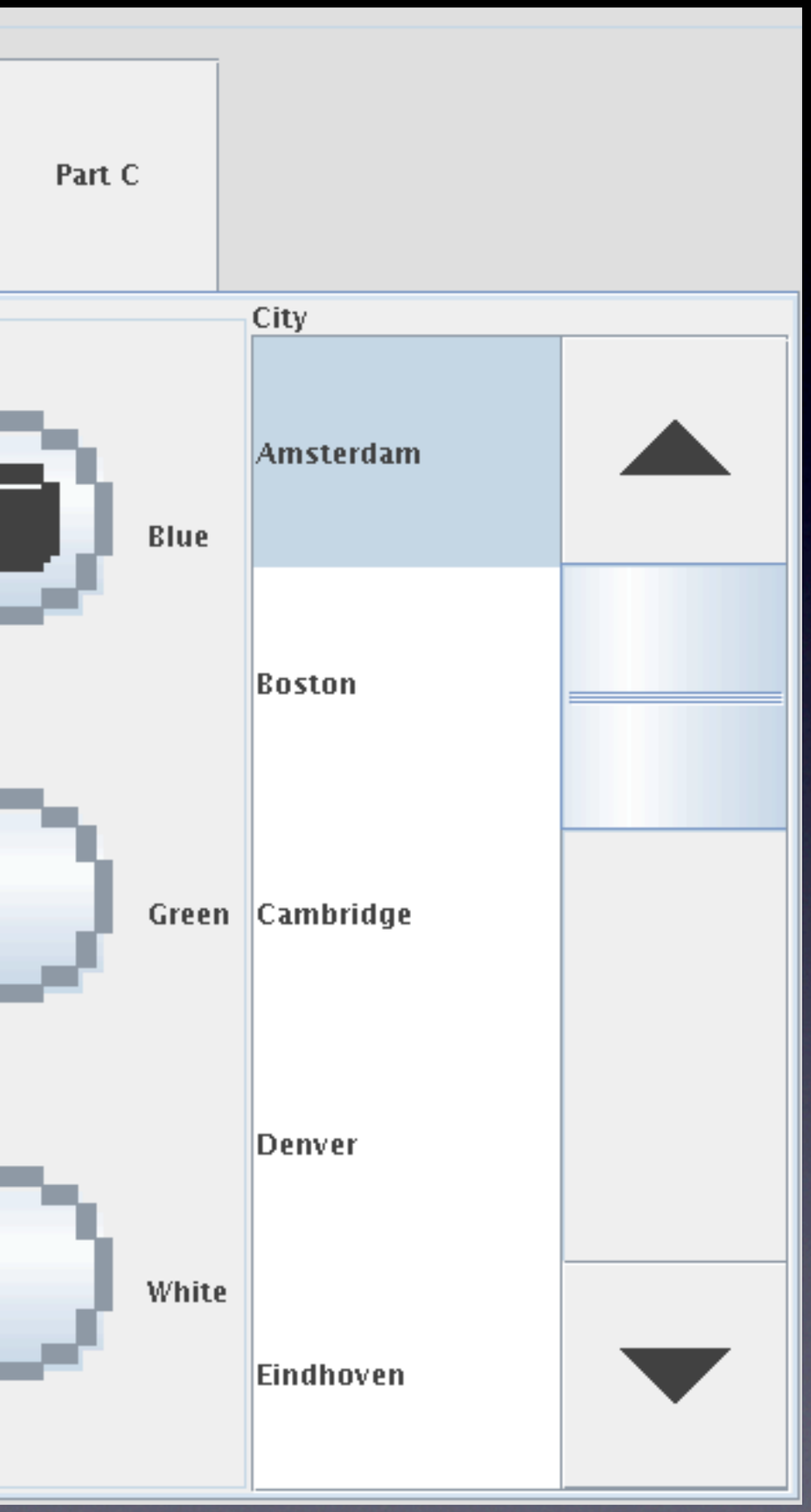
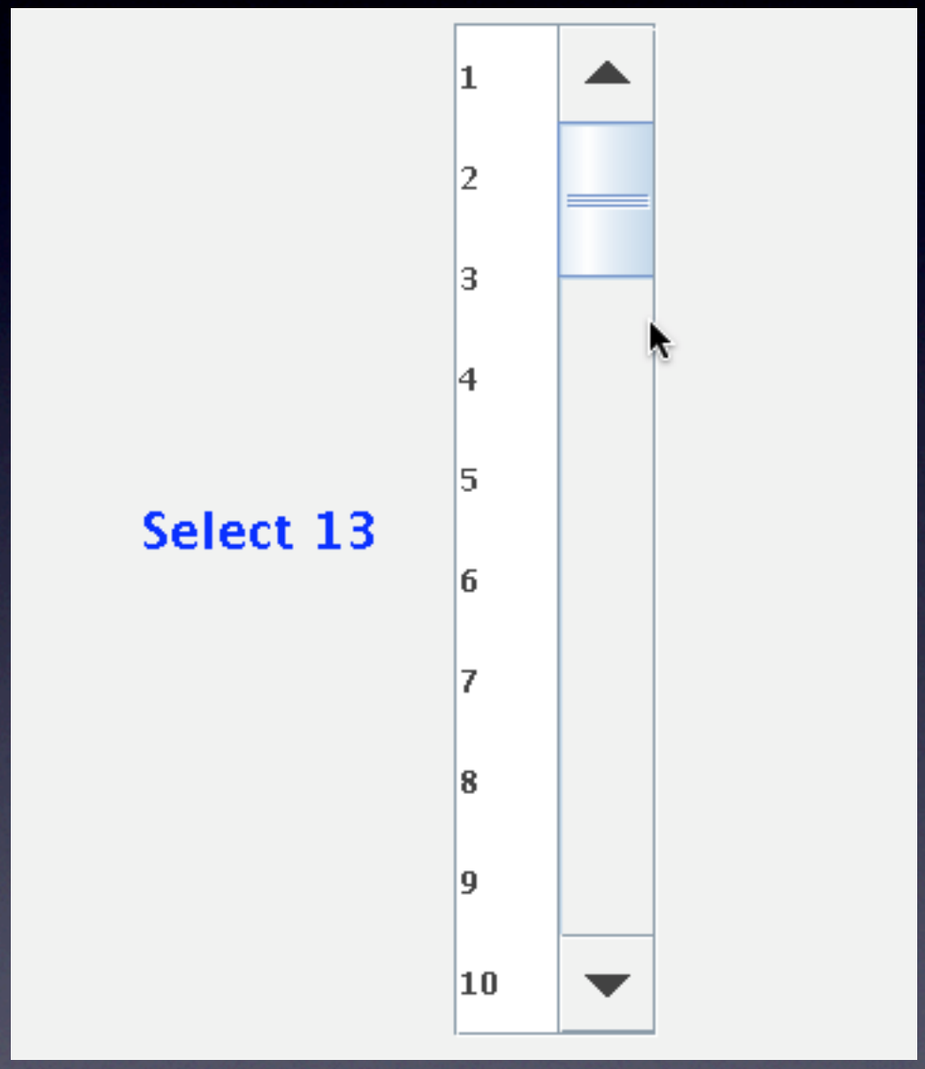


- List selection ≠ drag + point

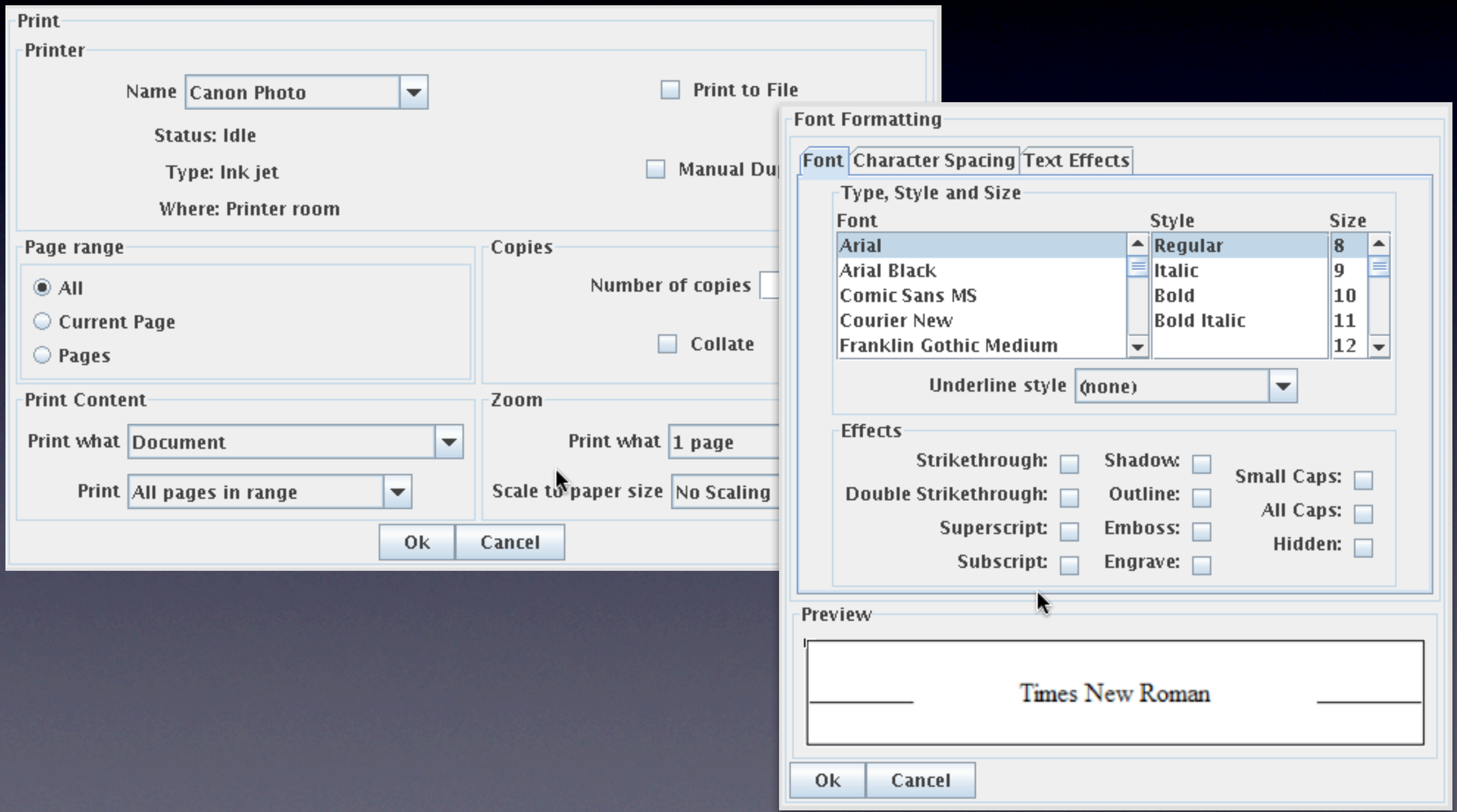
$R^2 = .09$

Modeling List Selection Times



direct model: $R^2 = .64$

Since this paper...



Since this paper...

- In the new study, we found that participants with motor impairments
  - were consistently **faster** (by 26%) using interfaces generated by Supple++
  - made 73% **fewer errors**
  - strongly **preferred** Supple++ interfaces to manufacturers' baselines

Summary of Contributions

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- **Supple++** for automatically generating user interfaces adapted to user's motor and vision capabilities

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- **Supple++** for automatically generating user interfaces adapted to user's motor and vision capabilities
- No expert necessary
- Custom regression models for individual motor capabilities
- Novel optimization-based algorithm for efficient ability-based GUI generation

Limitations & Future Work

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- Limitations of modeling

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- Pointer-only interactions

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  - How to address other concerns?

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- Limitations of modeling
  - Pointer-only interactions
  - Movement time as proxy for performance
  - How to address other concerns?
- Design tools

More Information

- SUPPLE:
  http://supple.cs.washington.edu/
  or Google : supple interfaces
- Krzysztof Gajos:
  kgajos@cs.washington.edu
- Jacob Wobbrock:
  wobbrock@u.washington.edu
- Daniel Weld:
  weld@cs.washington.edu