Human-Computer Interaction

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IGR203

Introduction

- foundations, history

Software design (continuation of IG201)

- Statecharts, MVC, etc.
- Web user interfaces

User-centered design, human factors

- Principles, interviews, brainstorming, prototyping, evaluation
- Perception/action, pointing, colors, ergonomical principles

Complements

- Electronics prototyping with Arduino
- Emerging techniques

IGR203

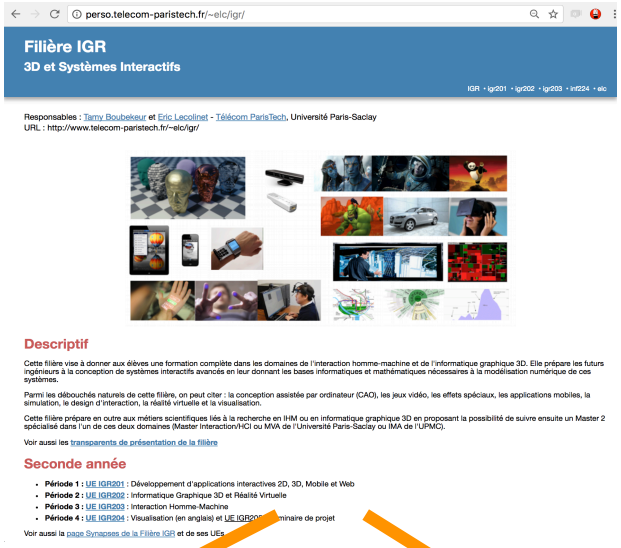
Grading

- 50% exams and labs *(will appear as IGR203a)*
- 50% group project *(as IGR203b)*

Resources

- **IGR203:** https://perso.telecom-paristech.fr/elc/igr203/
- **ecampus (IGR203a)**: https://ecampus.paris-saclay.fr/course/view.php?id=20444
- **Team Project:** https://perso.telecom-paristech.fr/eagan/class/igr203/

IGR & IGD



http://www.telecom-paristech.fr/~elc/igr

Option interne IGR & other Masters

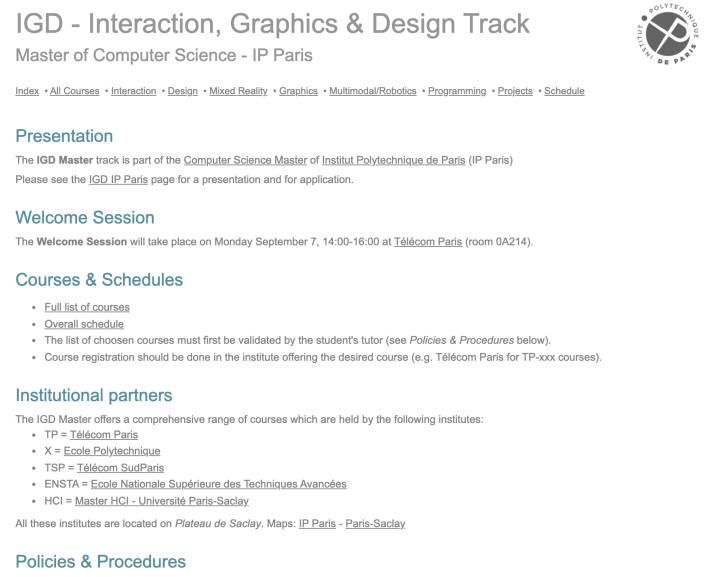
IGD Master

Troisième année

Plusieurs possibilités :

- **1. Suivre le Master IGD** (Interaction, Graphics & Design) de l'Institut Polytechnique de Paris
  - L'entrée se fait alors au niveau M2
  - Site IP Paris et inscriptions
- **2. Suivre** l'**Option interne IGR**
- **3. Candidater à un M2 associé :**
  - M2 IMA : Image, Spécialité de la mention Informatique (Sorbonne Université)
  - M2 HCI : Interaction, Human Computer Interaction (Université Paris Saclay), Mention Informatique
  - M2 MVA : Parcours Mathématiques, Vision et Apprentissage (U. Paris Saclay), Mention Mathématiques et Applications
- **4. Suivre une formation équivalente à l'étranger** :
  - Voir cette page et contacter James Eagan responsable mobilité internationale de la filière IGR

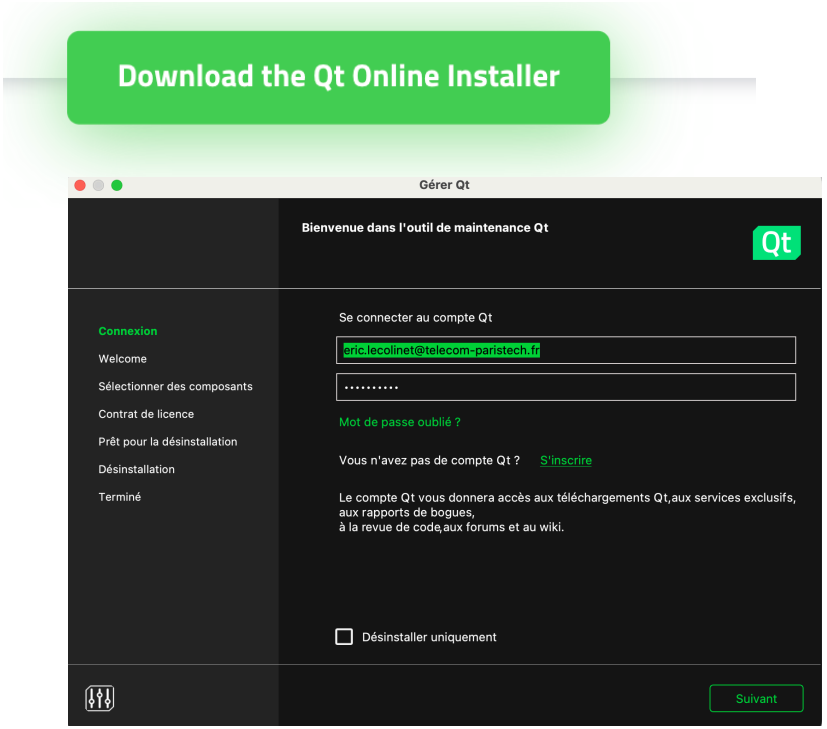
Il est également possible de choisir un cursus transverse (option entrepreneuriat) ou un des cursus alternatifs.



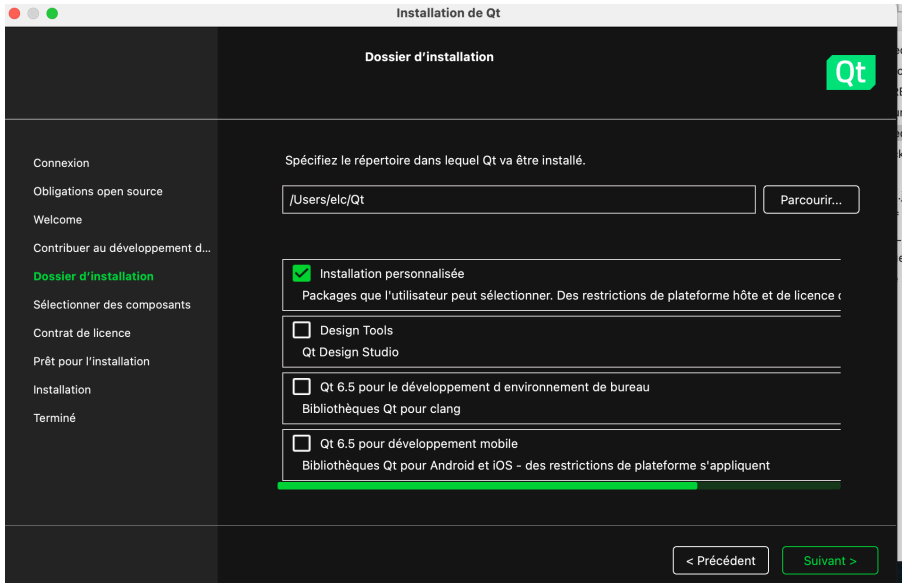
Note on **Qt** (for first labs)

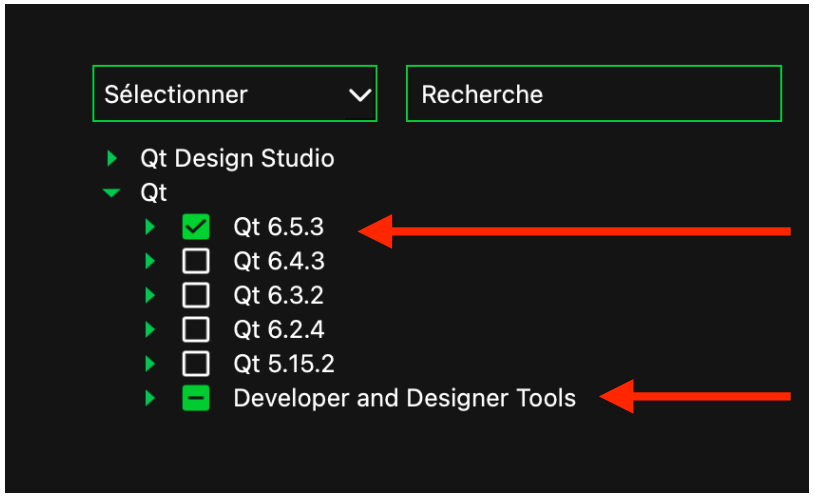
- **Labs**: http://www.telecom-paristech.fr/~elc/qt
- **Qt Web site**: http://www.qt.io/
- **Documentation:** http://doc.qt.io/qt-6/

- **Installation (Open Source Version):**
  - In **https://www.qt.io/download-open-source**
    - *click on "Download the Qt Online Installer"*
    - *download Installer for your OS*
  - Open Qt **MaintenanceTool** app



Install (MaintenanceTool)

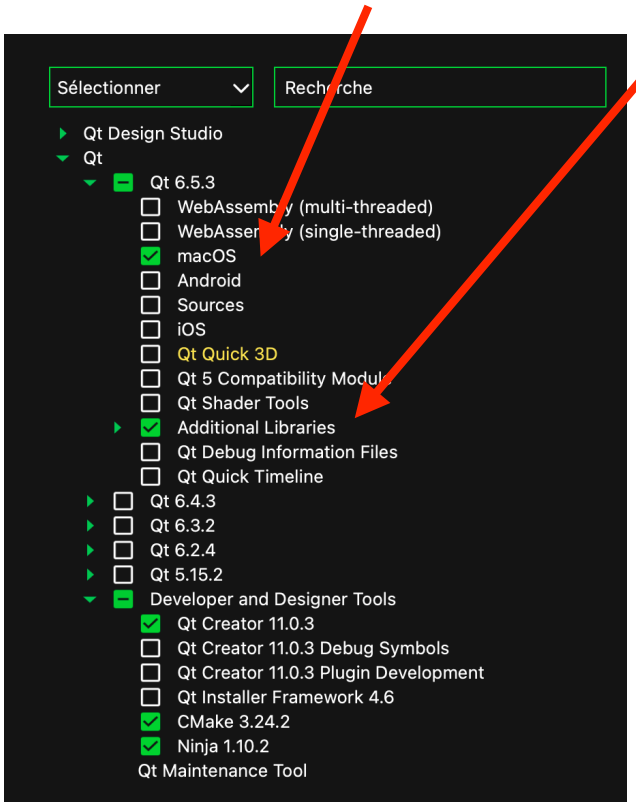


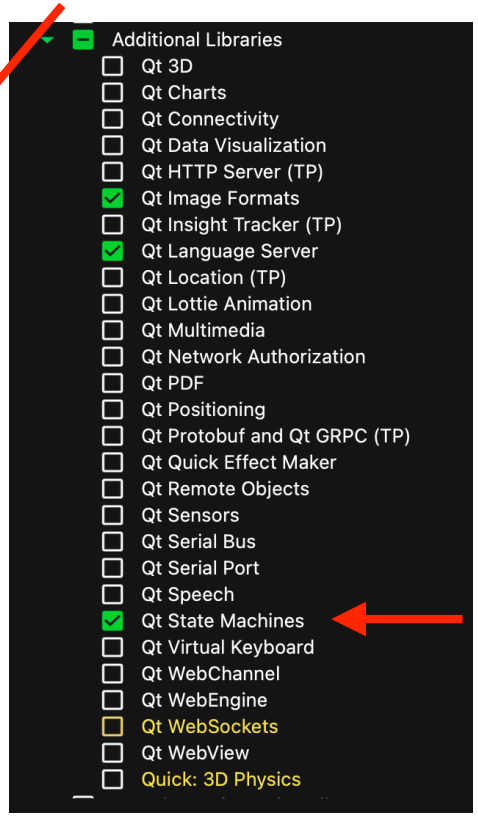


Qt State Machines needed!

your OS

additional libraries

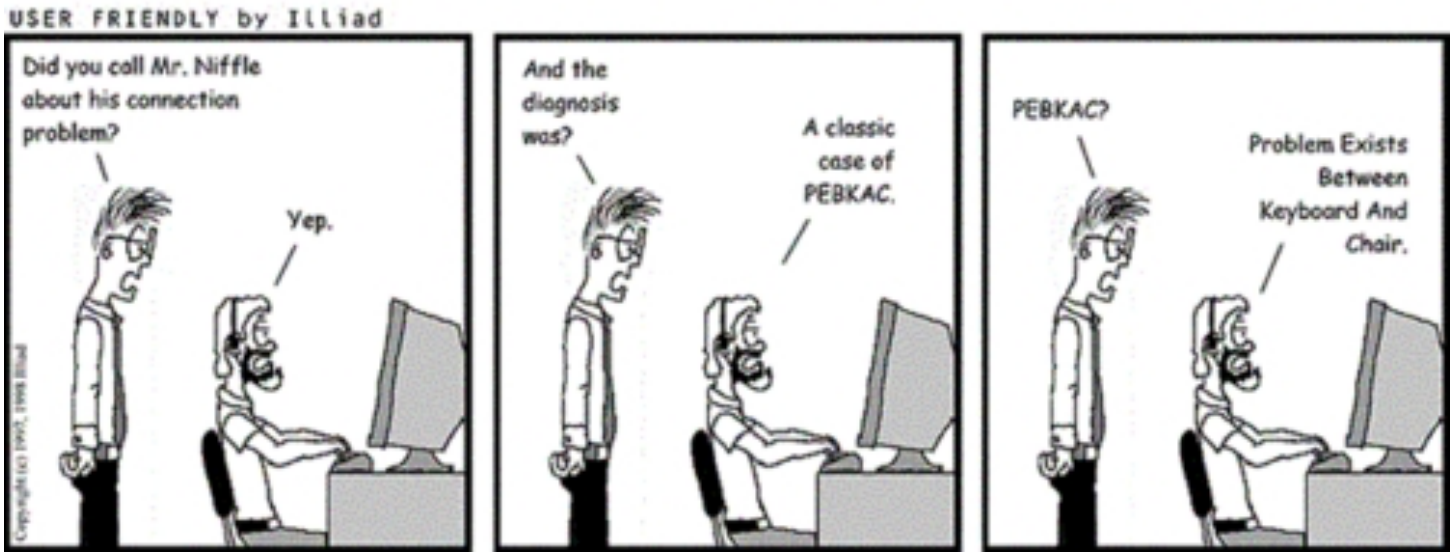




Human-Computer Interaction

HCI =

- **Design**
- **Implementation** of **interactive** systems... used by **human** **users!**
- **Evaluation**



THE PEBKAC PROBLEM...

Human-Computer Interaction

Multi-disciplinary domain

Engineering

- computer science, software development, GUI toolkits, AI & machine learning...
- electronics, hardware, material science...

Psychology, ergonomics, design

- ergonomics, cognitive psychology, physiology...
- sociology...
- industrial design, graphic arts, typography...

Human-Computer Interaction

Goals

1) Usability: reliable and **easy-to-use** interactive systems

Efficient user interaction, user satisfaction

Criteria:

- **learning** cost
- **speed** of execution
- **fatigue** (cf. repetitive actions)
- ability to use **advanced** functionalities
- **errors** (especially for critical interfaces)

Human-Computer Interaction

Goals

1) Usability: reliable and **easy-to-use** systems

Efficient user interaction, user satisfaction

2) Reasonable development cost

GUI development tends to take a huge amount of time!

Don't think system first!

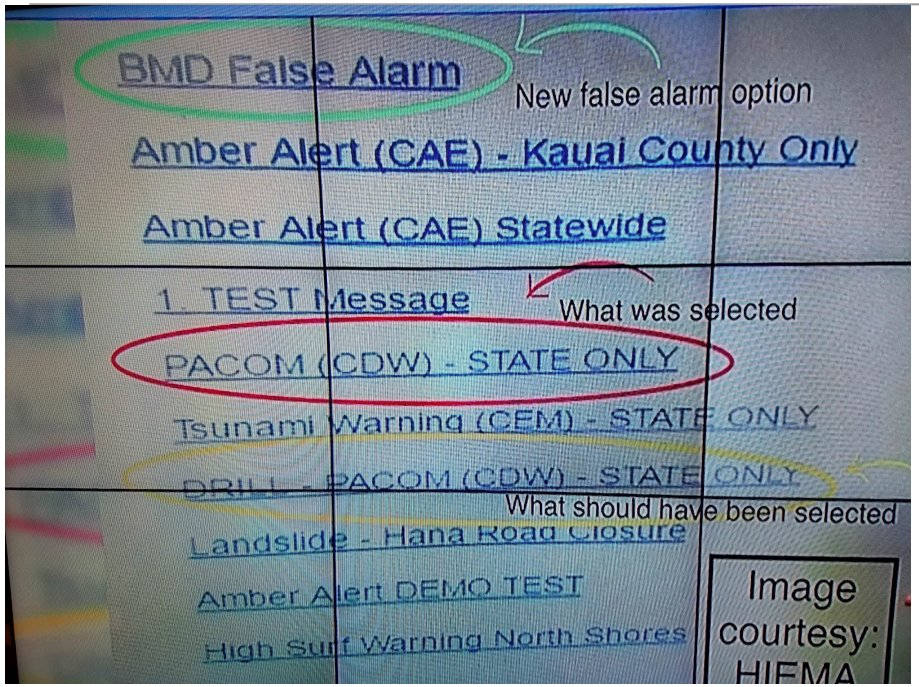
=> Dedicated **design methodologies, user-centric design**

Examples

ATM Machine

- Money then card?
- Card then money?

Examples



False Alarm in Hawaii Could Have Caused

Nuclear War (JDD - Jan. 15, 2018)

A **€85 billion typo**

at Samsung's brokerage

(les Echos - April 11, 2018)

Examples (critical interfaces)

Mont Saint Odile disaster

- Crash of an **Airbus A-320** on January 20, 1992
- 87 dead, 9 survivors
- Charged in January 1997 for "homicide and involuntary injuries"
  in relation to "**the ergonomics of the descent mode of the aircraft**"

Examples (critical interfaces)

Mont Saint Odile disaster

- The pilot confused the **selected descent mode**
- He entered **33** believing he was in **FPA** mode, but he was in **VS** mode!
    - **FPA** mode => descent **angle**
    - **VS** mode => vertical **speed**
    - **33** can mean **3.3°** or **3300** fpm!

=> VSpeed = **3300 fpm** (16.7 m/s) about **4 times** the normal speed!

Cockpit comparison

Boeing 747 (in the 90')

Airbus A330

Cockpit comparison

- New **type of cockpit:** new possibilies involve new errors!
- No physical **visual cues**, different infos can be displayed at the same place
- Poor visibility of **modes**, no **units** (33 can mean 3.3° or 3300 fpm)

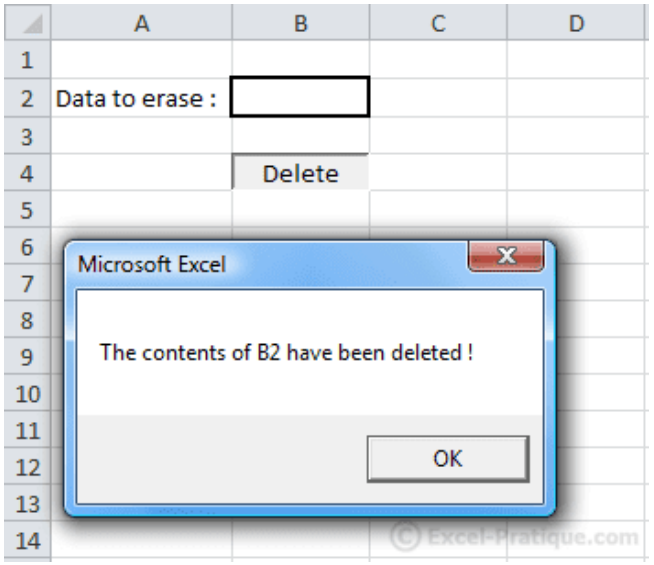
Previous user knowledge

The user may understand something else!

I'm an IT specialist on a hotline and I get a call:

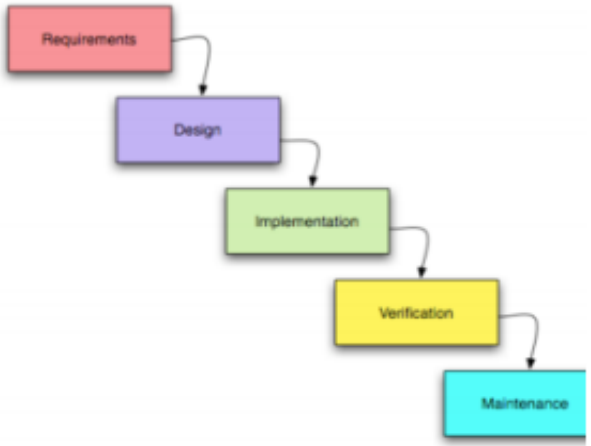
"Sir, just to be sure, if I put the seagull in the box, does that mean I won't have to retype my password?"

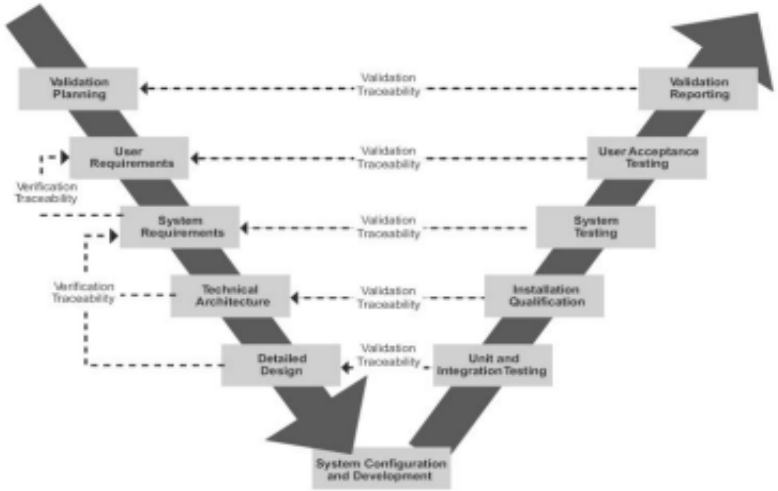
... Seagull in the box = check the box !



Why **OK** rather than **Do It** on dialog boxes?

Traditional design models





Waterfall **V** **Spiral**

Traditional development models:

- involve users at the **beginning** and the **end** of the design process
- => can't take **human factors** into account effectively

User-centred design

- **iterative design**, trial and error approach
- the users are the **domain experts** => **active role** in the design proces

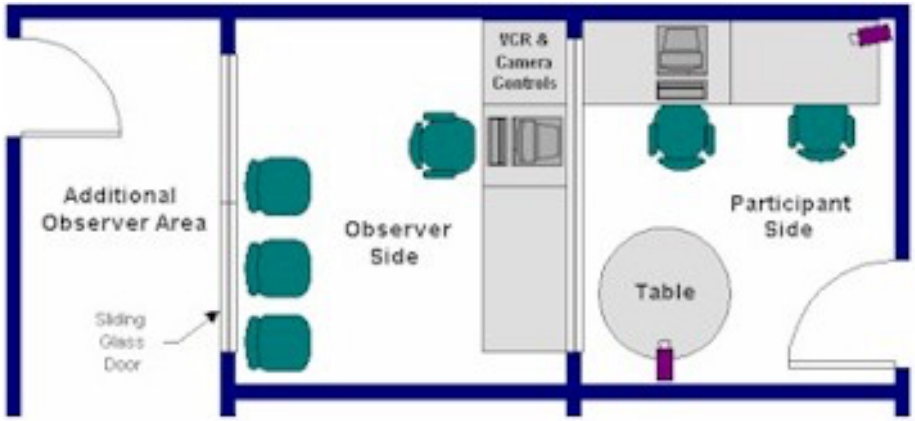
User-centred design

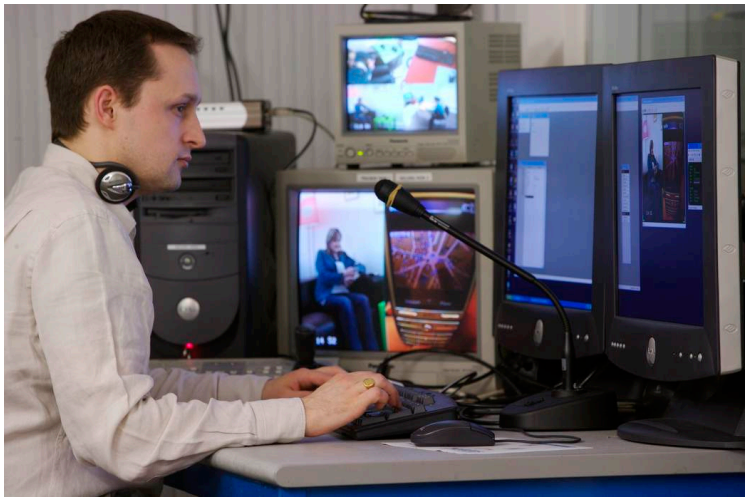
jour	tâche prévue
vendredi	vérification de l'état des features à tester
lundi	développement des tâches de test de la semaine
mardi	reception du prototype. pre-test en interne du proto pour en déterminer les limites
mercredi	test avec sujets les responsables développeurs participent à l'obsercation
jeudi / ven	analyse des tests, recommandations, synthèses

Example: Word 6 development

- over several months
- 43 user testings / more than 250 participants

Usability Labs

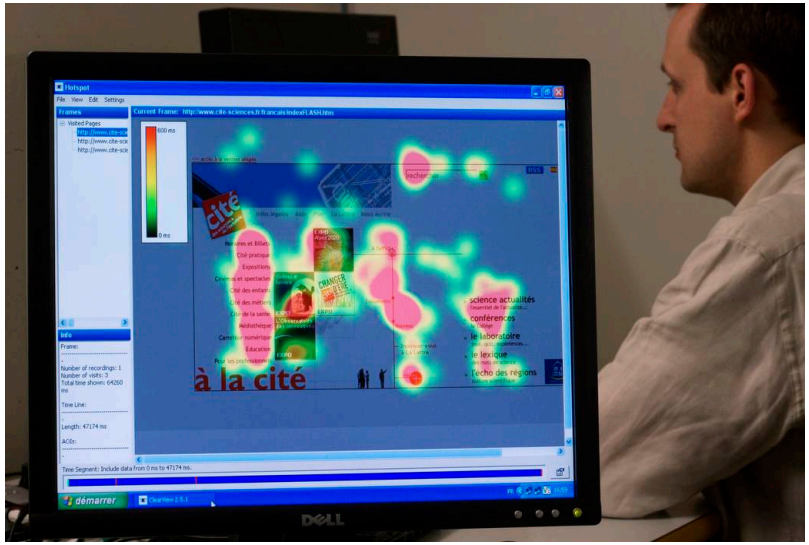




LUTIN Lab (La Villette)

Usability Labs

Eye tracking



Heat map

LUTIN Lab (La Villette)

Physiological measures

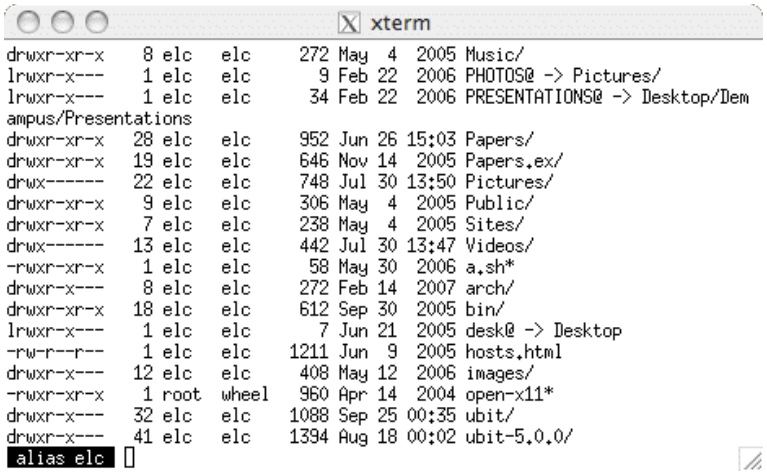
Interaction styles

Evolution

système conversationnel (shell) → fenêtres (minitel!) → manipulation directe (WIMP) → réalité virtuelle (ou augmentéé)

Conversational interaction

- **System**-imposed
- Typical of command languages
  - ex: Unix Shell
- Only for **expert users**



Interaction styles

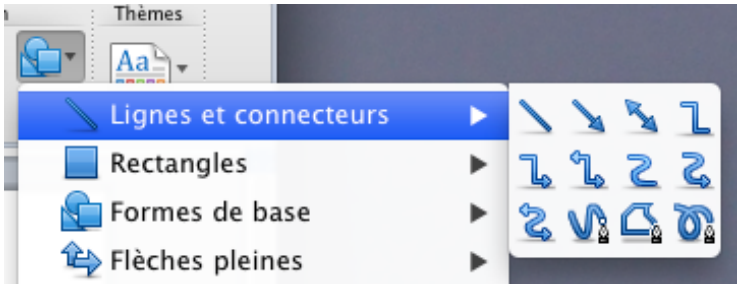
Forms

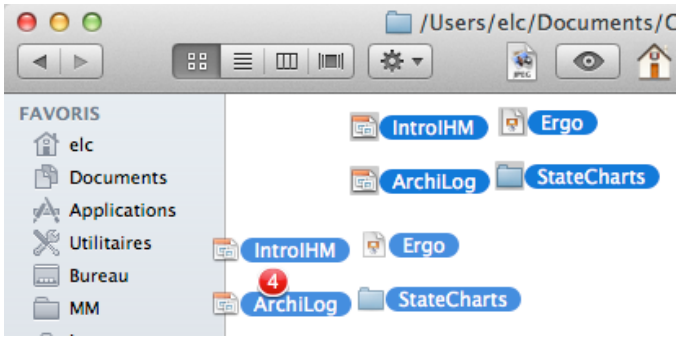
- System-imposed, but with **hints** (labels)
- Limited interaction
- Web 1.0, Minitel...

Interaction styles

WIMP

- **Window, Icon, Menu, Pointer**
- **Permanent** representation **(metaphors)**
- **Direct manipulation**:
  fast, incremental, reversible operations
- Immediate **feedback**





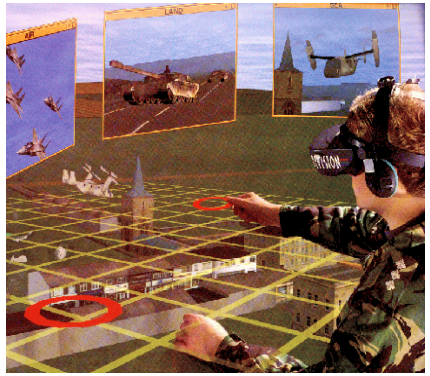
Goals

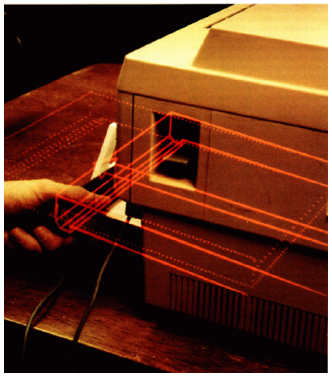
- Exploratory learning
- Transfer of experience by analogy

Interaction styles

Post-WIMP

- Mobile interaction
- Virtual / Augmented / Mixed Reality
- 3D interfaces
- Tangible interfaces
- Gestural / vocal / multimodal interaction
- Very large displays
- etc.





Conferences and journals

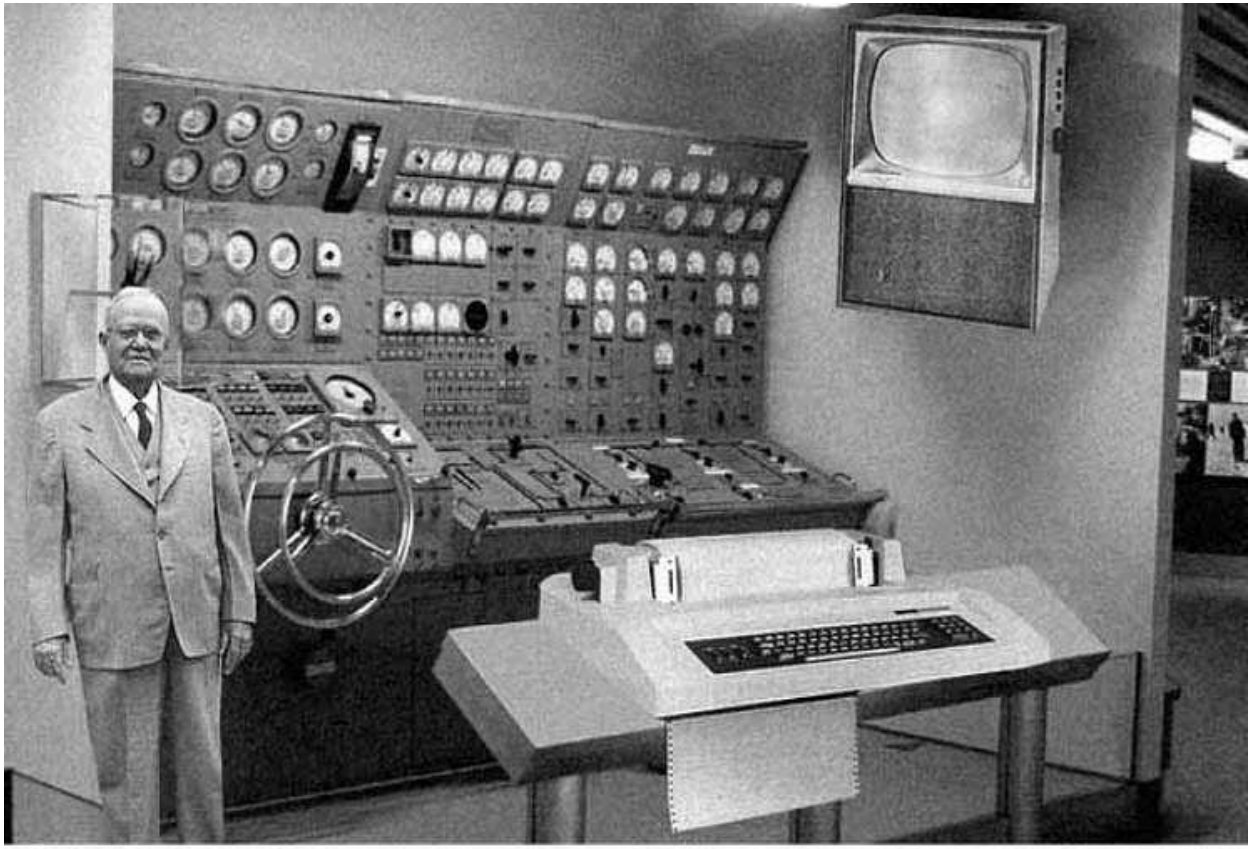
Conferences

- ACM CHI
  - CHI vidéos previews:
    https://www.youtube.com/watch?v=owjYbVI9eGQ&ab_channel=ACMSIGCHI
- ACM UIST
- IHM (AFIHM: www.afihm.org)
- AVI
- INTERACT
- IEEE Visualization

Journals

- ACM Interaction

A brief history of HCI



Scientists from the RAND Corporation have created this model to illustrate how a "home computer" could look like in the year 2004. However the needed technology will not be economically feasible for the average home. Also the scientists readily admit that the computer will require not yet invented technology to actually work, but 50 years from now scientific progress is expected to solve these problems. With teletype interface and the Fortran language, the computer will be easy to use.

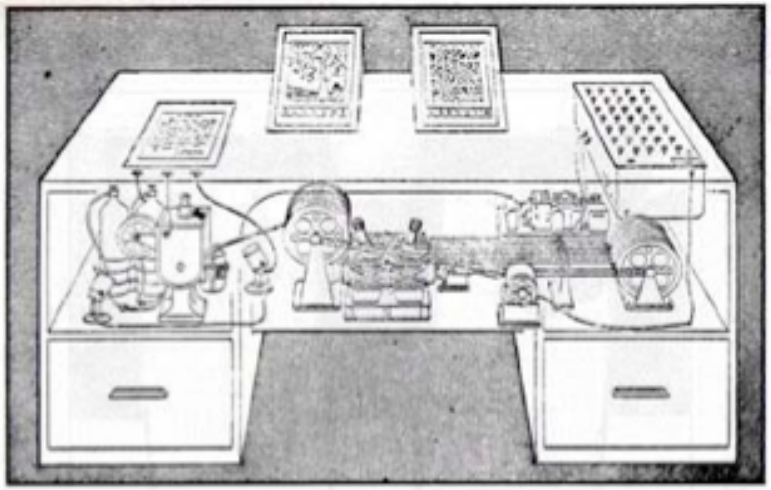
1954 : A vision of the "home computer in 2004"

1956: a 5 Mb disk

A brief history of HCI

1945: Memex (Vannevar Bush)

- idea of an "external memory"
- **hypertext** concept
  - keywords, references, indexing, links, annotation...
- tech not ready (microfilms!)



Memex in the form of a desk would instantly bring files and material on any subject to the operator's fingertips. Slanting translucent viewing screens magnify supermicrofilm filed by code numbers. At left is a mechanism which automatically photographs longhand notes, pictures and letters, then files them in the desk for future reference (*LIFE* 19(11), p. 123).

A brief history of HCI

1963: Sketchpad (Ivan Sutherland MIT)

First drawing software with **icons**

- d**irect manipulation** (optical pen)
- **high resolution** screen (oscilloscope)
- OO programming

A brief history of HCI

A brief history of HCI

1962+ : Douglas Engelbart

- Invented the **mouse!**
- High resolution screen
- Word processing
- Hypertext and hypermedia
- Electronic messaging
- Videoconference
- Groupware

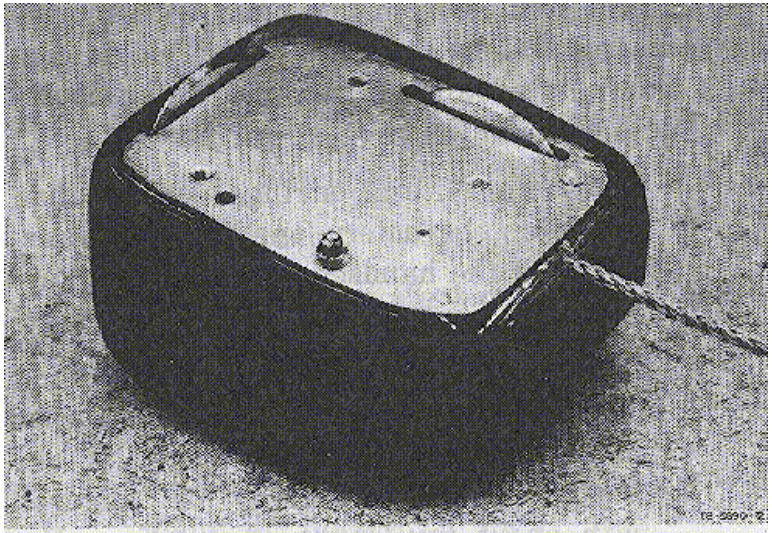


FIGURE 2—Underside of mouse

A brief history of HCI

Xerox PARC (Palo Alto, CA)

- Research center founded in 1970
- Office automation...

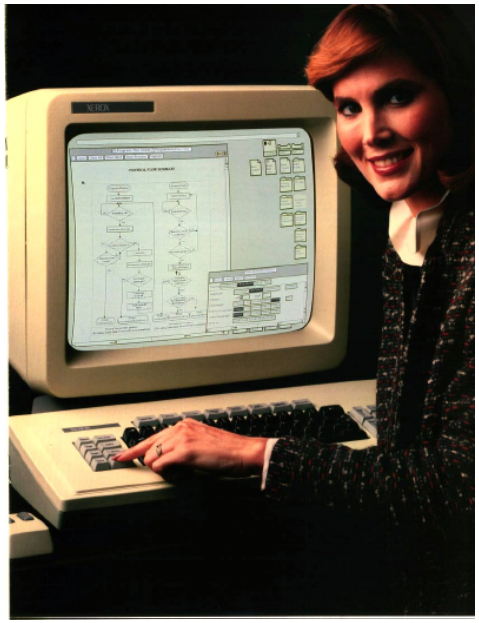
Alain Kay

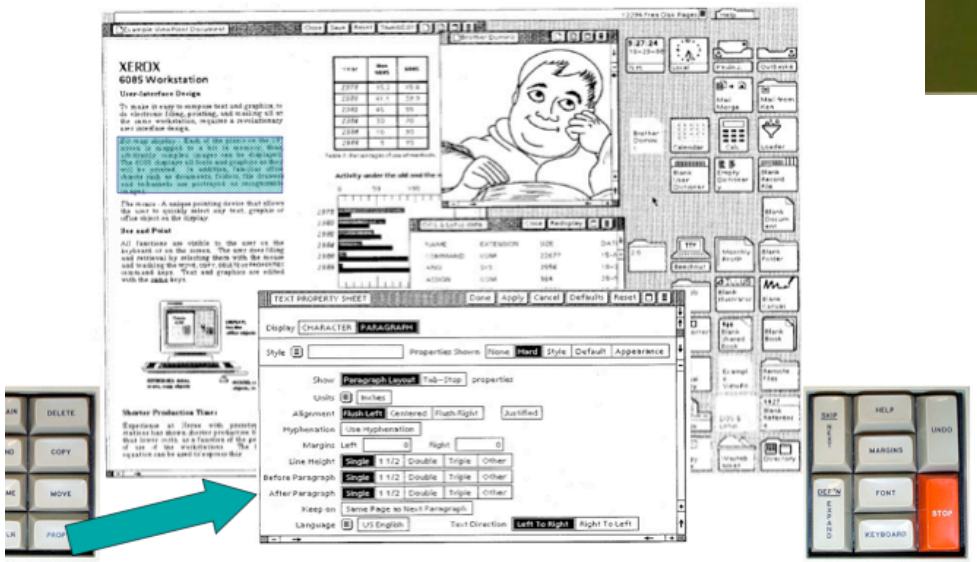
- One of the founders of the PARC
- **Personal Computer** concept in 1969
- A radical vision compared to what existed at that time!

A brief history of HCI

1981: Xerox Star

- First commercial workstation
- Advanced graphical environment
- GUI, "desktop metaphor"
- Very expensive, commercial failure



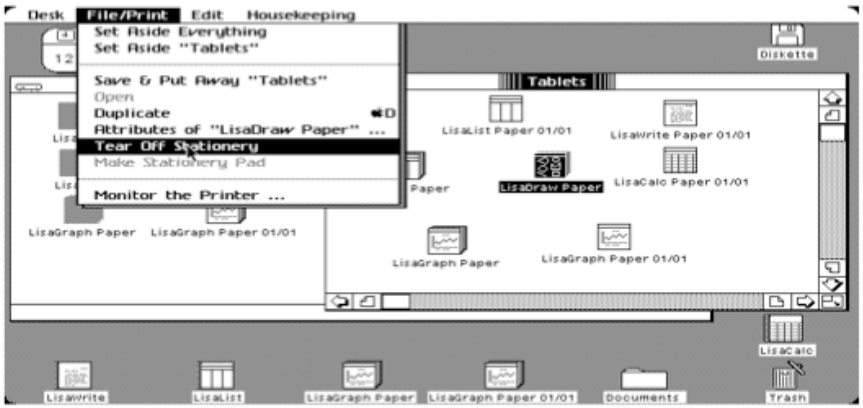


A brief history of HCI

1984: Apple MacIntosh

- Inspired from PARC research
- Mature technology, open architecture
- **WYSIWYG**, laser printing
- "Reasonably" priced ($ 2500)
- **Style guides** (consistency

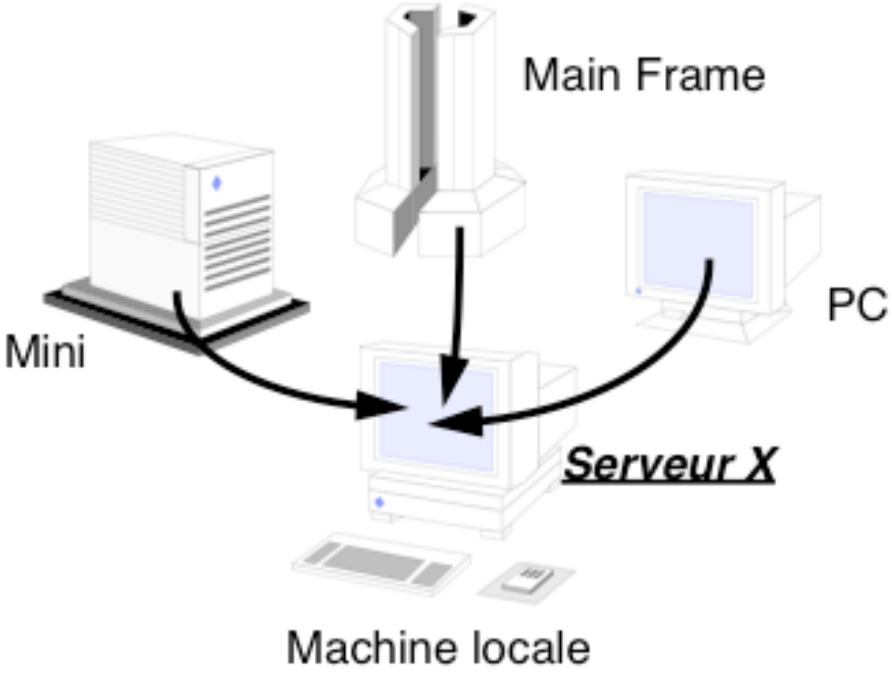
Succesor of **Lisa**,
another commercial failure



A brief history of HCI

1985: X Window System (MIT)

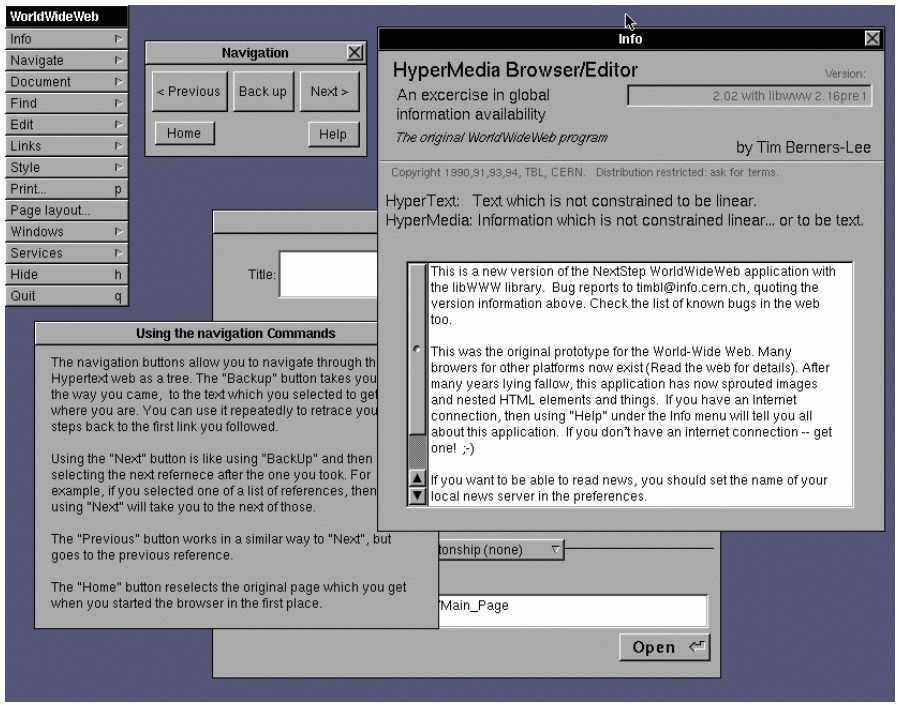
- For high-end workstations
- **Multi-platform**
- Hardware and software independent
- **Networked**: client / server architecture
- **Still used** nowadays! (Linux)



A brief history of HCI

1990/1991: World Wide Web (Tim Berners-Lee - CERN)

- Networked hypertext model
- **Internet + hypertext**
  - creation of URL / HTTP / HTML
- Paper refused at the prestigious ACM Hypertext conference!
- Small project that changed the world!



source: Wikipedia

HCI Software Development

Eric Lecolinet - Télécom ParisTech
www.telecom-parist.fr/~elc

Components of a GUI

Components of a Graphical User Interface (GUI)

- **Structure**: relationships between graphical objects *(e.g. HTML)*

- **Presentation**: graphical attributes *(e.g. CSS)*

- **Data** *(e.g. text, table content)*

- **Interaction**: **behavior of the GUI**

    - Most difficult part!
    - Graphical toolkits provide limited help (e.g. callback functions)

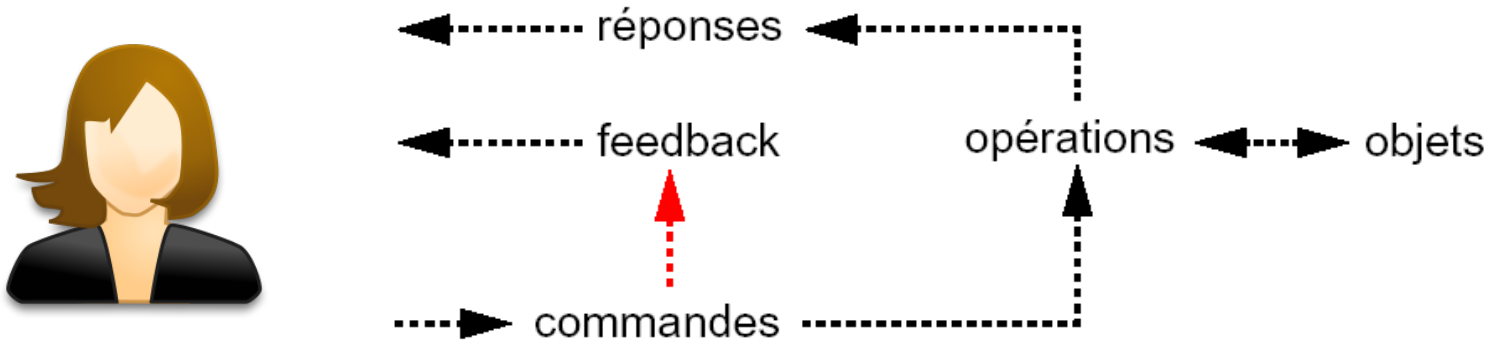
Specifying + encoding interaction

Specification

- How to **specify** the behavior in a **concise** and **unambiguous** manner?

Encoding

- How to **implement** it in a reliable and scalable way



src: M. Beaudoin Lafon

Specification

Specification languages

- UAN : User Action Notations
  (R. Hartson et al.)

Table I. Summary of Some Useful UAN Symbols

Action	Meaning
~	move the cursor
[X]	the context of object X, the "handle" by which X is manipulated
~[X]	move cursor into context of object X
~[*x*, *y*]	move the cursor to (arbitrary) point *x*, *y* outside any object
~[*x*, *y* in A]	move the cursor to (arbitrary) point within object A
~[X in Y]	move to object X within object Y (e.g., [OK__icon in dialogue__box])
[X]~	move cursor out of context of object X
˅	depress
˄	release
X˅	depress button, key, or switch called X
X˄	release button, key, or switch X
X˄˅	idiom for clicking button, key, or switch X
X"*abc*"	enter literal string, *abc*, via device X
X (*xyz*)	enter value for variable *xyz* via device X
( )	grouping mechanism
*	iterative closure, task is performed zero or more times
+	task is performed one or more times
{ }	enclosed task is optional (performed zero or one time)
A B	sequence; perform A, then B (same if A and B are on separate, but adjacent, lines)
OR	disjunction, choice of tasks (used to show alternative ways to perform a task)
&	order independence; connected tasks must all be performed, but relative order is immaterial
⇔	interleavability; performance of connected tasks can be interleaved in time
‖	concurrency; connected tasks can be performed simultaneously
;	task interrupt symbol; used to indicate that user may interrupt the current task at this point (the effect of this interrupt is specified as well, otherwise it is undefined, i.e., as though the user never performed the previous actions)
∀	for all
:	separator between condition and action or feedback

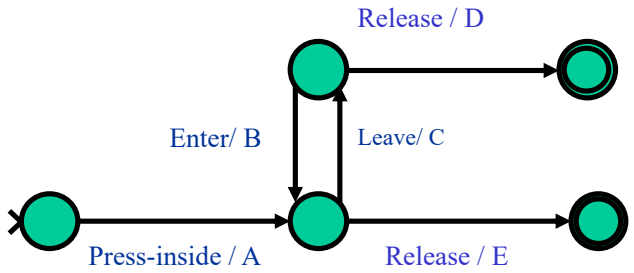
Table 1: UAN specification of the task "select icon"

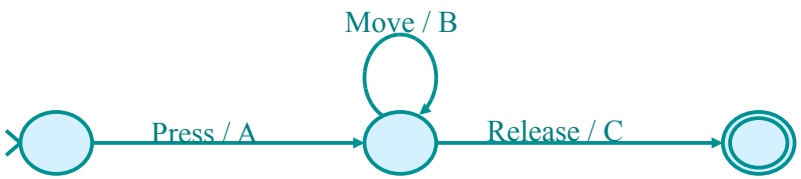
TASK: **select file**		
USER ACTIONS	**INTERFACE FEEDBACK**	**INTERFACE STATE**
~[file🗎] M^	file🗎 ! ∀ file🗎' ≠ file🗎 : file🗎' -!	
Mv		selected = file

Finite state machines (FSM)

Finite state machines

- Simple and effective for **modeling behaviors**
- Avoid **"spaghettis"** of callback functions
- Compatible with **event-driven** management





Double benefit

- Graphical **representation** => **GUI specification**
- Can **generate** source code => **GUI implementation**

State machine example

Rubber banding

```
Accept the press for endpoint p1;
P2 = P1;
Draw line P1-P2;
Repeat
    Erase line P1-P2;
    P2 = current_position();
    Draw line P1-P2;
Until release event;
Act on line input;
```

(adapted from Scott Hudson - CMU)

Problem?

State machine example

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```
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Until release event;
Act on line input;
```
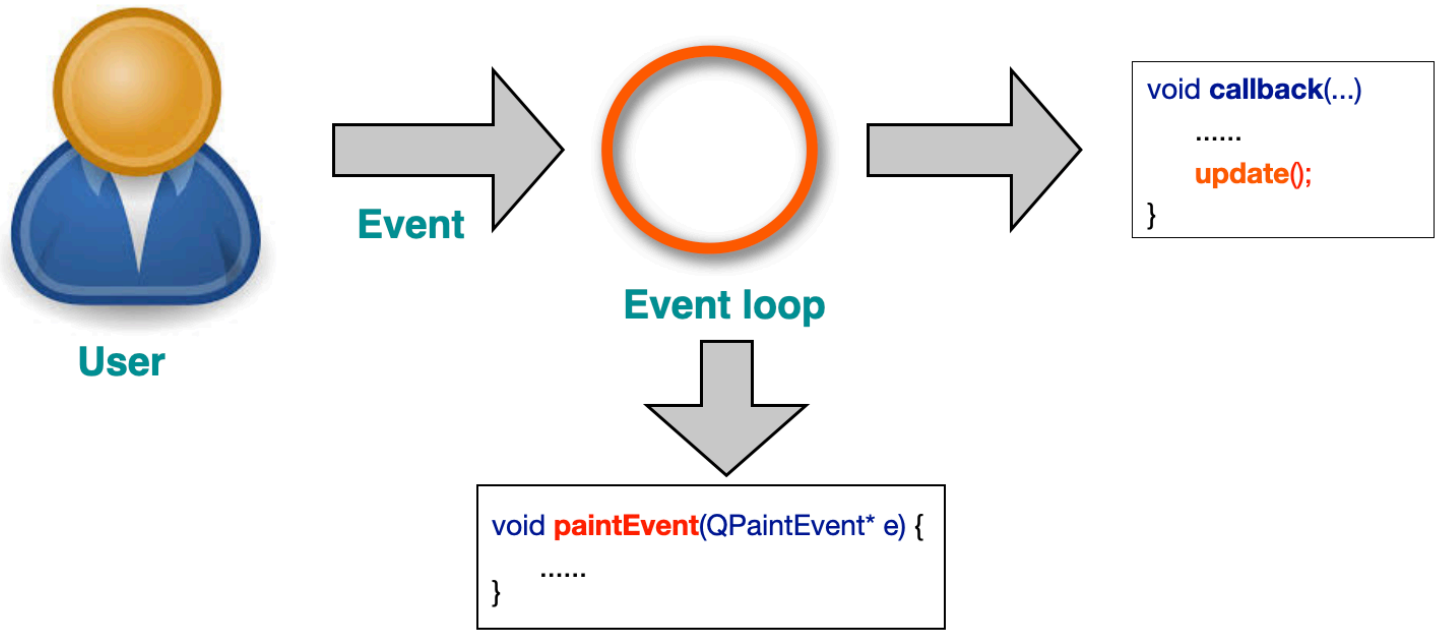

Problem:

incompatible with event-driven management!

Event-driven management



Events are provided by the event loop

- We cannot *"repeat an action"* in a loop
- The event loop must not be **blocked**
- Other events should not be **ignored**

State machine example

Accept the press for endpoint p1;

```
P2 = P1;
Draw line P1-P2;
```

A

Repeat

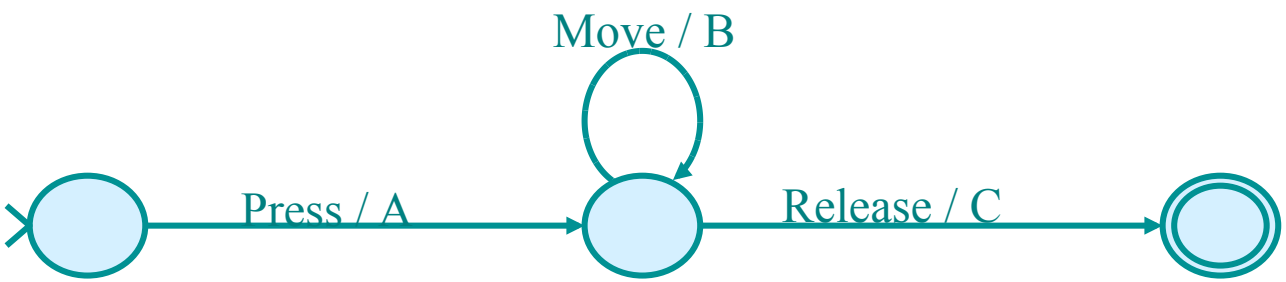
```
Erase line P1-P2;
P2 = current_position();
Draw line P1-P2;
```

B

Until release event;

```
Act on line input;
```

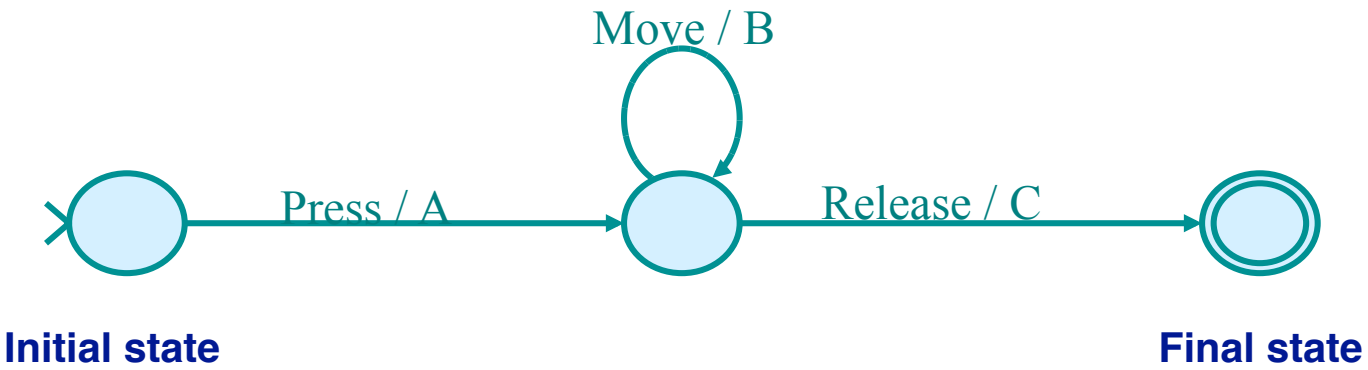
C



States and transitions

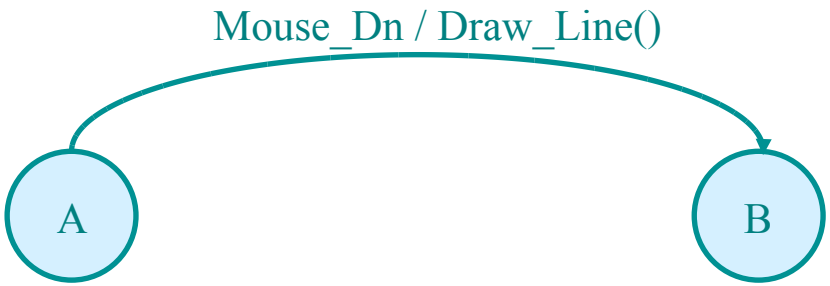
States

- **Circles**

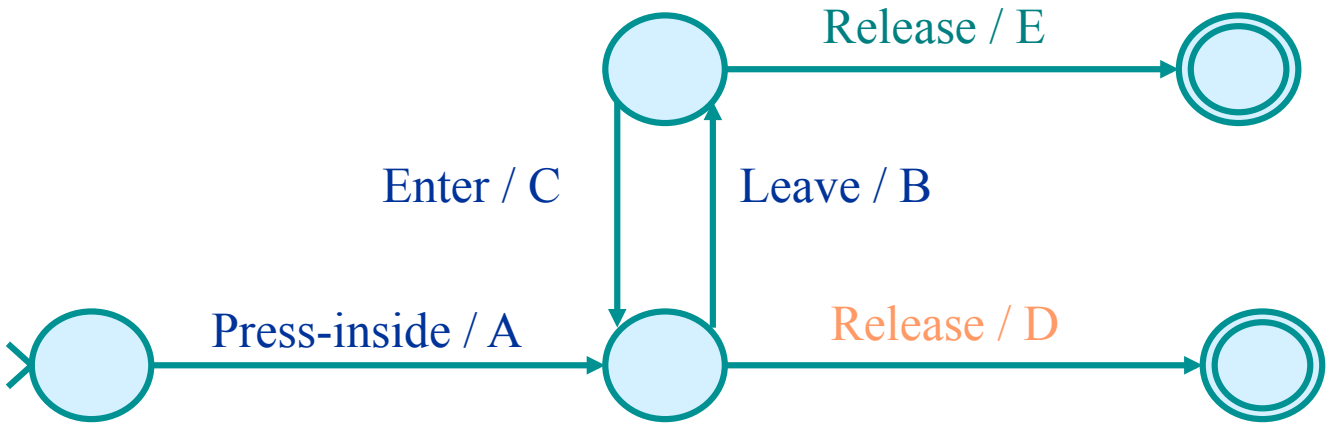


Transitions

- **Arcs** with an **event / action** label
- When the **event** occurs:
  - 1) the **state** changes
  - 2) the **action** is executed



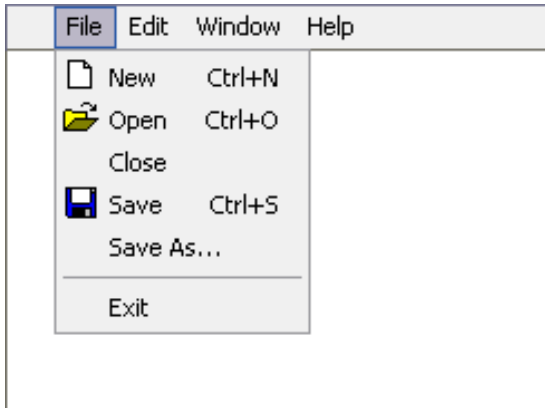
Clicking on a button



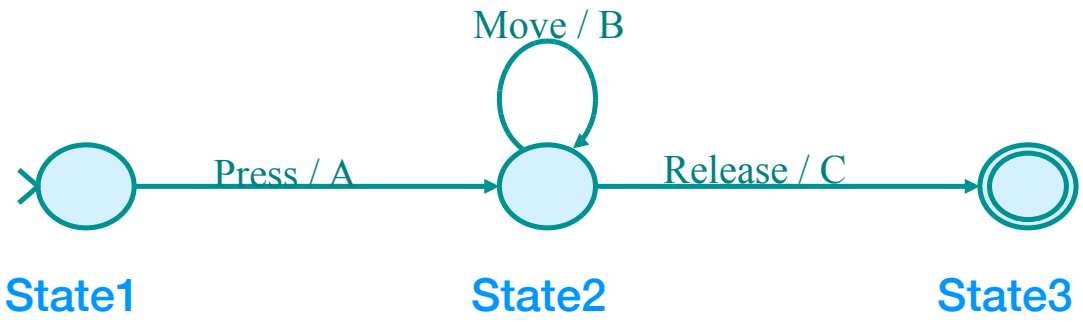
A: highlight button
B: unhighlight button
C: highlight button
D: do button action
E: do nothing

Limitations of this example

- No keyboard interaction
- Menu systems are more complex



FSM Implementation




```
state = start_state;

while (true) {
    event = wait_for_event();
    state = fsm(state, event);
}
```

```
state fsm (state, event) {

    switch (state) {

    case State2:
        switch (event.kind) {
        case MouseMove:
            actionB ( );
            state = State2;

        case MouseRelease:
            actionC ( )
            state = State3;
        }

     case State1:
        switch (event.kind) {
         case ...
        }
    }

   return state;
}
```

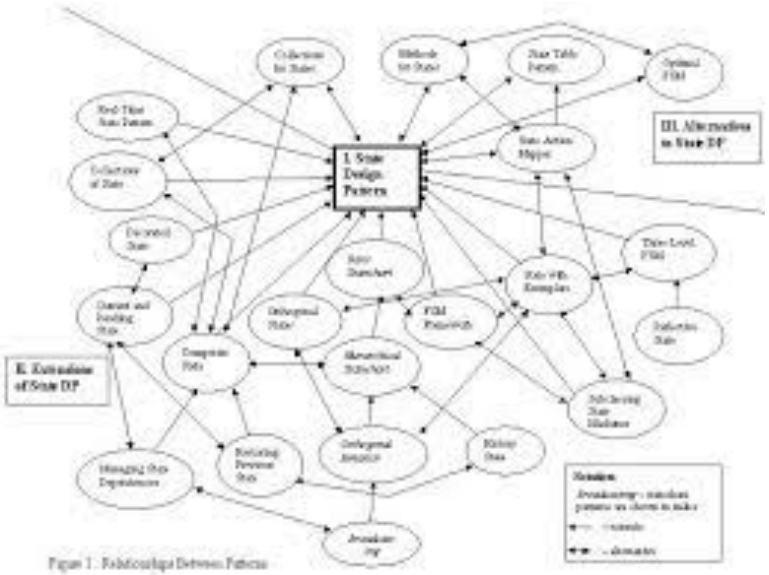
Tools

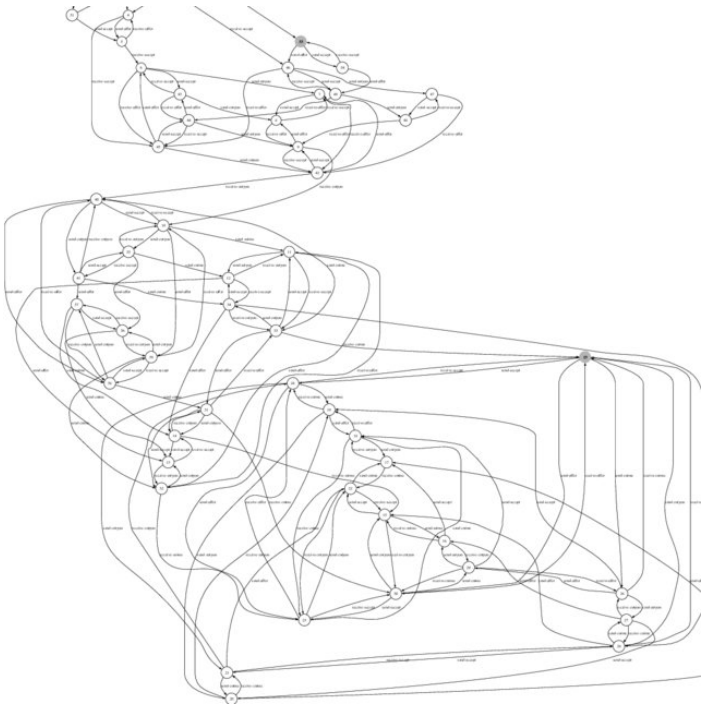
- generally based on **state/transitions tables**

Limitations

FSM limitations

- Nice for simple examples
- But GUIs involve **many interactive objects** => **combinatorial explosion!**





Statecharts

Statecharts

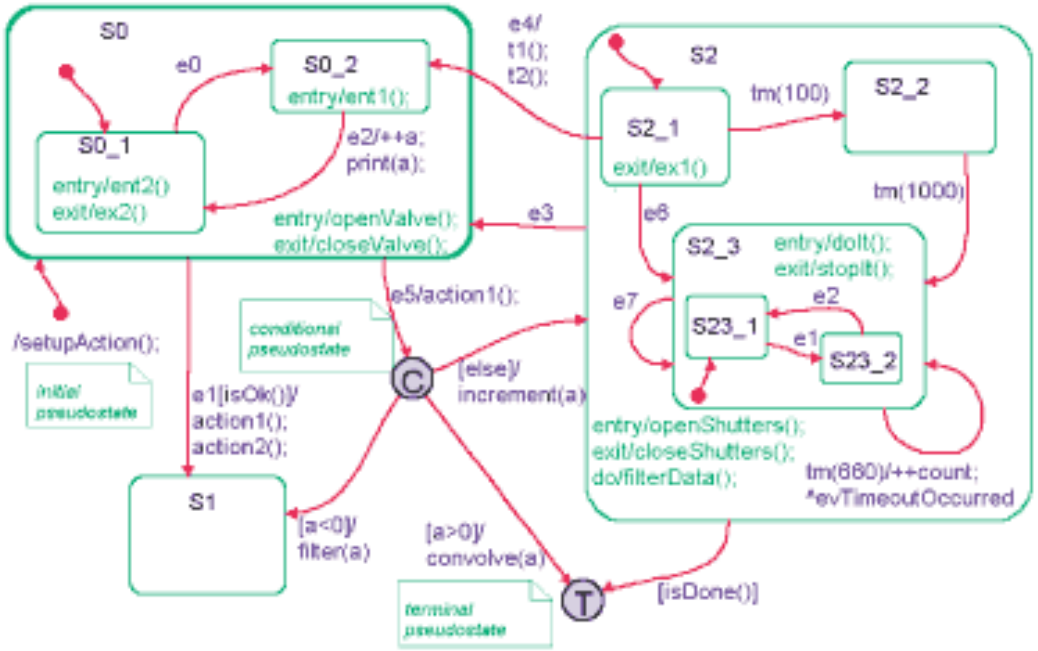
Hierarchical state machines

=> subsystem **decomposition**

=> **considerably reduce** the number of transitions

Many tools

- including **UML**

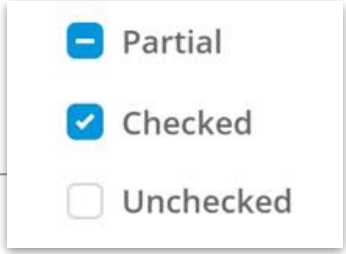


Qt State Machines

Qt State Machine Framework

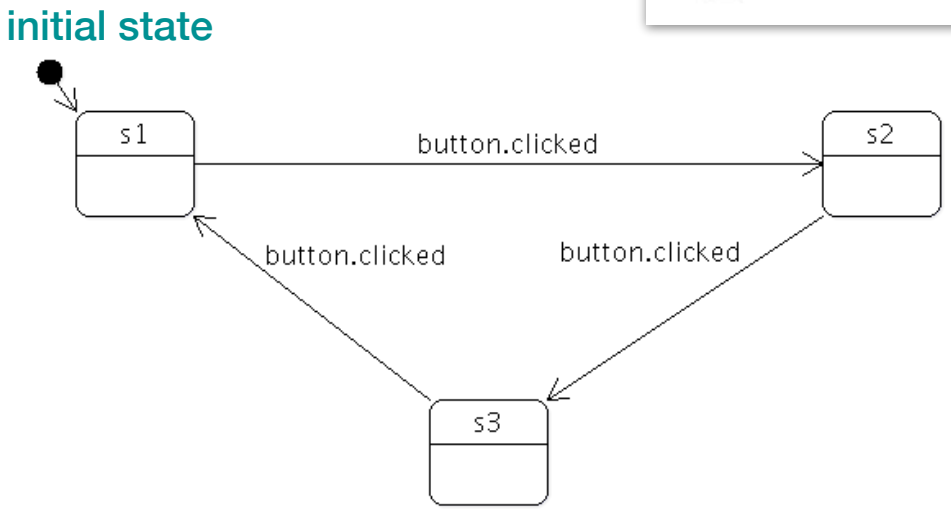
- **Statecharts** based on **SCXML**
- Alllow:
    - **grouped states** : for **hierarchies**
    - **parallel states** : to avoid **combinatorial explosion**
    - **history states** : to **save** and **restore** the state
    - **user-defined** events
- Also useful for **animations**

Qt State Machines



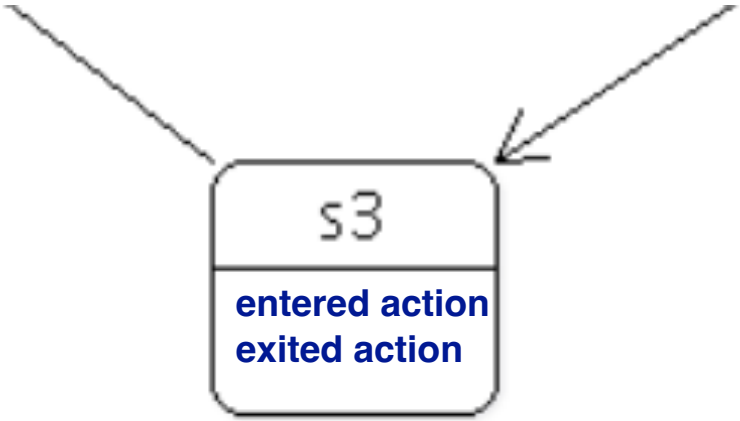
States

- The **initial state** must be specified
- Often GUIs have **no final state**

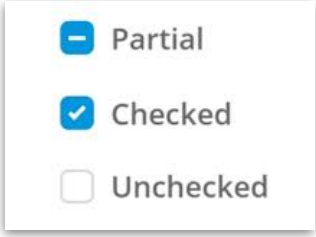


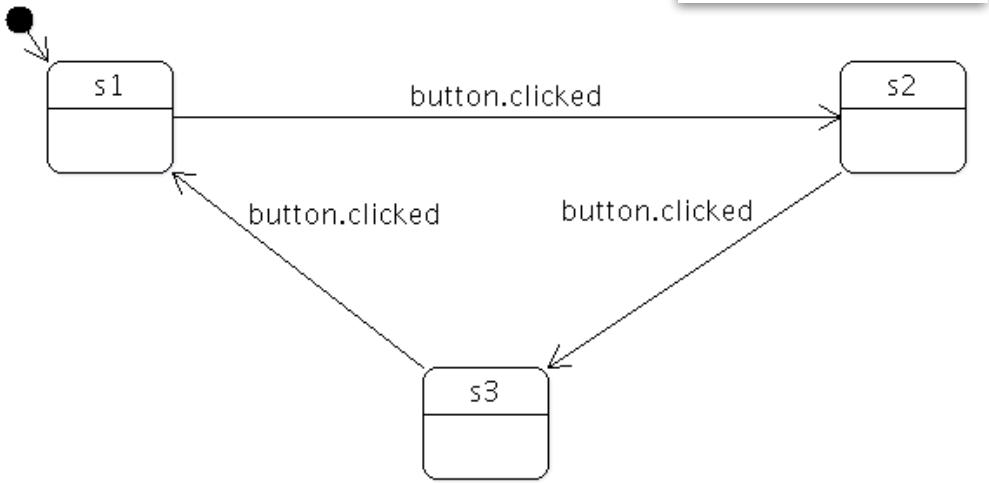
Actions

- **Qt actions** generally on **states**
  - when **entered**
  - when **exited**
- Can also be on **transitions**
  - (slightly more complicated)



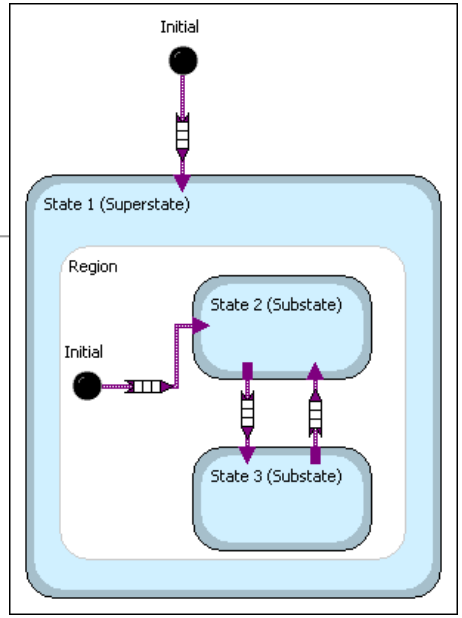
Three state button






```
// creates the state machine
auto * mac = new QStateMachine( );

QState *s1 = new QState( );
QState *s2 = new QState( );
QState *s3 = new QState( );
mac->addState(s1);
mac->addState(s2);
mac->addState(s3);
s1->addTransition(button, SIGNAL(clicked( )), s2);    // transition from s1 to s2 when bouton is clicked
s2->addTransition(button, SIGNAL(clicked( )), s3);
s3->addTransition(button, SIGNAL(clicked( )), s1);

QObject::connect(s3, SIGNAL(entered( )), window, SLOT(showMaximized( )));   // actions are on states
QObject::connect(s3, SIGNAL(exited( )), window, SLOT(showMinimized( )));

mac->setInitialState(s1);    // sets the initial state (don't forget!)
mac->start( );               // starts the state machine
```

Hierarchies



Substates and superstates

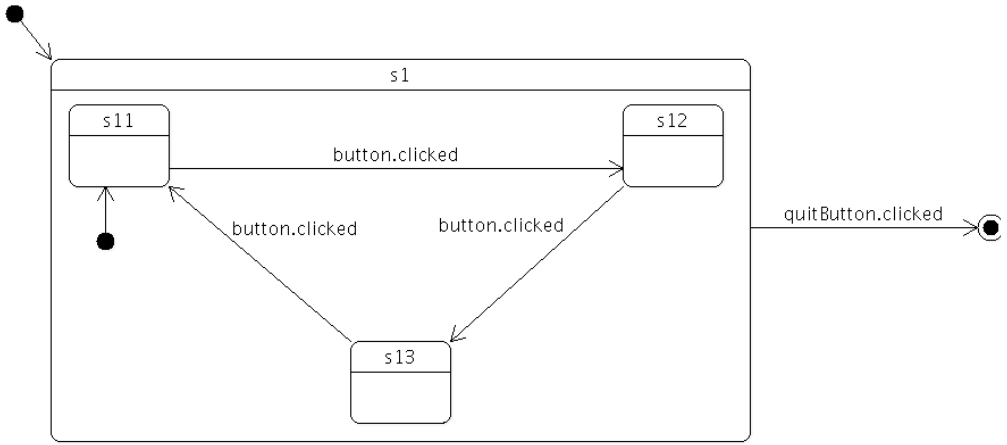
- **Substates inherit transitions** from their **superstates**
- They can be **both entered**

=> Less transitions: simpler diagrams

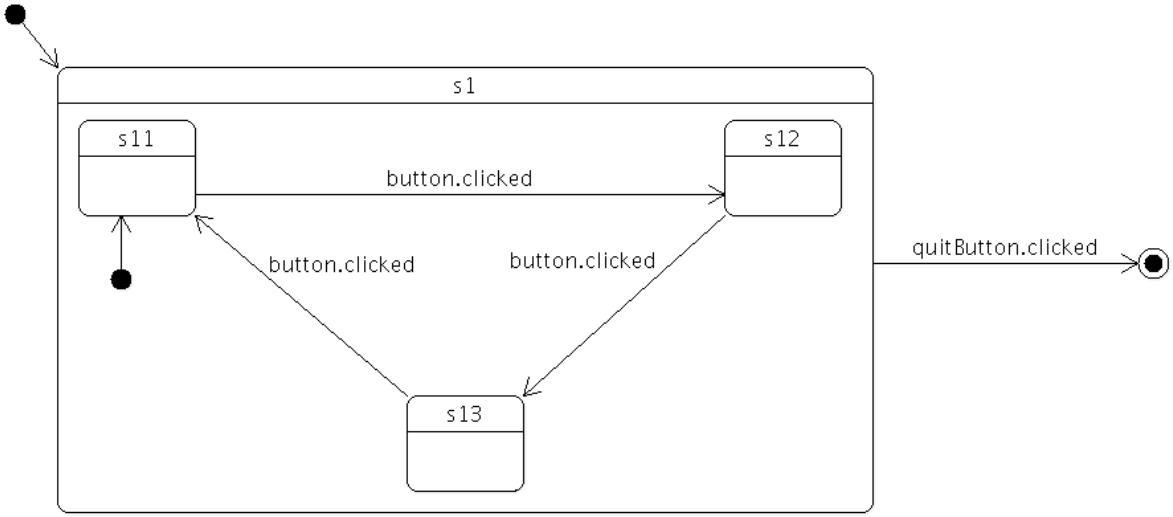
Example

- As previous example, but with **quit button** that exits the application
- without a hierarchy

=> transition **from each state** to **final state**



Hierarchies

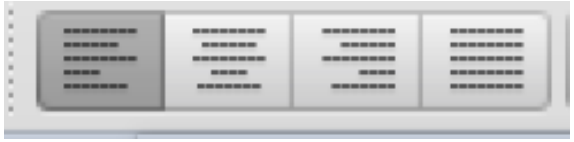



```
QState *s1 = new QState( );
mac->addState(s1);

// s11, s12, s13 are grouped in s1
QState *s11 = new QState(s1);
QState *s12 = new QState(s1);
QState *s13 = new QState(s1);

s11->addTransition(button, SIGNAL(clicked( )), s12);
s12->addTransition(button, SIGNAL(clicked( )), s13);
s13->addTransition(button, SIGNAL(clicked( )), s11);
s1->setInitialState(s11);

QFinalState *s2 = new QFinalState( );                    // s2 is a final state
mac->addState(s2);
                                                         // the children of s1 inherit the s1 -> s2 transition
s1->addTransition(quitButton, SIGNAL(clicked( )), s2);
                                                         // the finished() signal is emitted when the final state is reached
connect(mac, SIGNAL(finished( )), QApplication::instance( ), SLOT(quit( )));
mac->setInitialState(s1);
mac->start( );
```

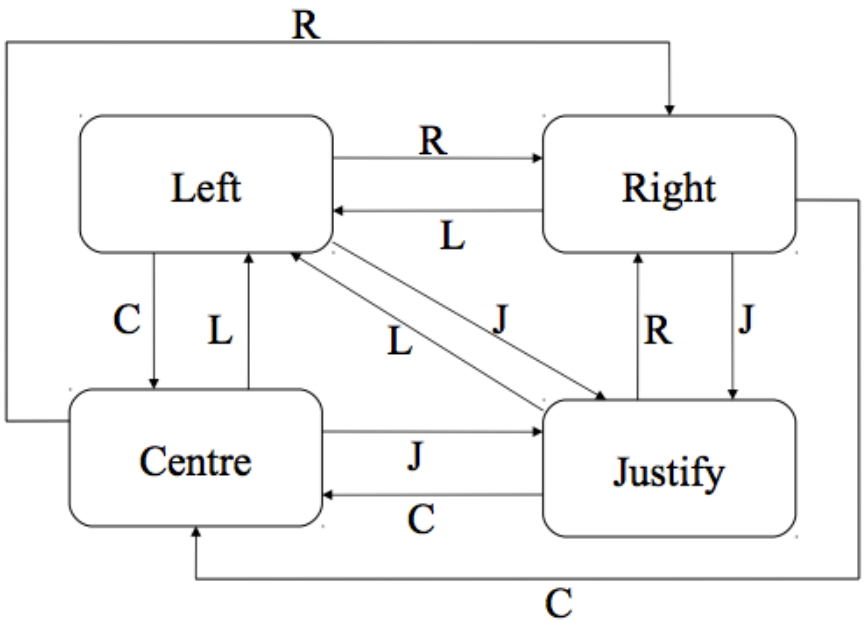
Hierarchies

Second exemple

- 4 radio buttons => 4 **exclusive states**
- Transition needed between each **couple of states**



text alignment

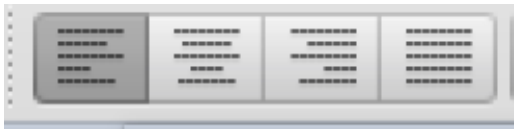


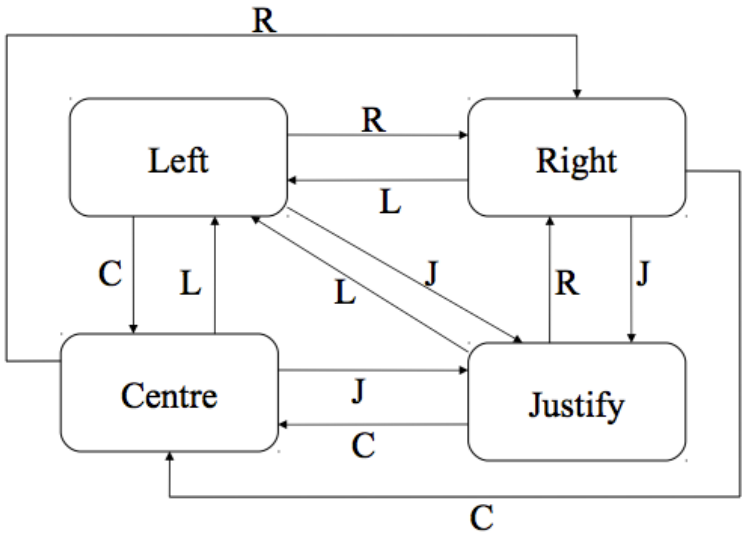
Quite **complex**

for such a **simple** case!

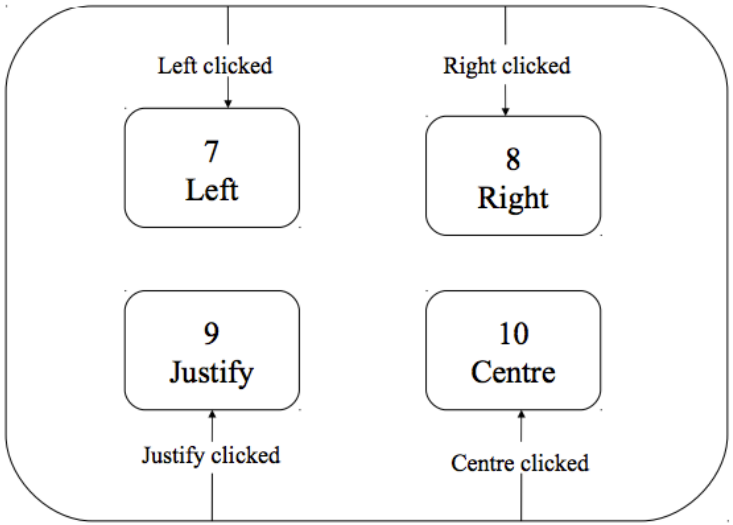
Hierarchies

- A **hierarchy** makes it simple!
- Only 4 **transitions**, all **inherited**
- The superstate is **always entered**





flat diagram

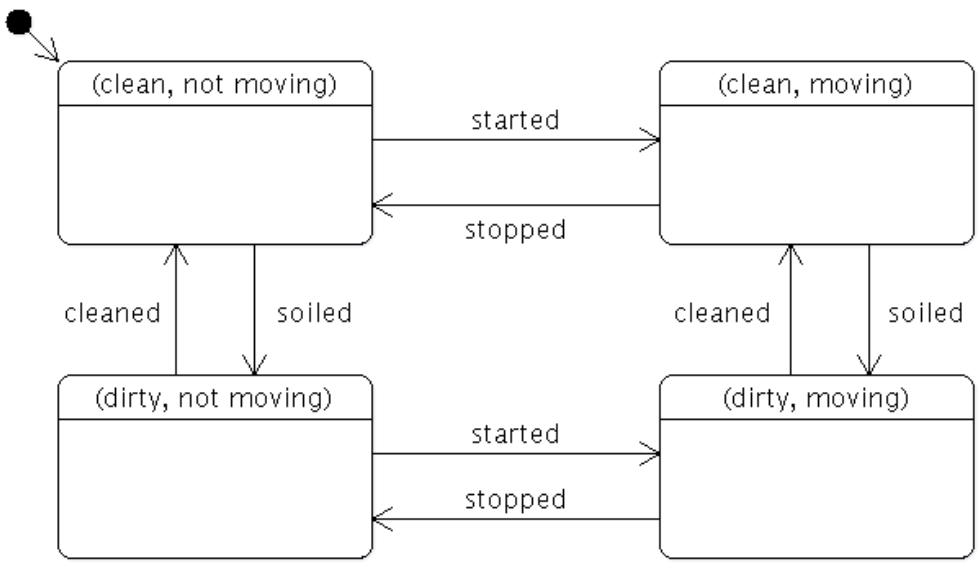


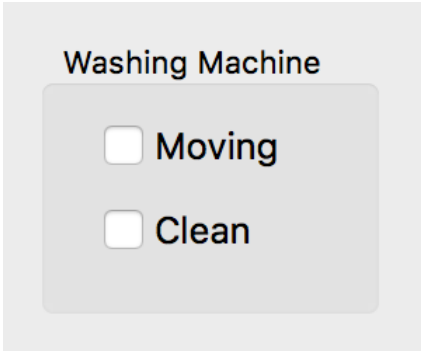
hierarchical diagram

Parallel states (concurrency)

Exemple

- Two **independant** check boxes
- Each check box has **two states** (on/off) => all **combinations** must be considered



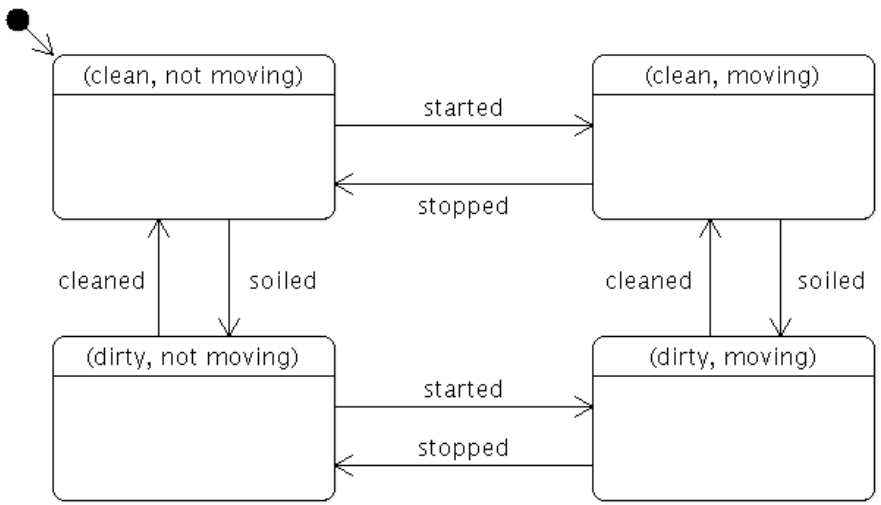


Parallel states

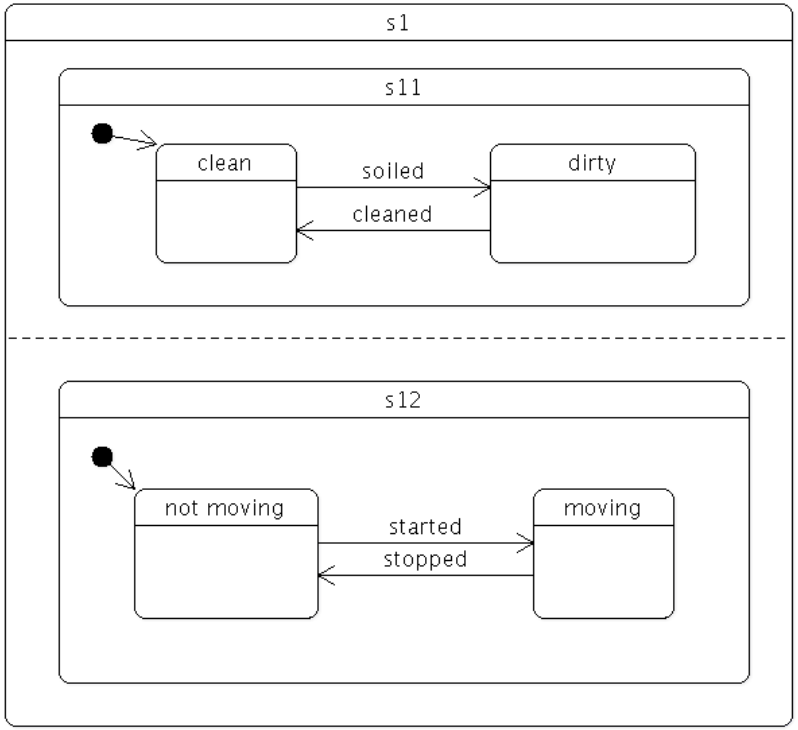
```
QState *s1 = new QState(QState::ParallelStates);
QState *s11 = new QState(s1);
QState *s12 = new QState(s1)
```

Solution: parallel states

- several states are **simultaneously entered**



flat diagram

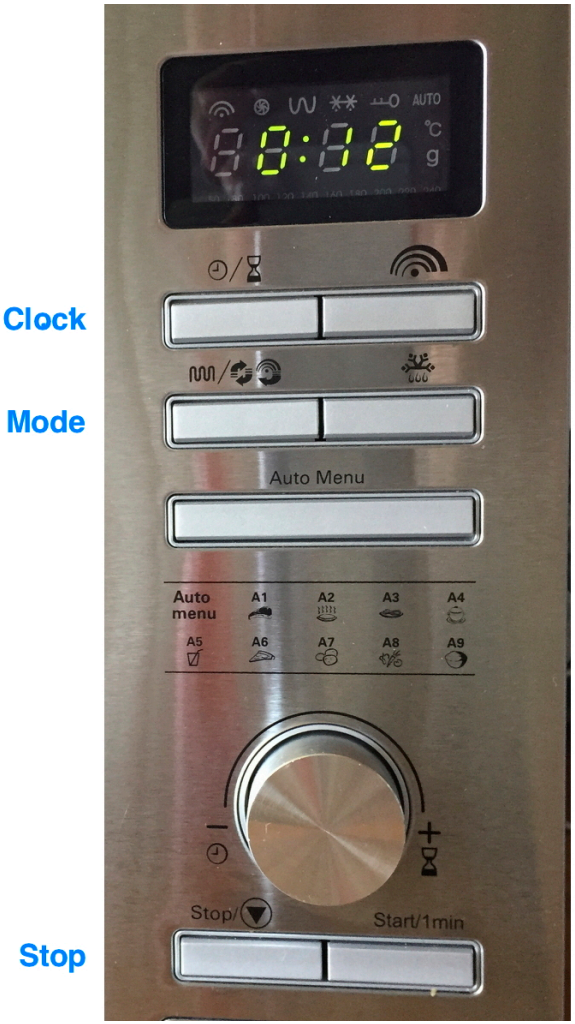


hierarchical diagram

Lab

Goal: implement the GUI and behavior of a microwave oven

TP3 on https://perso.telecom-paris.fr/elc/qt/



Lab

If possible, use qmake (not CMake !)

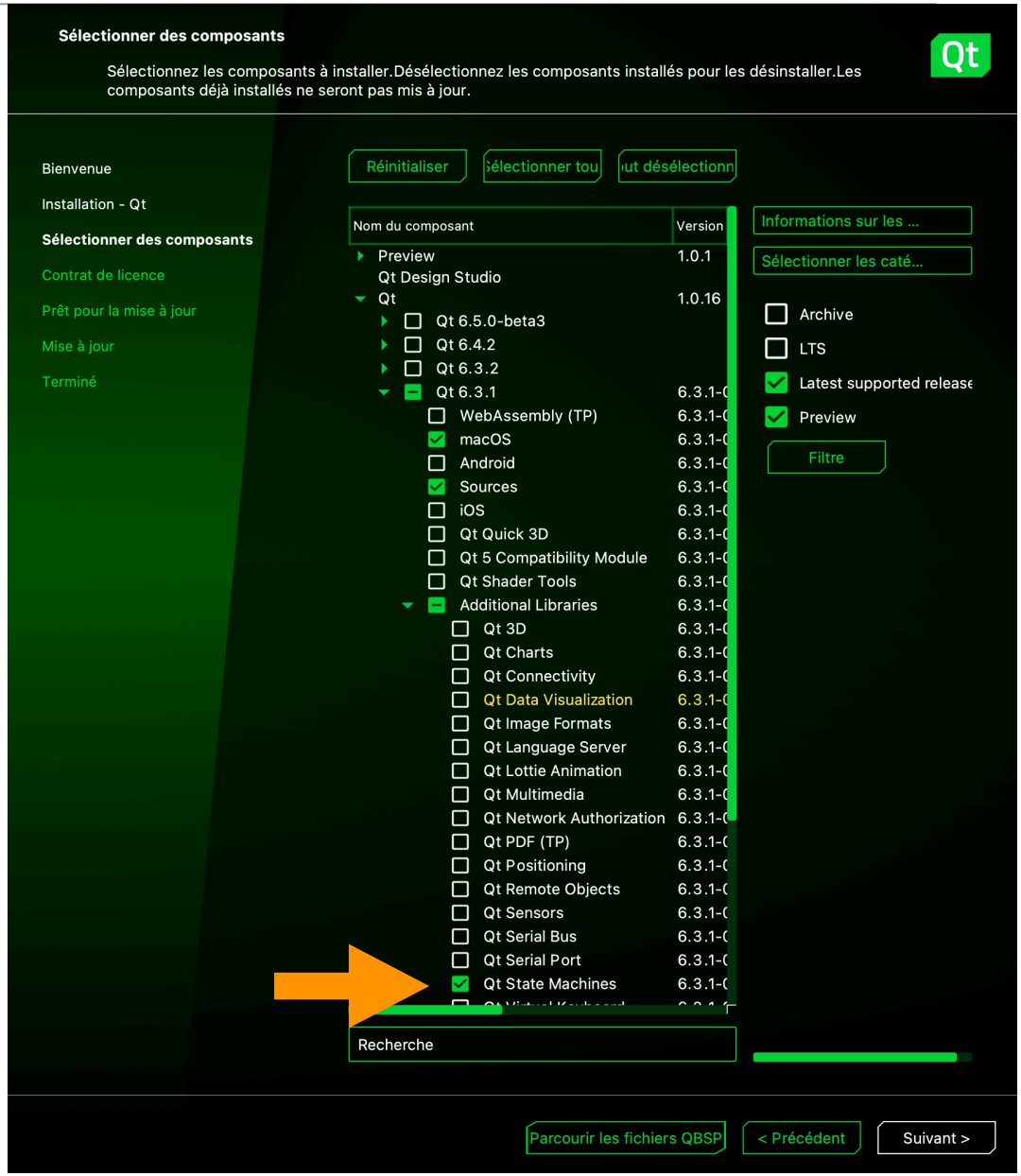
With Qt6 the State Machine module must be added explicitely

- MaintenanceTool
  - Add or remove components
    - Additional Libraries
      - Qt State Machine

In the .pro file add statemachine

```
QT += core gui widgets statemachine

TARGET = proj
TEMPLATE = app

SOURCES += main.cpp MainWindow.cpp

HEADERS  += MainWindow.h

FORMS    += MainWindow.ui
```

MaintenanceTool



Timeouts

State transitions can also be fired by timers

- To execute an action after a **delay**:

```
QTimer * timer = new QTimer( );
state1->addTransition(timer, SIGNAL(timeout( )), state2);
....
timer->start(delay);
....
timer->stop();
```

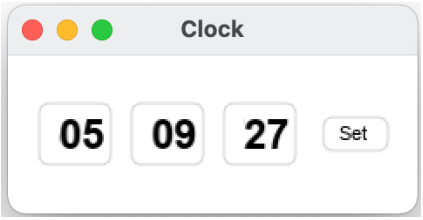
Action on timeout

```
connect(timer, SIGNAL(timeout( )), widget, SLOT(doSomething( )));
```

Is the state entered?

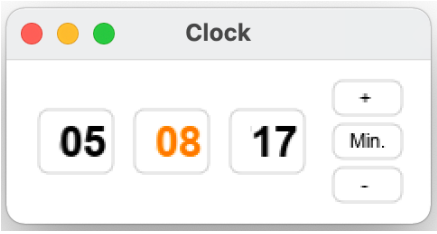
Example

- Clock displayed **differently** depending on the **active state**



idle state

set-hour state



set-min state

```
void MainWindow::setClock(int value) {
  if (hour_state->active()) {
     setHour(value);
  }
  else if (min_state->active()) {
     setMin(value);
  }
}
```

(only available in recent versions of Qt)

Note: no active state during the transition!

```
QSet<QAbstractState*>
config  = machine->configuration();

if (config.contains(hour_state)) {
    ...
 }
 else if (config.contains(min_state)) {
    ...
}
```

Transitions.h

Transitions.h header

- Provides a set of **helper functions**
- http://www.telecom-paris.fr/~elc/qt/Transitions.h

Allows

- Combining **transitions** and **actions** on **signals**
- But also on **events**, mouse events specifying **buttons**, and **custom events**

Qt :

```
state1->addTransition (button, SIGNAL(clicked( )), state2);
QObject::connect (state2, SIGNAL(entered( )), this, SLOT(doIt( )));
```

*adds **action** on **state***

Transitions.h :

```
addTrans (state1, state2, button, SIGNAL(clicked( )), this, SLOT(doIt( )));
```

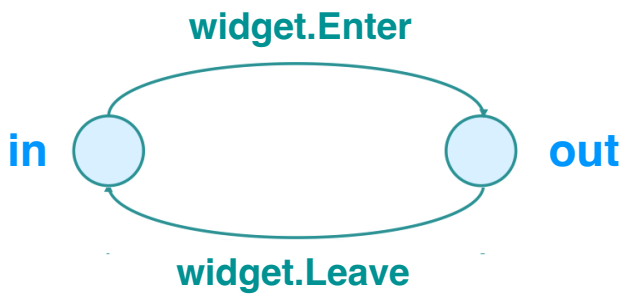
*adds **action** on **transition***

Transitions on events

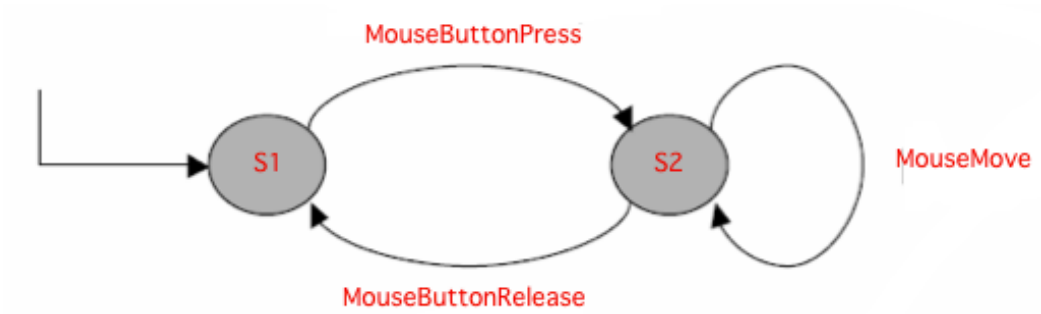
Events

addEventTrans (out, in, widget, QEvent::Enter);

addEventTrans (in, out, widget, QEvent::Leave);



Mouse Events



*from s1 to s2 when the **left button** is pressed*

addMouseTrans (s1, s2, canvas, QEvent::MouseButtonPress, Qt::LeftButton, this, SLOT(newLine( )));

addMouseTrans (s2, s2, canvas, QEvent::MouseMove, Qt::NoButton, this, SLOT(adjustLine( )));

addMouseTrans (s2, s1, canvas, QEvent::MouseButtonRelease, Qt::LeftButton);

Transitions on events

Modifiers

shift + left or right button

```
addMouseTrans (s1, s2, canvas, QEvent::MouseButtonPress, Qt::LeftButton | Qt::RightButton)
->setModifierMask(Qt::ShiftModifier);
```

Mouse position

updates mouse position

```
QPoint mousepos;
addMouseTrans (s2, s2, canvas, QEvent::MouseMove, Qt::NoButton, mousepos,
                this, SLOT(adjustLine( )) );
```

returns the mouse position

(slightly inaccurate on XWindows)

```
QPoint cursorPos(QWidget* w)  { return w->mapFromGlobal(QCursor::pos( ));
```

Guards

Guards

- The transition is performed if a predicate is true
- Notation: **predicate : event / action**

button.enabled : PressMouse / DrawLine()

With Transitions.h

```
addTrans (guard, state1, state2, SIGNAL(clicked( )));
addTrans (guard, state1, state2, SIGNAL(clicked( )), this, SLOT(doIt( )) );;
```

guard = bool or object that can be compared to a bool

Animations and properties

Properties

```
s1->assignProperty( label, "text", "In state s1" );
s1->assignProperty( button, "geometry", QRectF(0, 0, 50, 50) );
```

Especially useful for animations

```
s1->assignProperty( button, "geometry", QRectF(0, 0, 50, 50) );
s2->assignProperty( button, "geometry", QRectF(0, 0, 100, 100) );
```

the size of the button will change smoothly:

```
s1->addTransition( button, SIGNAL(clicked( )), s2)
                    ->addAnimation( new QPropertyAnimation( button, "geometry" ) );
```

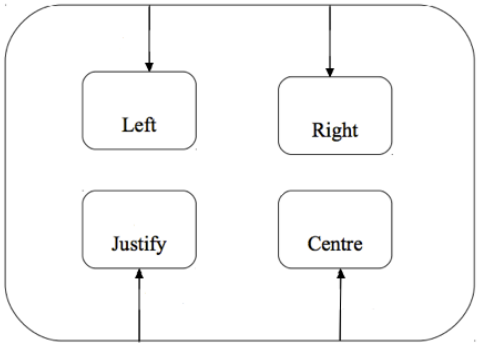
Custom events

Custom Events

- The user can create her **own events**: **QEvent**(int *type*)
  - *type* = the type of the event (between QEvent::User et QEvent::MaxUser)
- **postEvent**(QEvent*) posts an event to a state machine
- **postDelayedEvent**(QEvent*, delay) posts with a delay

Transitions and events

```
addUserEventTrans(s, s_left, LEFT);
addUserEventTrans(s, s_right, RIGHT);
....
mac.postEvent( new QEvent(LEFT) );      // triggers the transition
```



Transition filters

- A transition can be made only if its eventTest( ) method is called and returns **true**
- Technique for implementing **guards** or **user-defined** behaviors

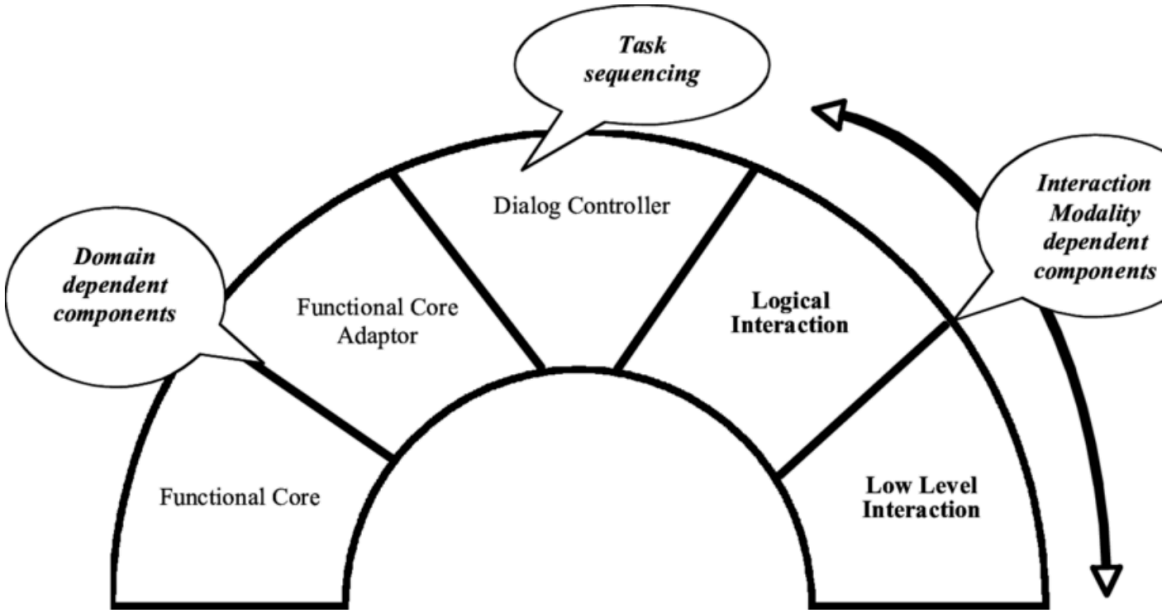
exemple: updates the mouse position at each transition

```
class MouseTransition : public QMouseEventTransition {
    QPoint& pos;
    bool eventTest(QEvent * e) {
        if ( ! QMouseEventTransition::eventTest(e))  return false;
        QEvent* realEvent = static_cast<QStateMachine::WrappedEvent*>(e)->event( );      // get event
        switch (realEvent->type( )) {
        case QEvent::MouseMove:
        case QEvent::MouseButtonPress:
        case QEvent::MouseButtonRelease:
            _pos = static_cast<QMouseEvent*>(realEvent)->pos( );            // update  mouse position
        }
        return true;                                          // true => the event triggers the transition
    }
};
```

Software architecture models

Arch Model

- Analogy with **natural language**
- three layers



from Bastide et al.

Presentation (lexical view)

- Graphical objects and primitives

Dialogue controller (syntax)

- UI logics

Functional core adapter (semantics)

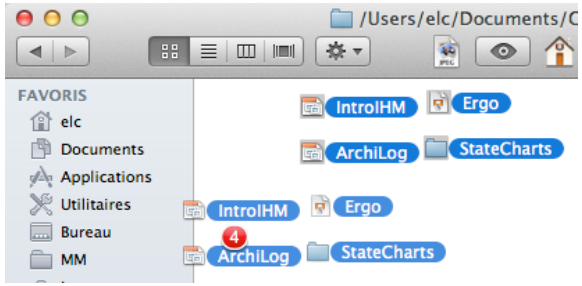
- API between UI and **functional core** (the non UI part)

Dialogue control

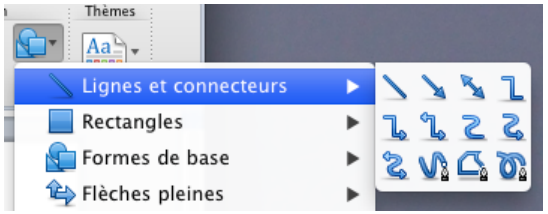
Syntax examples

- object verb

- (object)* verb



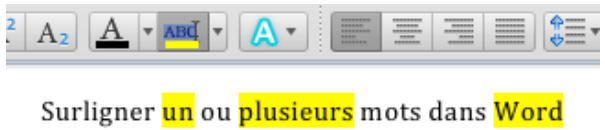
- (object)* verb object



- verb object

- verb (objects)*

- verb object or (object)* verb

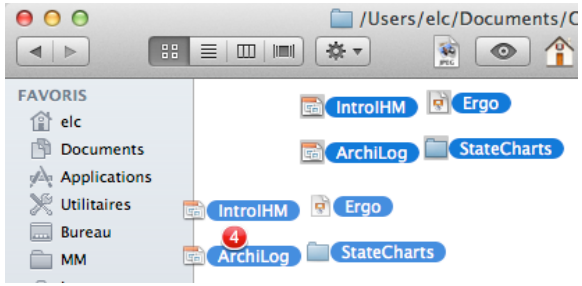


Dialogue control

Syntax examples

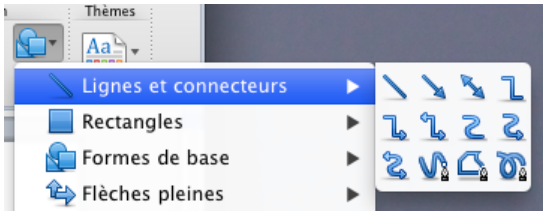
- **object verb**
  - put text in orange

- **(object)* verb**
  - destroy several files



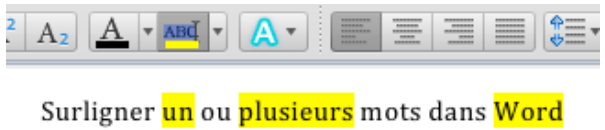
- **(object)* verb object**
  - drag multiple files

- **verb object**
  - draw a single line



- **verb (objects)***
  - draw several lines (implies a mode)

- **verb object or (object)* verb**
  - MSWord highlighter

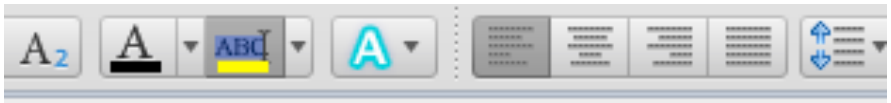


Spatial modes

the effect of an action depends on **where** it is performed

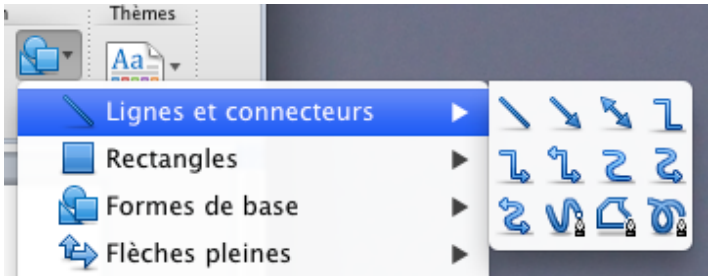
examples :

- buttons, menus...



Advantages

- visibility
- discovery
- memorization (always at the same place)



Temporal modes

the effect of an action depends on **when** it is performed

often used for creating **new objects**

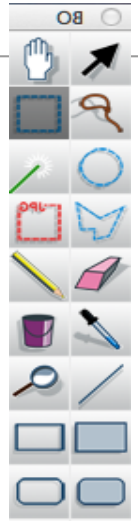
examples :

- drawing tool palettes
- modal dialog box

Drawbacks

- lack of **visibility** => risk of **errors** (what is the current state?)

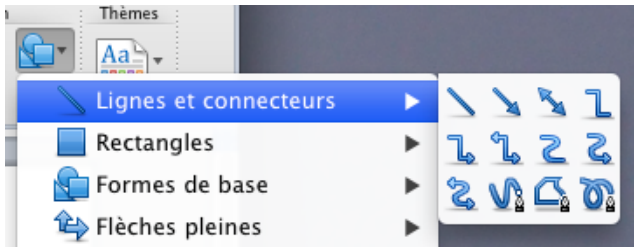
Temporal modes



Persistent modes

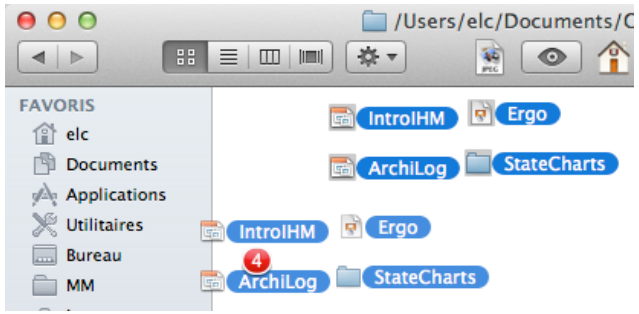
- remain activated
  - e.g.: draw several lines in a row
  - syntax: **verb (objects)***

One shot



- takes effect only on the **following action**
  - e.g.: draw a single line
  - syntax: **object verb**

Quasi modes



- **automatically disabled** at the end of the action
  - Ctrl, Alt modifiers
  - Drag and drop

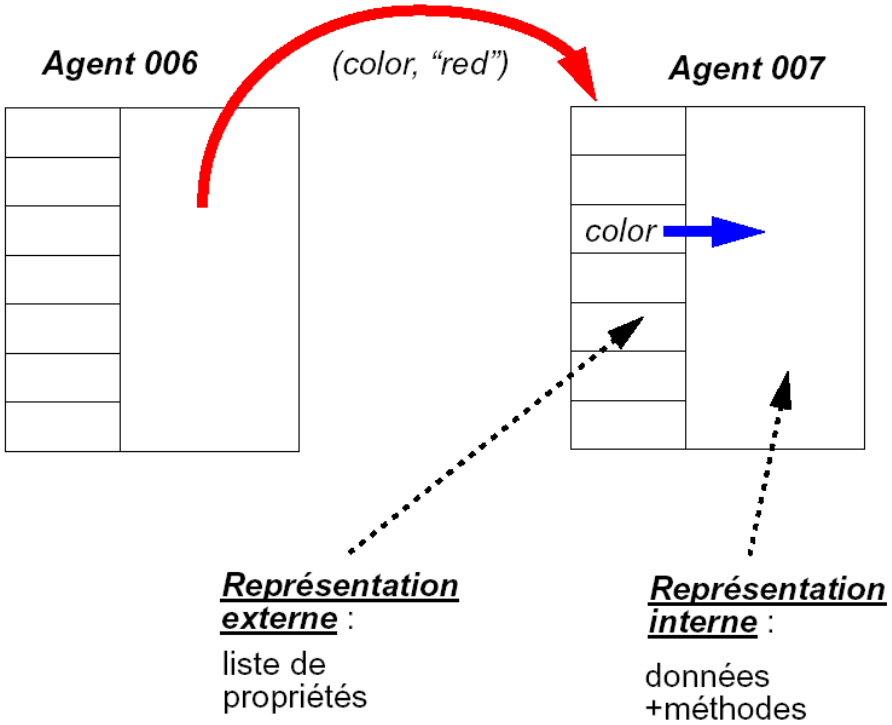
Multi-agent models

Vision: interactive system =

- set of **agents**
- react to / produce **events**

Agent = treatment system with:

- **memory**
- **states**
- a "**processor**"
- a set of event **senders** / **receivers**



Inspiration of various models

- XWindow, **MVC**, etc.

MVC

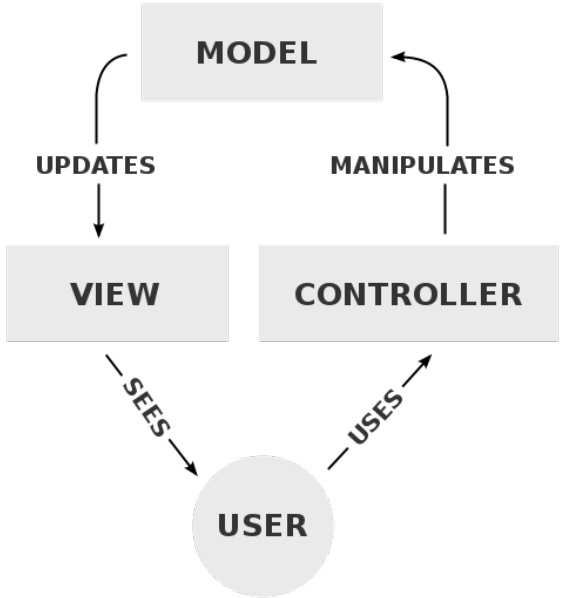
Goals

- Better **structure** applications, reduce complexity:
  - Clear separation between the **data** and the **GUI**
  - Ex: *spreadsheet* : data vs. graphical representation
- Allow managing **multiple views**
- Help **reusing** source code
- Help **team** development

MVC

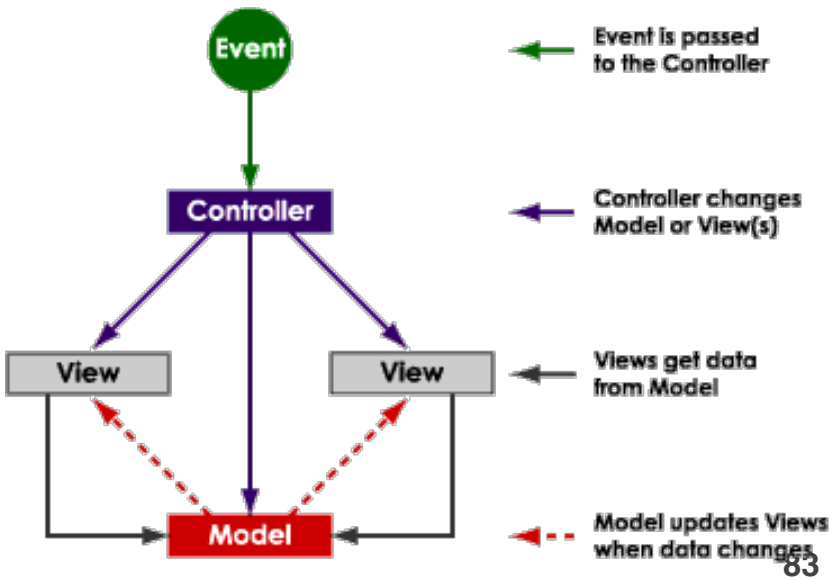
Original model

- **Smalltalk** GUI toolkit (1978)



Three components

- **Model** : **data** (and data **logics**)
- **View** : **visual** representation
- **Controller** : **input** management and **behavior** of interactive system

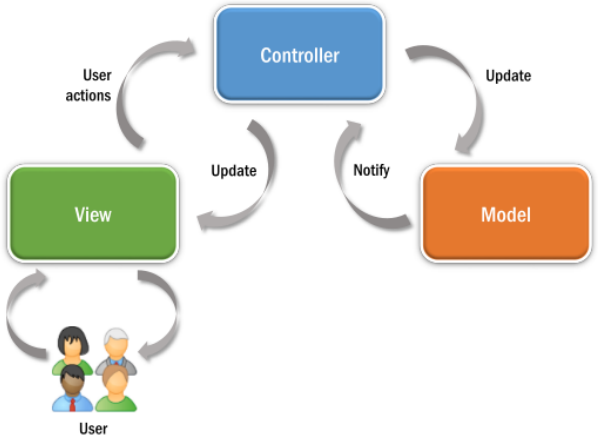


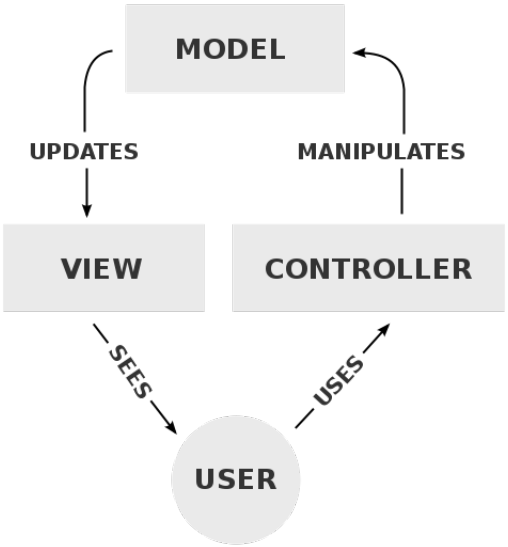
variant with multiple views

MVC variants

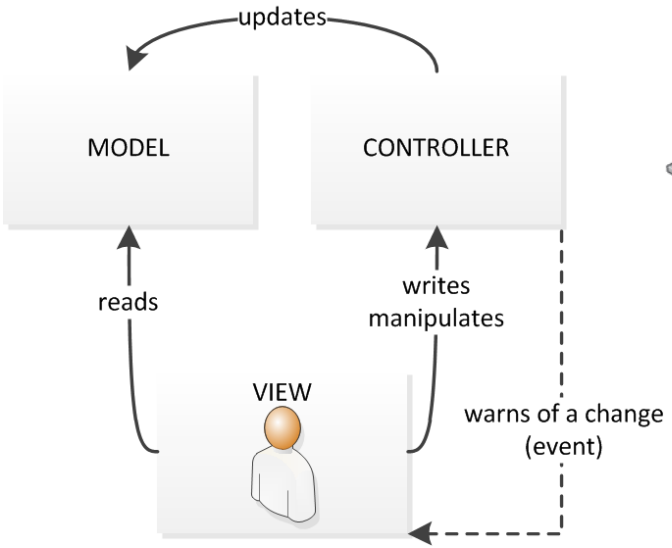
Various flavors

- for graphical interfaces, Web development, etc.

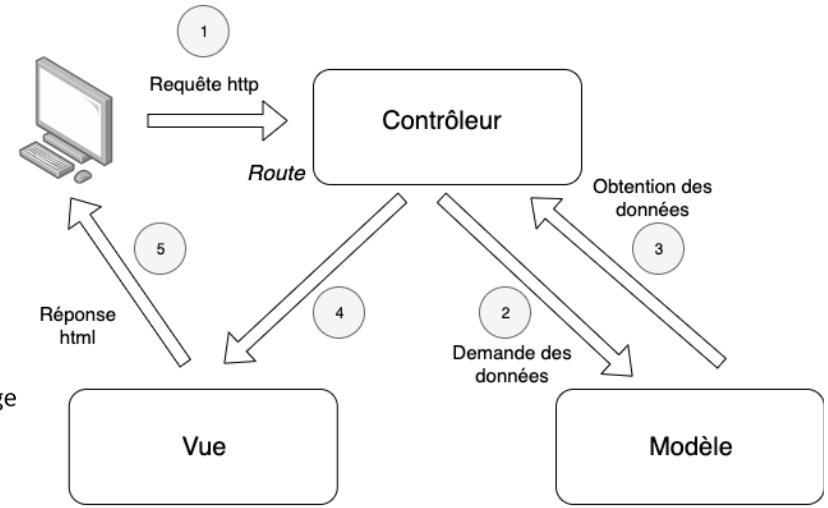




original model



variant

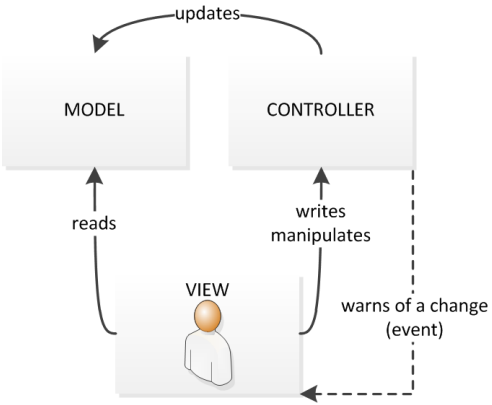


Web development

Variants and other models

Variants

- model–view–adapter (MVA)
- model–view–presenter (MVP)
- model–view–view model (MVVM)
- hierarchical model–view–controller (HMVC)
- etc.

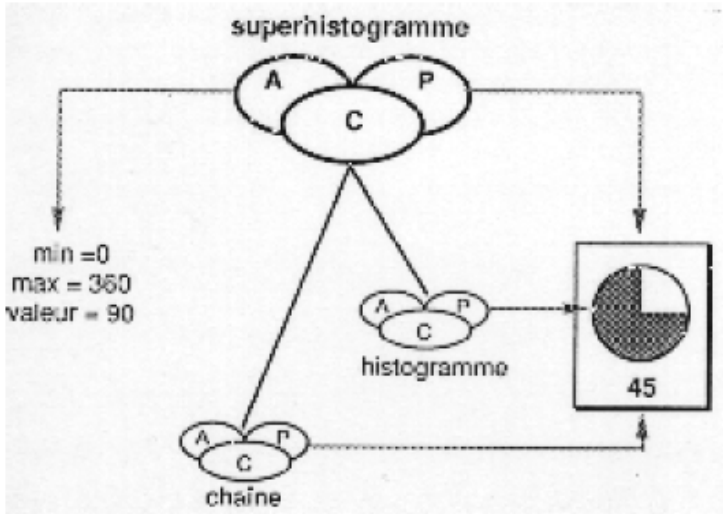


PAC (J. Coutaz, LIG)

Each object has **3 facets:**

- **Presentation = View**
- **Abstraction = Model**
- **Control = Controller**

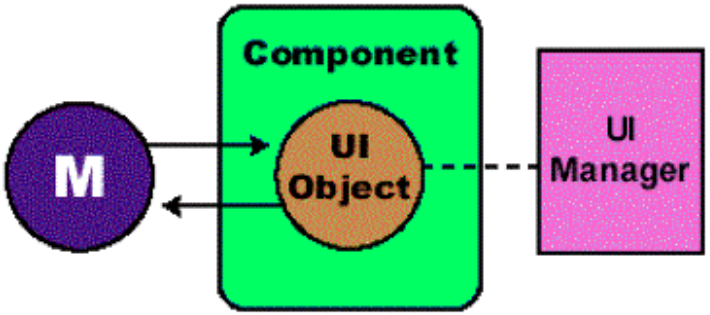
Moreover, PAC is **hierarchical**



MVC & Java Swing

Internal M+VC architecture

- a **JComponent** =
  - a **Model** (for components managing data)
  - a **UIComponent**

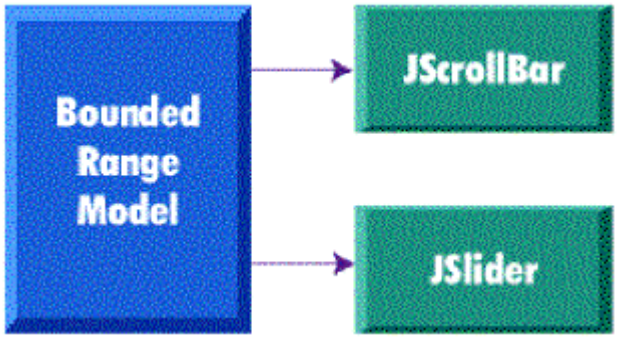


- a **UIComponent (UI Object) =**
  - **Controller** + **View** (mixed)

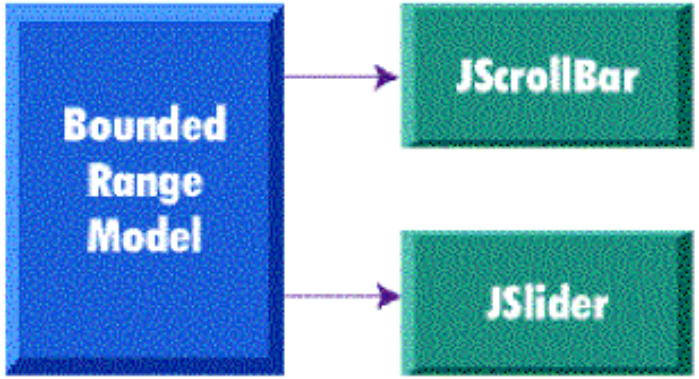
- The **Model** can be shared

Example

- JScrollBar and JSlider own a BoundedRangeModel



MVC & Java Swing



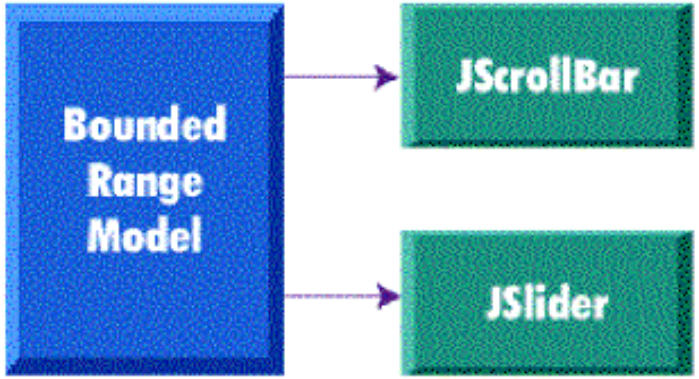
In the JSlider API

```
public BoundedRangeModel getModel();
public void setModel(BoundedRangeModel);
```

Changing the JSlider model

```
JSlider slider = new JSlider();
BoundedRangeModel model =
    new DefaultBoundedRangeModel( ) {
        public void setValue(int n) {
            System.out.println("SetValue: "+ n);
            super.setValue(n);
        }
    });
slider.setModel(model);
scrollbar.setModel(model);
```

MVC & Java Swing



In the JSlider API

```
public BoundedRangeModel getModel();
public void setModel(BoundedRangeModel);
```

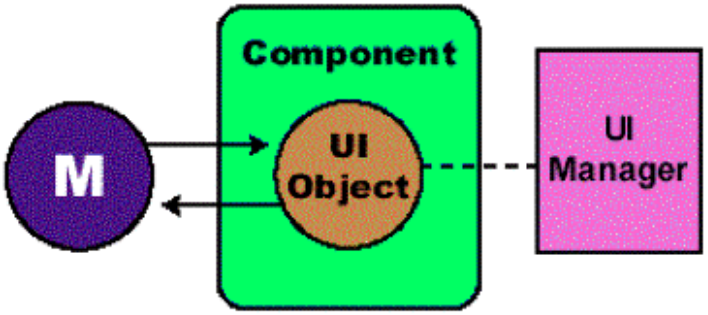
One can also ignore models

```
JSlider slider = new JSlider();
int value = slider.getValue();

// coherent because:
public int getValue()  {return getModel().getValue(); }
```

MVC & Java Swing

Pluggable Look and Feel

The **UIManager** changes the **ComponentUI**s dynamically



Java Metal:

```
public static void main(String[ ] args) {
   try {
        UIManager.setLookAndFeel(UIManager.getCrossPlatformLookAndFeelClassName());
   } catch (Exception e) { }
}
```

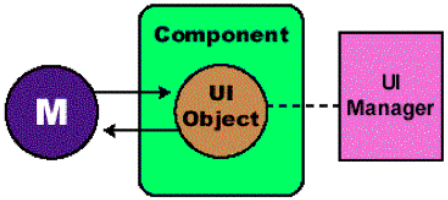
Windows:

```
UIManager.setLookAndFeel( “com.sun.java.swing.plaf.windows.WindowsLookAndFeel” );
```

MVC & Java Swing

Internal M+VC architecture

- a **JComponent** =
  - a **Model**
  - a **V+C** **UIComponent**



Another point of view

- **Controllers** = Java **Listeners**
- **Views** = **JComponents**
  (include low level **Controllers**)
- **Models**

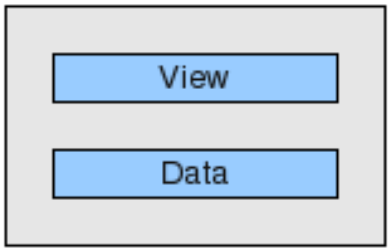
MVC

- can be used in different ways
- at different levels of abstraction

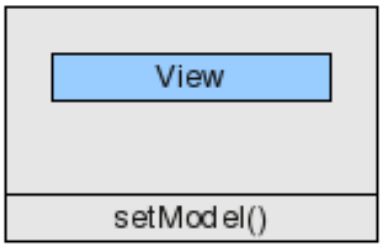
MVC & Qt

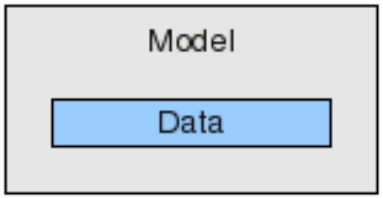
Some widgets have 2 implementations

- **Standard** widget implementation
- **Model/View** implementation
  - Manage **external data**
  - Make it easy to deal with **multiple views**

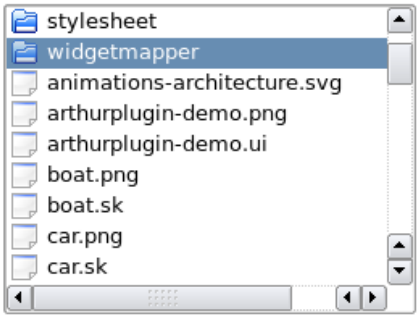


standard



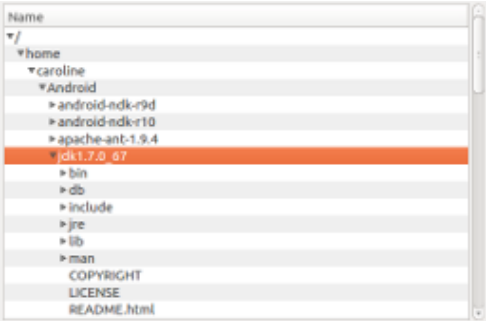


model / view



QListWidget
QListView

QTableWidget
QTableView



QTreeWidget
QTreeView

MVC & Qt: example

Example

- List of **Persons**

- Each **Person** has :
  - a first name
  - a last name
  - a phone number

- The list is stored in a **std::vector**

	1	2	3
1	Jean	Dupond	01 01
2	Alfred	Einstein	03 14
3	Désiré	Landru	66 66

```
struct Person {
    std::string firstname, lastname, phonenumber;
};

std::vector<Person> persons;
```

MVC & Qt: example

main.cpp

```
#include <QApplication>
#include <QtWidgets/QTableView>
#include "mymodel.h"

int main (int argc, char *argv[])
{
    QApplication app (argc, argv);

    MyModel model;
    QTableView view;
    view.setModel(&model);
    view.show();
    return app.exec();
}
```

	1	2	3
1	Jean	Dupond	01 01
2	Alfred	Einstein	03 14
3	Désiré	Landru	66 66

Note :

- objects can be created in the stack only in the main() function!
- why?

mymodel.hpp

	1	2	3
1	Jean	Dupond	01 01
2	Alfred	Einstein	03 14
3	Désiré	Landru	66 66

```
#include <QAbstractTableModel>
#include <string>
#include <vector>

class MyModel : public QAbstractTableModel {
    Q_OBJECT

public:
    MyModel (QObject *parent);
```

returns the number of rows and columns

```
    int rowCount(const QModelIndex& = QModelIndex()) const override { return persons.size(); }
    int columnCount(const QModelIndex& = QModelIndex()) const override {return 3;}
```

reads / changes a cell in the model

```
    QVariant data(const QModelIndex& index, int role = Qt::DisplayRole) const override;

    bool setData(const QModelIndex & index, const QVariant & value, int role);

    Qt::ItemFlags flags(const QModelIndex & index) const override;
```

options

```
private:
    struct Person {
        std::string firstname, lastname, phonenumber;
    };
    std::vector<Person> persons;
};
```

	1	2	3
1	Jean	Dupond	01 01
2	Alfred	Einstein	03 14
3	Désiré	Landru	66 66

mymodel.cpp

```
#include "mymodel.h"

MyModel::MyModel(QObject *parent) : QAbstractTableModel(parent) {
    persons = { {"Jean", "Dupond", "01 01"}, {"Alfred", "Einstein", "03 14"}, {"Désiré", "Landru", "66 66"} };
}

QVariant MyModel::data(const QModelIndex &index, int role) const {      reads a cell in the model
    if (role == Qt::DisplayRole) {    display mode
        switch (index.column()) {
        case 0:
            return QString( persons[index.row()].firstname.c_str() );
            break;
        case 1:
            return QString( persons[index.row()].lastname.c_str() );
            break;
        case 2:
            return QString( persons[index.row()].phonenumber.c_str() );
            break;
        }
    }
    return QVariant();
}
```

E

mymodel.cpp (continued)

changes a cell in the model

```
bool MyModel::setData(const QModelIndex & index, const QVariant & value, int role) {
    if (role == Qt::EditRole) {
        switch (index.column()) {
        case 0:
            persons[index.row()].firstname = value.toString().toStdString();
            break;
        case 1:
            persons[index.row()].lastname = value.toString().toStdString();
            break;
        case 2:
            persons[index.row()].phonenumber = value.toString().toStdString();
            break;
        }
        emit dataChanged (index,index);
    }
}
```

edit mode

signal that this cell was modified

```
Qt::ItemFlags MyModel::flags (const QModelIndex &index) const {
    return Qt::ItemIsEditable | QAbstractTableModel::flags(index);
}
```

options: means that the table can be edited

MVC & Qt

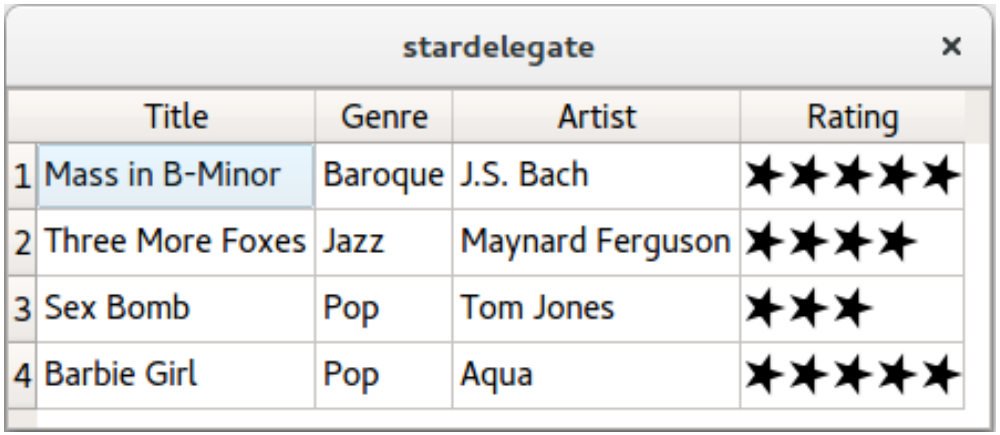
Synchronizing 2 views

- The **selection** can be synced
- Works also with **other data types** than text
- **Other widgets** can use models (see QDataWidgetMapper)

```
MyModel * model = new MyModel;
QTableView * view1 = new QTableView;
QTableView * view2 = new QTableView;

view1->setModel (model);
view2->setModel (model);
```

two views

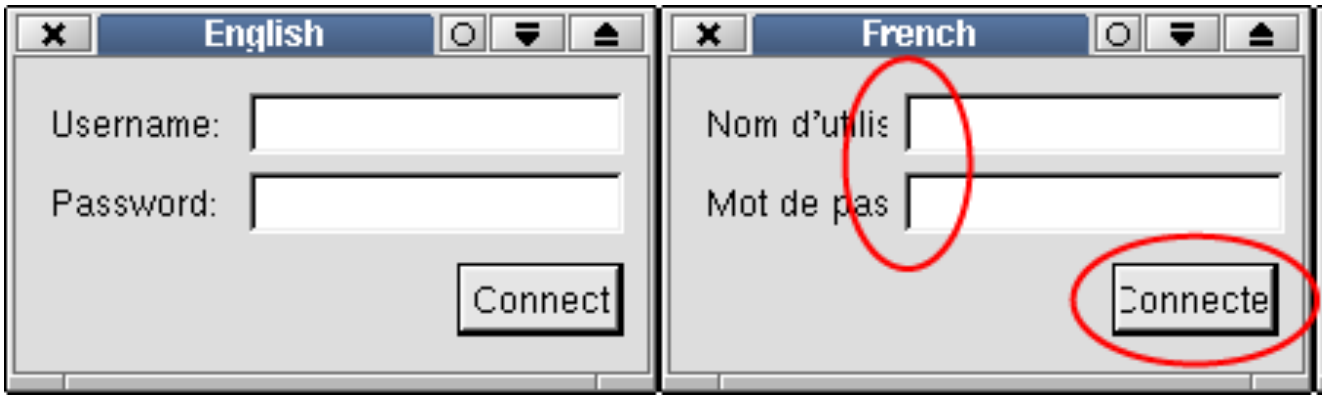
not only text



Layout management

Manual layout

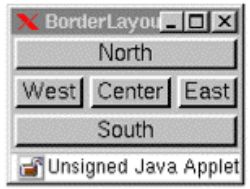
- Easy when using an **IDE** (by dragging and dropping widgets)
- **Drawback:** the UI is not **localizable** (word sizes depend on languages)

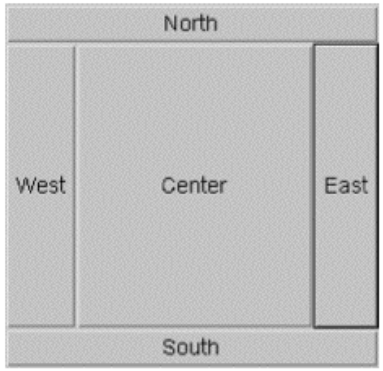


Layout management

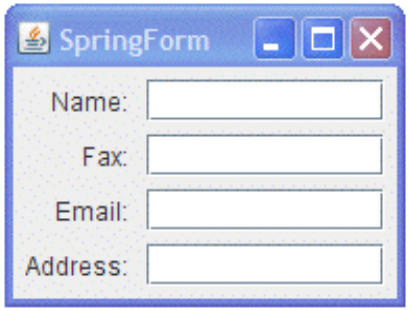
Automatic layout

- **Automatic calculation** of positions and sizes
- Two approaches:

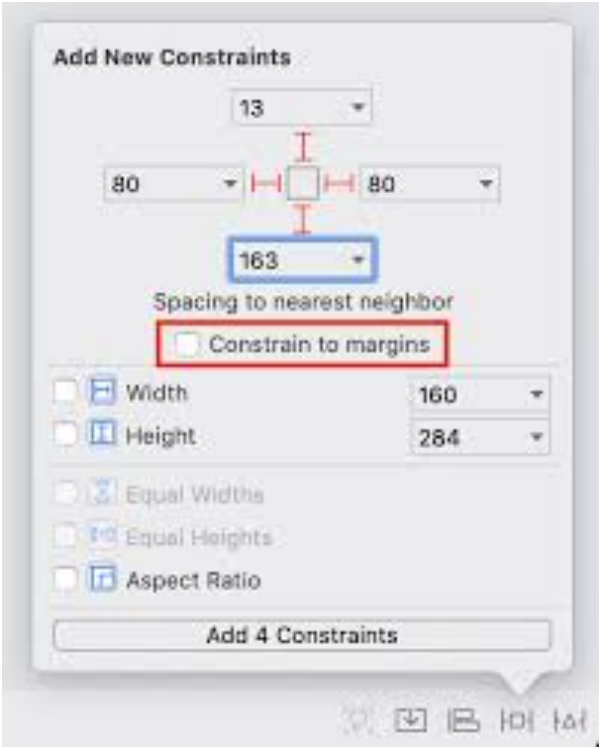




- **Layout managers**
  - Java Swing, JavaFX, Qt, etc.
  - Not as nice?



- **Constraints**
  - Apple Xcode, etc.
  - Can be somewhat complex



Layout management

Automatic layout + CSS

- Cascaded **Style Sheets**
- Typical in **Web interfaces**
- Flexibility, configurability
- Many modern GUI toolkits support CSS-like styles (e.g. Qt, JavaFX, .NET)

This div element has a top margin of 100px, a right margin of 150px, a bottom margin of 100px, and a left margin of 80px.

```
<!DOCTYPE html>
<html>
<head>
<style>
div {
  border: 1px solid black;
  margin-top: 100px;
  margin-bottom: 100px;
  margin-right: 150px;
  margin-left: 80px;
  background-color: lightblue;
}
</style>
</head>
<body>

<h2>Using individual margin properties</h2>

<div>This div element has a top margin of 100px, a right
margin of 150px, a bottom margin of 100px, and a left
margin of 80px.</div>

</body>
</html>
```

Localization

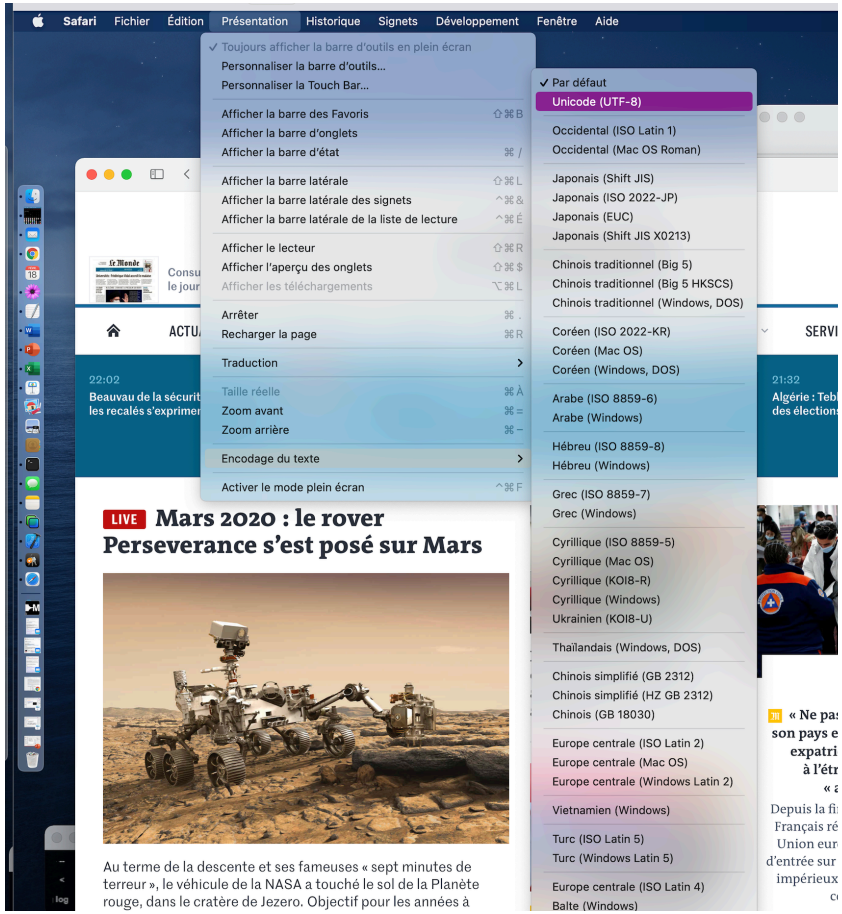
Process of adapting a product's translation to a specific country or region

- **Language, numbers, dates, currency,** etc.
  - Beware of dates 10/09 vs 09/10
  - And numbers: 1,000.1 vs 1000,1

- Application "**locale**"

- Encoding of **text**

```
dhcpwifi-22-132:~> locale
LANG="fr_FR.UTF-8"
LC_COLLATE="fr_FR.UTF-8"
LC_CTYPE="fr_FR.UTF-8"
LC_MESSAGES="fr_FR.UTF-8"
LC_MONETARY="fr_FR.UTF-8"
LC_NUMERIC="fr_FR.UTF-8"
LC_TIME="fr_FR.UTF-8"
LC_ALL=
```



Unicode

Standard for consistent encoding, representation and handling of text

UTF8

- **Web**, Linux, Windows (partly)
- **Variable length**: one symbol = **1 to 4 bytes**
- Compatible with **ASCII**

UTF16

- Java, Qt, Windows (now moving to UTF8)
- **Variable length**: one symbol = **2 or 4 bytes**
- **Almost fixed** in practice: 1 symbol = 2 bytes for most languages and ideographs

UTF32

- 1 symbol = 4 bytes

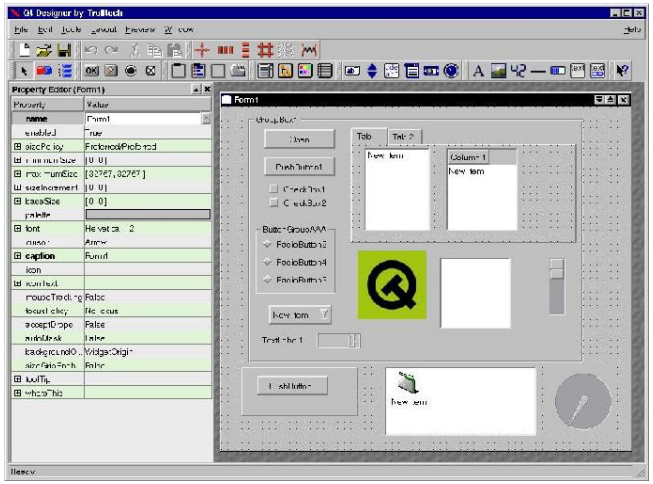
Visual tools

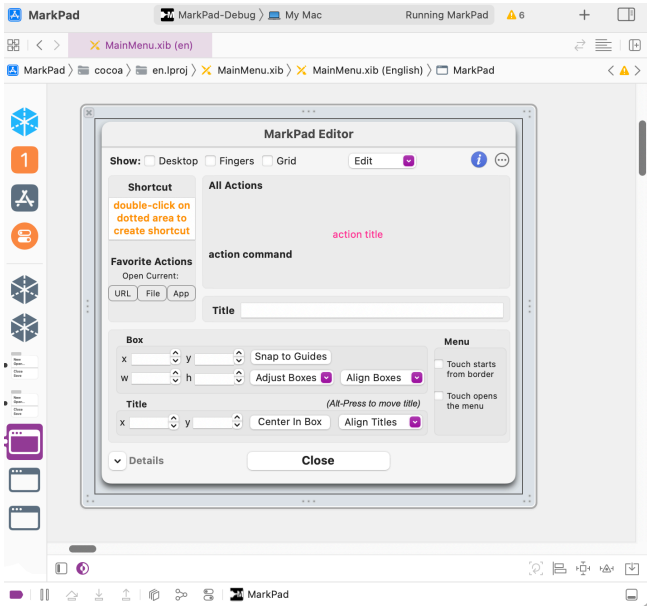
IDEs and Interface Builders

- Many tools: Eclipse, Visual Studio, XCode, NetBeans, QtCreator, etc.

Benefits

- Helpful for **prototyping**
- Importantly, can be used by **non-programmers**





Visual tools

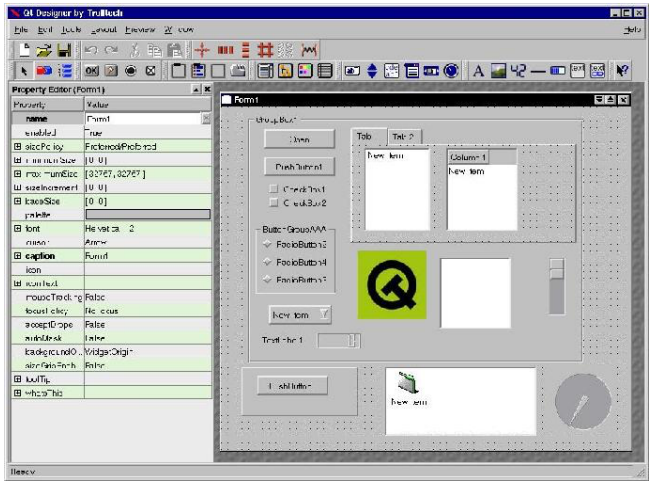
Limitations

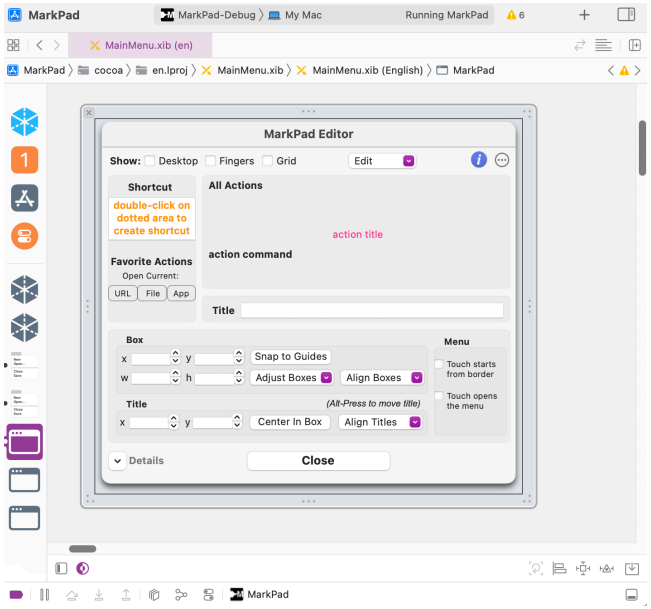
- Mostly useful for creating **static** user interfaces (menus, forms...)

- Little support for **controlling the interaction**, drag & drop, **dynamic** aspects...

- Layout not **localizable** if drag & drop is used

- Restrictions on **generated code**: can't be edited freely





Dedicated languages

User Interface Markup Languages

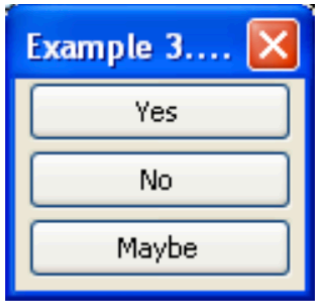
a) For building the **structure of the app** (mostly)

- **XAML** (Microsoft), **FXML** (JavaFX), **XUL** (Mozilla), etc.
- Compatible with visual tools
- Most of the interaction specified elsewhere

b) For building the structure and **specifying the interaction**

- **UIML**, **QML** (Qt), etc.

```
<?xml version="1.0"?>
<?xml-stylesheet href="chrome://global/skin/" type="text/css"?>

<window id="vbox example" title="Example 3...."
xmlns="http://www.mozilla.org/keymaster/gatekeeper/there.is.only.x
ul">
  <layout>
    <button id="yes1" label="Yes"/>
    <button id="no1" label="No"/>
    <button id="maybe1" label="Maybe"/>
  </layout>
</window>
```



XUL

QML

QML (Qt Modeling Language)

- **Declarative** language for specifying GUIs

- Allows inline **JavaScript** code

- Simplifies **interactive aspects** and **animations**

```
Rectangle {
    id: canvas
    width: 250
    height: 200
    color: "blue"

    Image {
        id: logo
        source: "pics/logo.png"
        anchors.centerIn: parent
        x: canvas.height / 5
    }
}
```

properties can reference other properties

Bindings

- **Constraints** that avoid writing callback functions
- A property is **automatically updated** when the value of another property **changes**
- Similar mechanism in other GUI toolkits (e.g. **JavaFX**)

```
Rectangle {
    width: otherItem.width
    height: otherItem.height
}
```

```
Rectangle {
    function calculateMyHeight() {
        return Math.max(otherItem.height, thirdItem.height);
    }
    anchors.centerIn: parent
    width: Math.min(otherItem.width, 10)
    height: calculateMyHeight()
    color: width > 10 ? "blue" : "red"
}
```

calls method

color changes when width changes

States

Objects can have states

Example:

- *myRect* is located at (0,0)
- In the *moved* **state**, it is located at (50,50)
- Clicking within the mouse area changes the **state**

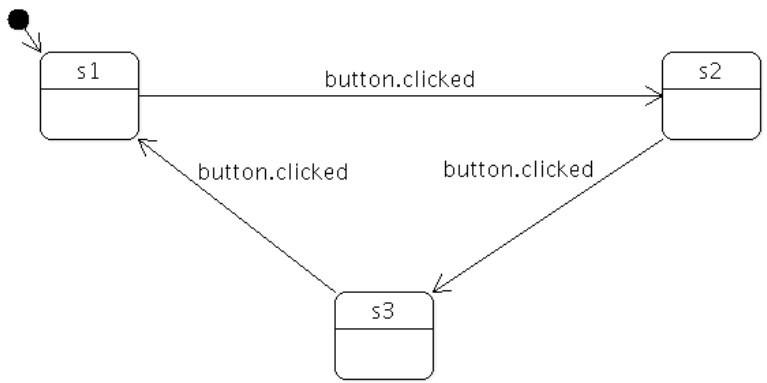
```
Item {
    id: myItem
    width: 200; height: 200

    Rectangle {
        id: myRect
        width: 100; height: 100
        color: "red"
    }
    states: [
        State {                                  state
            name: "moved"
            PropertyChanges {
                target: myRect
                x: 50
                y: 50
            }
        }
    ]
    MouseArea {                                  changes state
        anchors.fill: parent
        onClicked: myItem.state = 'moved'
    }
}
```

Statecharts

Can be drawn interactively

Example

- 3 state button




```
StateMachine {
    id: stateMachine
    // set the initial state
    initialState: s1

    // start the state machine
    running: true

    State {
        id: s1
        // create a transition from s1 to s2 when the button is clicked
        SignalTransition {
            targetState: s2
            signal: button.clicked
        }
        // do something when the state enters/exits
        onEntered: console.log("s1 entered")
        onExited: console.log("s1 exited")
    }

    State {
        id: s2
        // create a transition from s2 to s3 when the button is clicked
        SignalTransition {
            targetState: s3
            signal: button.clicked
        }
        // do something when the state enters/exits
        onEntered: console.log("s2 entered")
        onExited: console.log("s2 exited")
    }
```

Animations

Properties can be animated

```
transitions: [
    Transition {
        from: "*"
        to: "moved"
        NumberAnimation { properties: "x,y"; duration: 500 }
    }
 ]
```

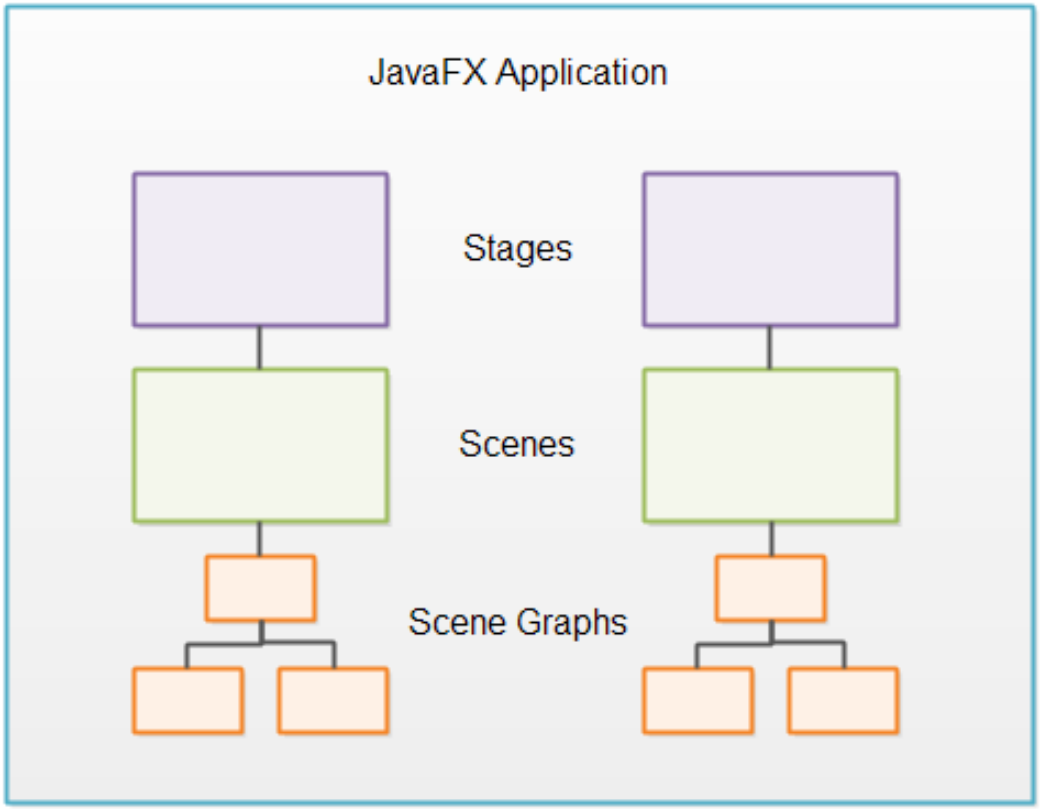
transition that triggers an animation

```
Rectangle {
    id: rect
    width: 120; height: 200

    Image {
        id: img
        source: "pics/qt.png"
        x: 60 - img.width/2
        y: 0

        SequentialAnimation on y {
            loops: Animation.Infinite
            NumberAnimation { to: 200 - img.height; easing.type: Easing.OutBounce; duration: 2000 }
            PauseAnimation { duration: 1000 }
            NumberAnimation { to: 0; easing.type: Easing.OutQuad; duration: 1000 }
        }
    }
}
```

JavaFX

A GUI is a Scene Graph

- **Nodes** :
  - widgets, 2D and 3D shapes, images, medias, etc.
- **States** :
  - geometric transforms, visual effects, etc.
- **Effects** :
  - change the visual aspect



JavaFX

Widgets

- Similar to **Swing** widgets
- Styles can be specified using **CSSs**
- The GUI can be written in **FXML**
  - can contain small scripts
- **SceneBuilder** editing tool

JavaFX

Properties and binding

- Widgets have **properties**
- It's possible to **observe** when their value change
- They can be **bound** together => powerful **synchronization** mechanism

  - **Unidirectional binding**:
    - `label.textProperty().bind(text.textProperty());`
  - **Bidirectional binding** (2 ways):
    - `text2.textProperty().bindBidirectional(text.textProperty())`

```java
import javafx.application.*;
import javafx.stage.*;
import javafx.scene.*;
import javafx.scene.layout.*;
import javafx.geometry.*;
import javafx.scene.control.*;

public class RolePlayer extends Application {
   TextField character;
   TextField actor;

   @Override public void start(Stage primaryStage) {
      character = new TextField();
      actor = new TextField();

      // omitted details ...

      Label role1 = new Label("The role of ");
      Label role2 = new Label();
      Label role3 = new Label(" will be played by ");
      Label role4 = new Label();

      role2.textProperty().bind(character.textProperty());
      role4.textProperty().bind(actor.textProperty());

      Label scene = new Label(pane);
        primaryStage.setScene(scene);
        primaryStage.setTitle("Role Player");
        primaryStage.show();
   }
```

source: dummies.com