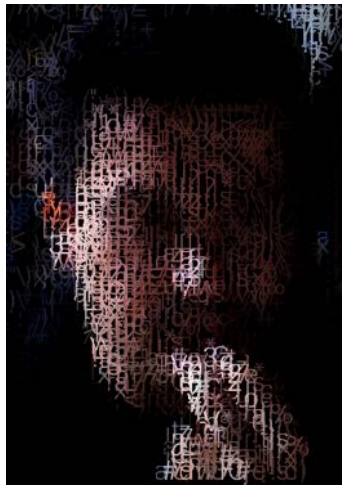
# M1 ENJMIN
# Bases de l'IHM
## 29 novembre 2017

Pierre Cubaud, CNAM
cubaud @ cnam.fr



le cnam
École nationale du jeu et des médias interactifs numériques
enjmin

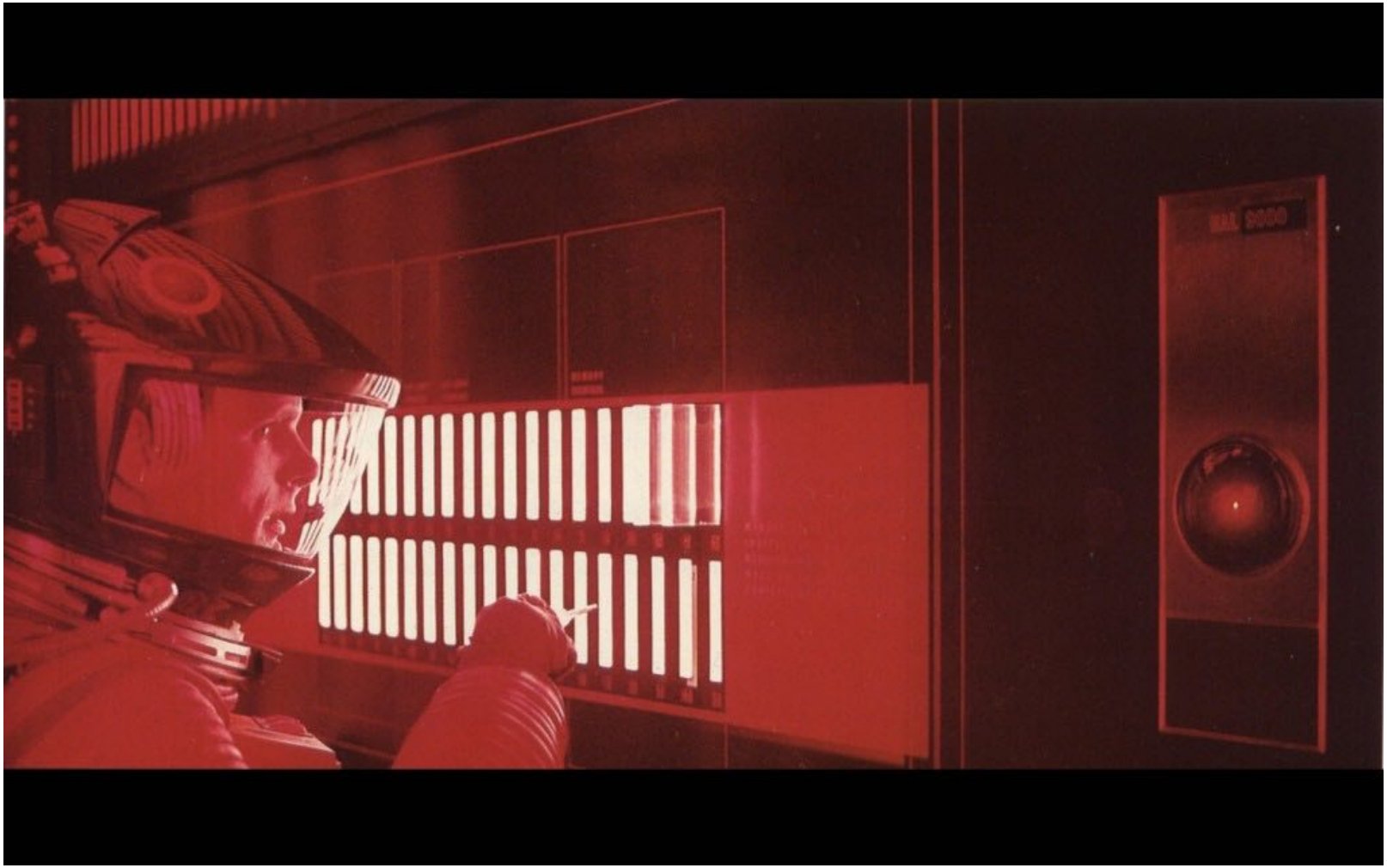
IHM = ?

Interface homme-machine

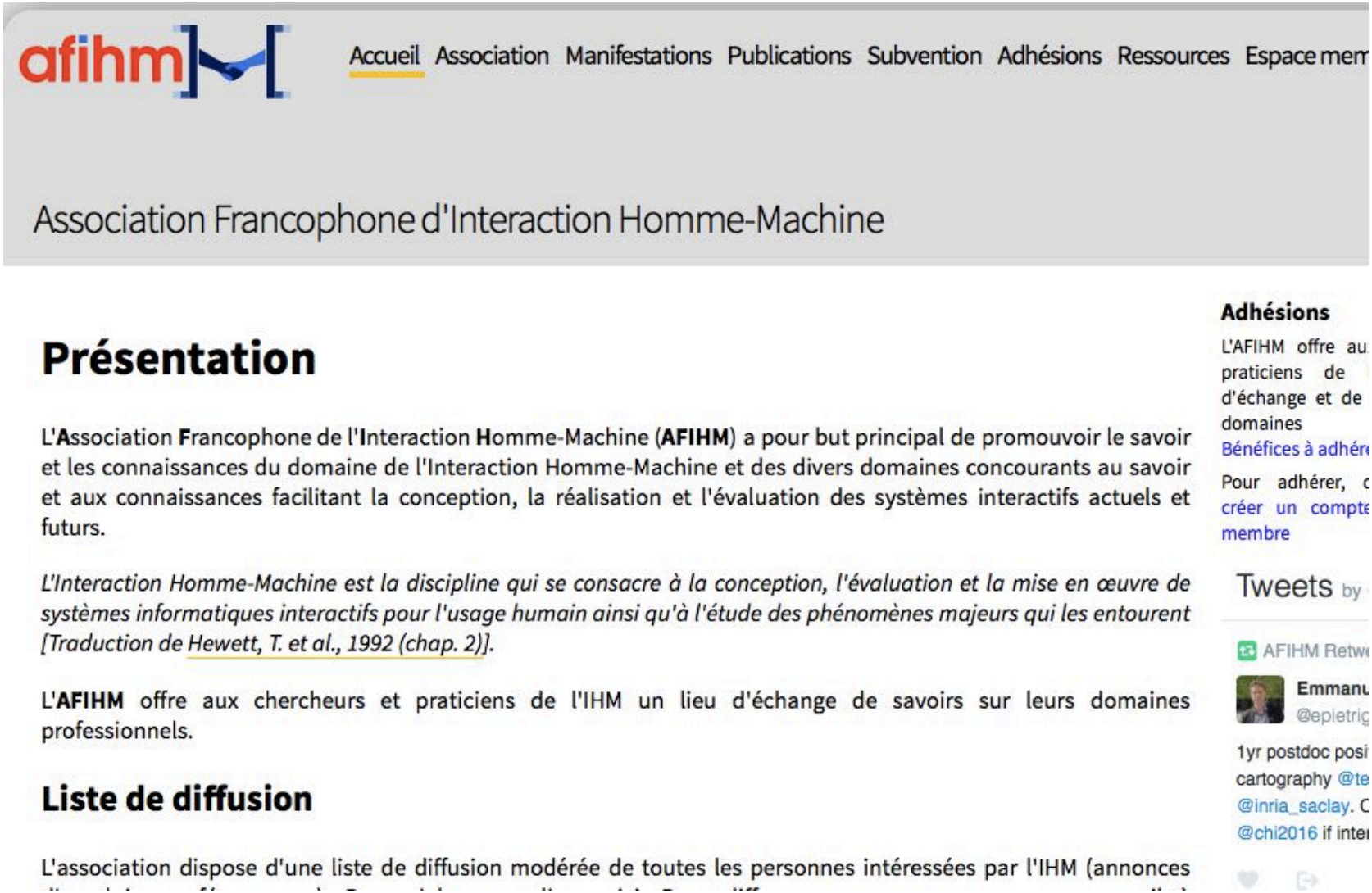
Interface humain-machine

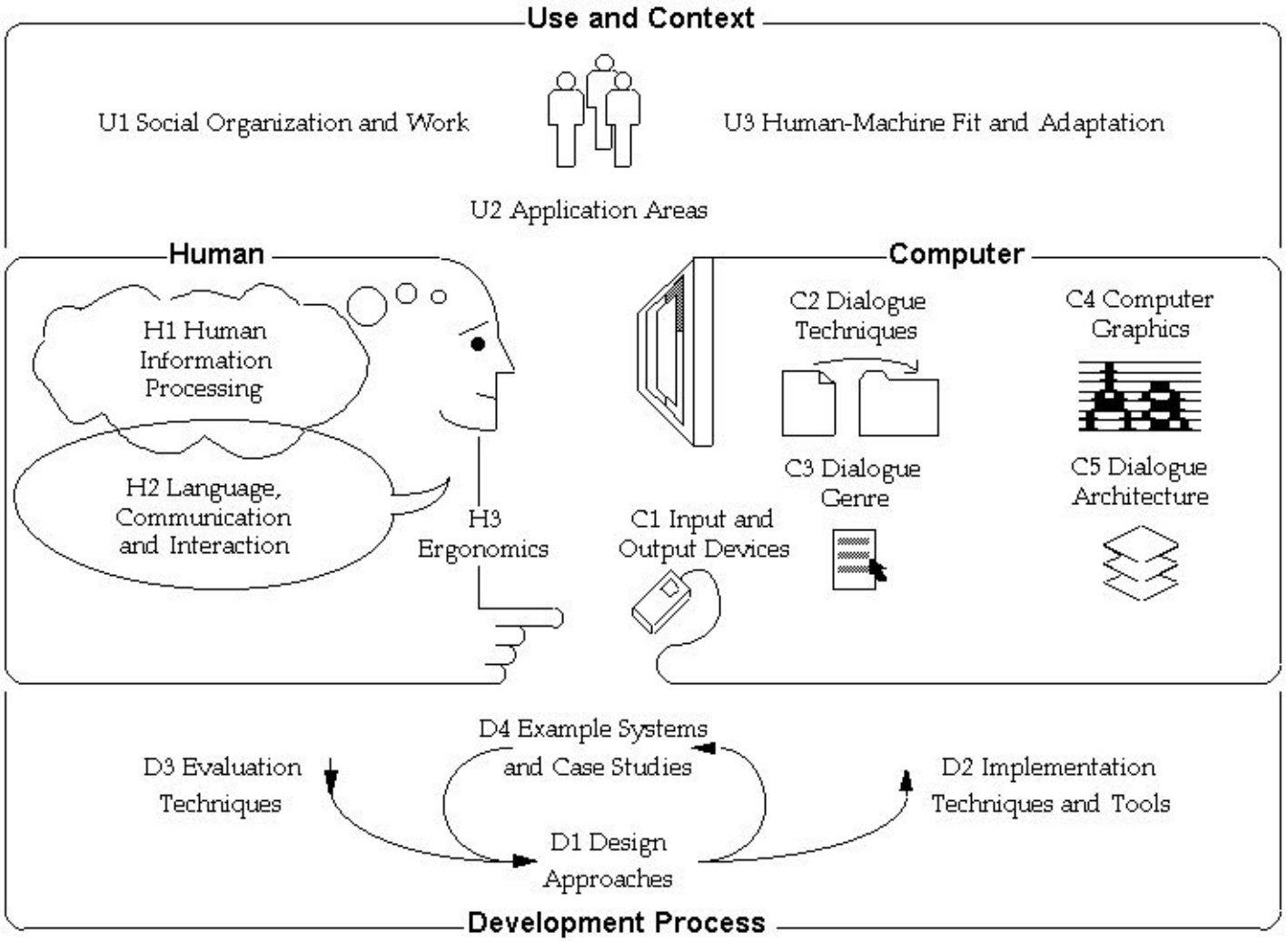
Interaction humain-machine

Interaction humaine médiatisée



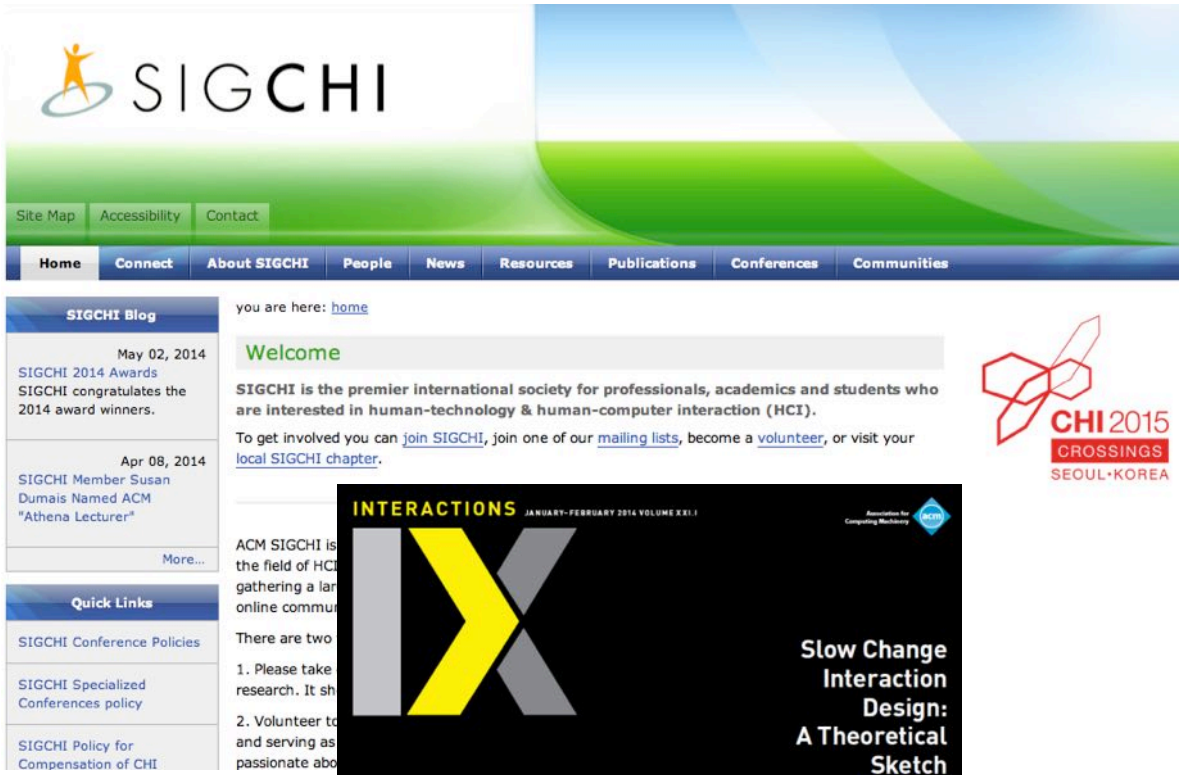

1968 : S. Kubrick "2001 l'odysée de l'espace"


afihm
Accueil Association Manifestations Publications Subvention Adhésions Ressources Espace mem
Association Francophone d'Interaction Homme-Machine
Présentation
L'Association Francophone de l'Interaction Homme-Machine (AFIHM) a pour but principal de promouvoir le savoir et les connaissances du domaine de l'Interaction Homme-Machine et des divers domaines concourants au savoir et aux connaissances facilitant la conception, la réalisation et l'évaluation des systèmes interactifs actuels et futurs.
L'Interaction Homme-Machine est la discipline qui se consacre à la conception, l'évaluation et la mise en œuvre de systèmes informatiques interactifs pour l'usage humain ainsi qu'à l'étude des phénomènes majeurs qui les entourent [Traduction de Hewett, T. et al., 1992 (chap. 2)].
L'AFIHM offre aux chercheurs et praticiens de l'IHM un lieu d'échange de savoirs sur leurs domaines professionnels.
Liste de diffusion
L'association dispose d'une liste de diffusion modérée de toutes les personnes intéressées par l'IHM (annonces
Adhésions
L'AFIHM offre au
praticiens de
d'échange et de
domaines
Bénéfices à adhér
Pour adhérer, c
créer un compte
membre
Tweets by
AFIHM Retw
Emmanu
@epietrig
1yr postdoc posi
cartography @te
@inria_saclay. C
@chi2016 if inte

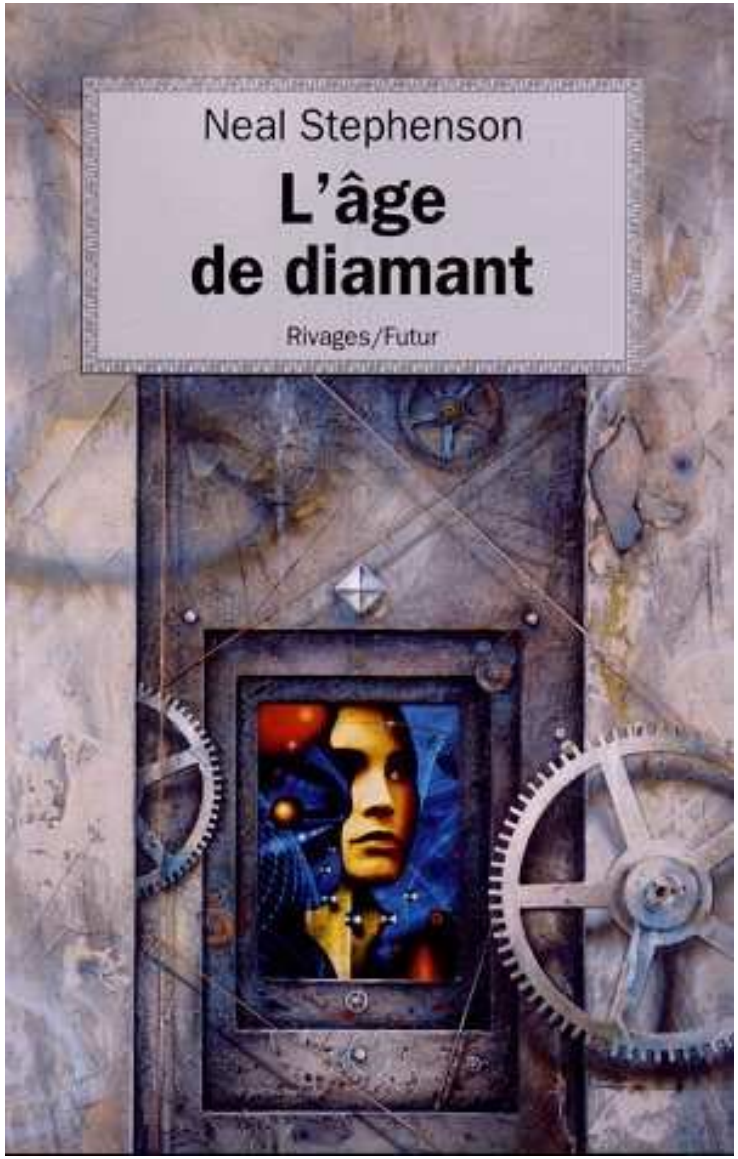



http://old.sigchi.org/cdg/index.html

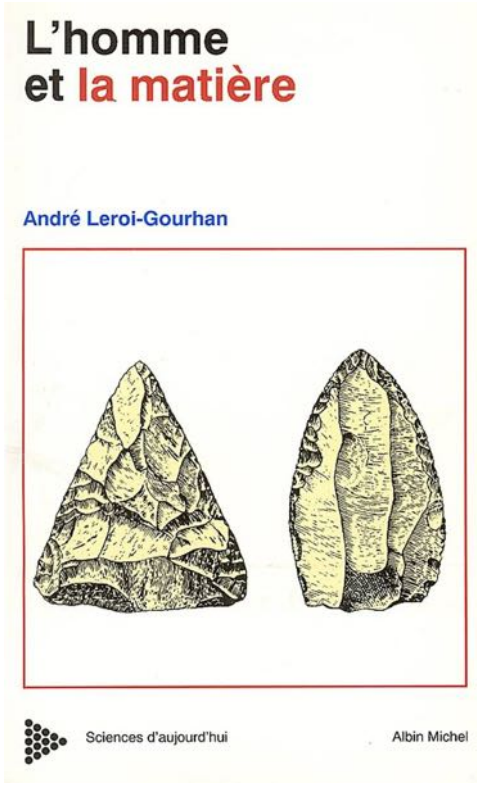
# pub : association mondiale ACM SIGCHI

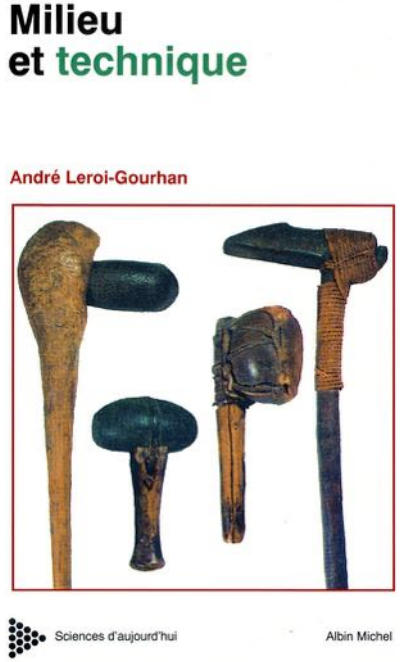


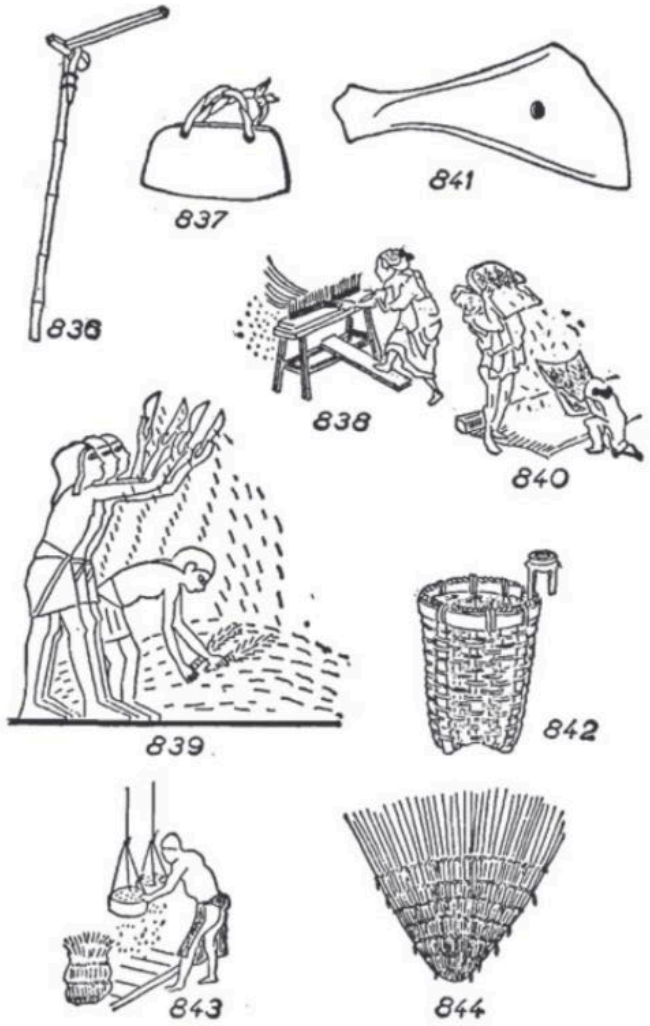

+ la revue


Neal Stephenson
L'âge de diamant
Rivages/Futur

# (re)lire Leroi-Gourhan



Exercice :
nommer un logiciel sans IHM

Exercice :
calculer la proportion d'heures de formation à l'IHM par rapport au total d'une licence

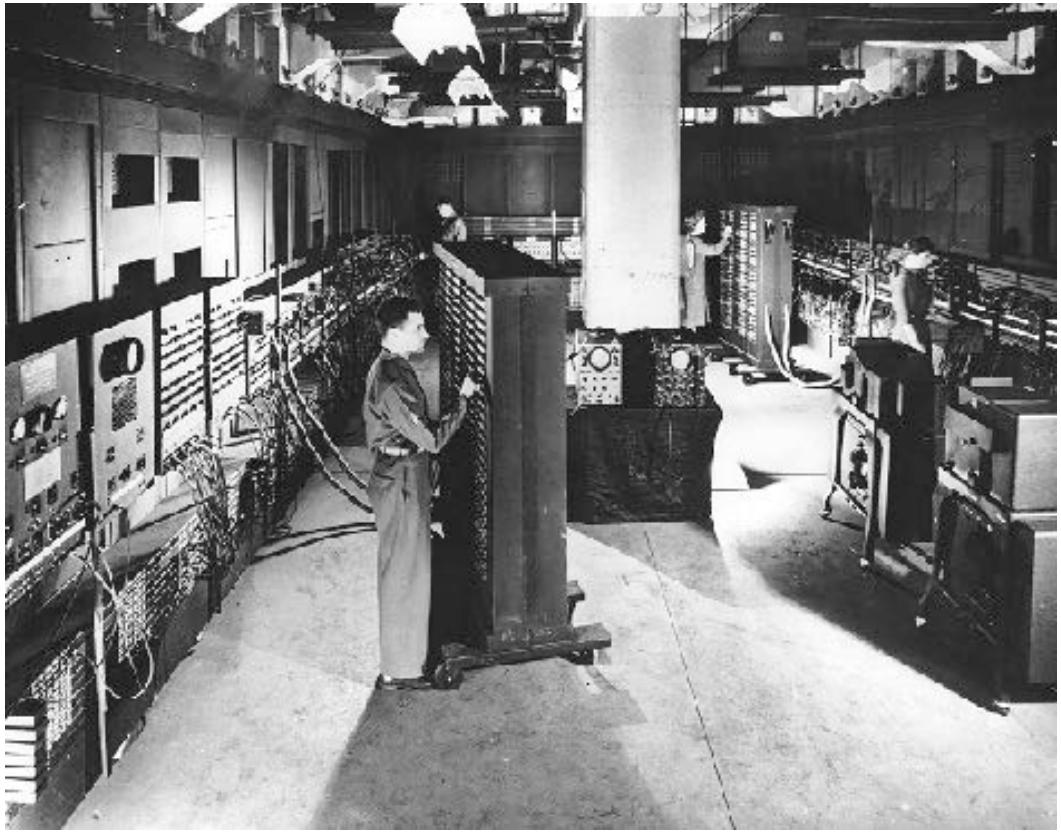
# Plan de l'exposé :

1. historique IHM ≤ WIMP
2. au-delà du WIMP
3. la captation

(pause ?)

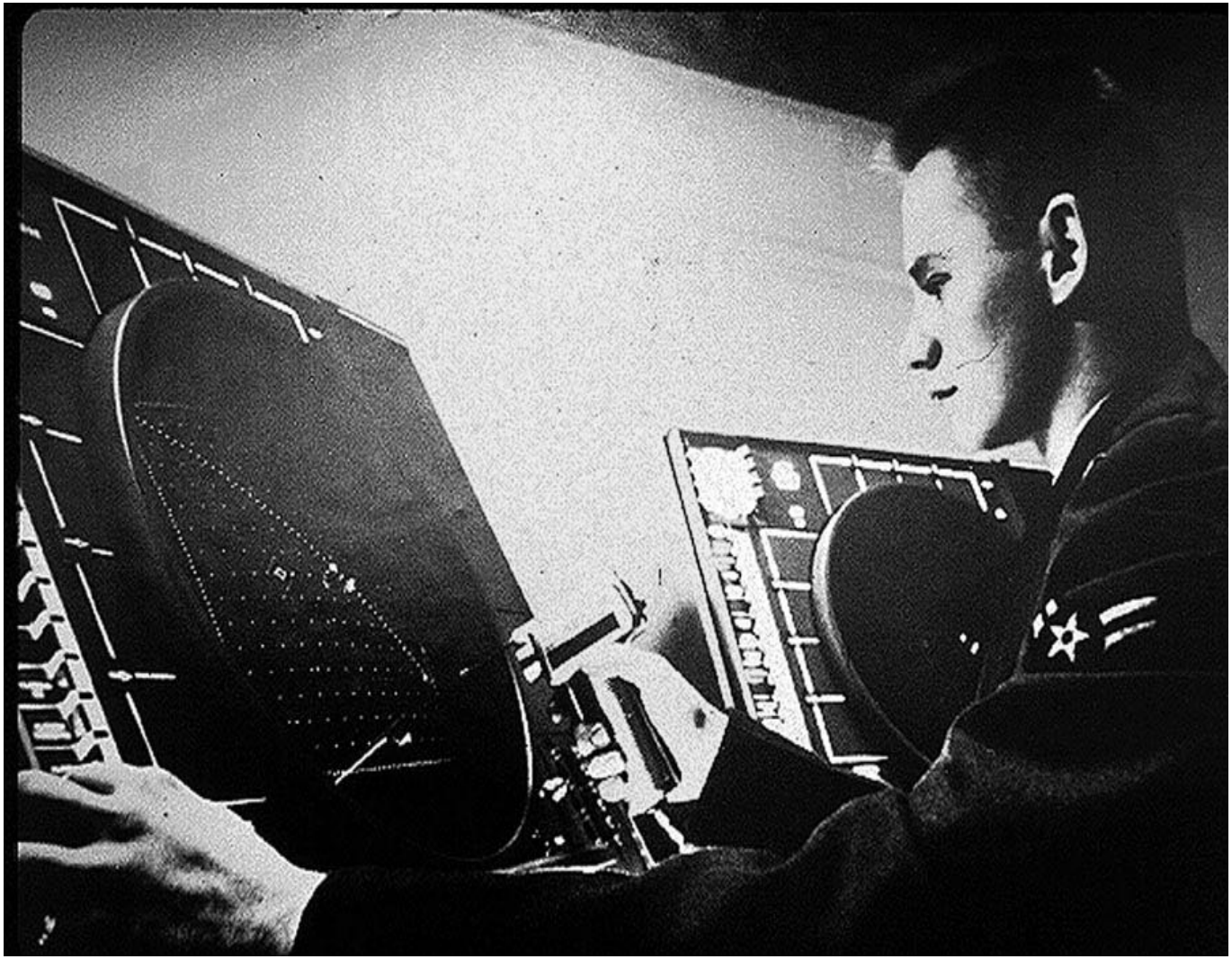
4. l'immersion
5. l'augmentation
6. les objets malins

# (1) Historique de l'IHM



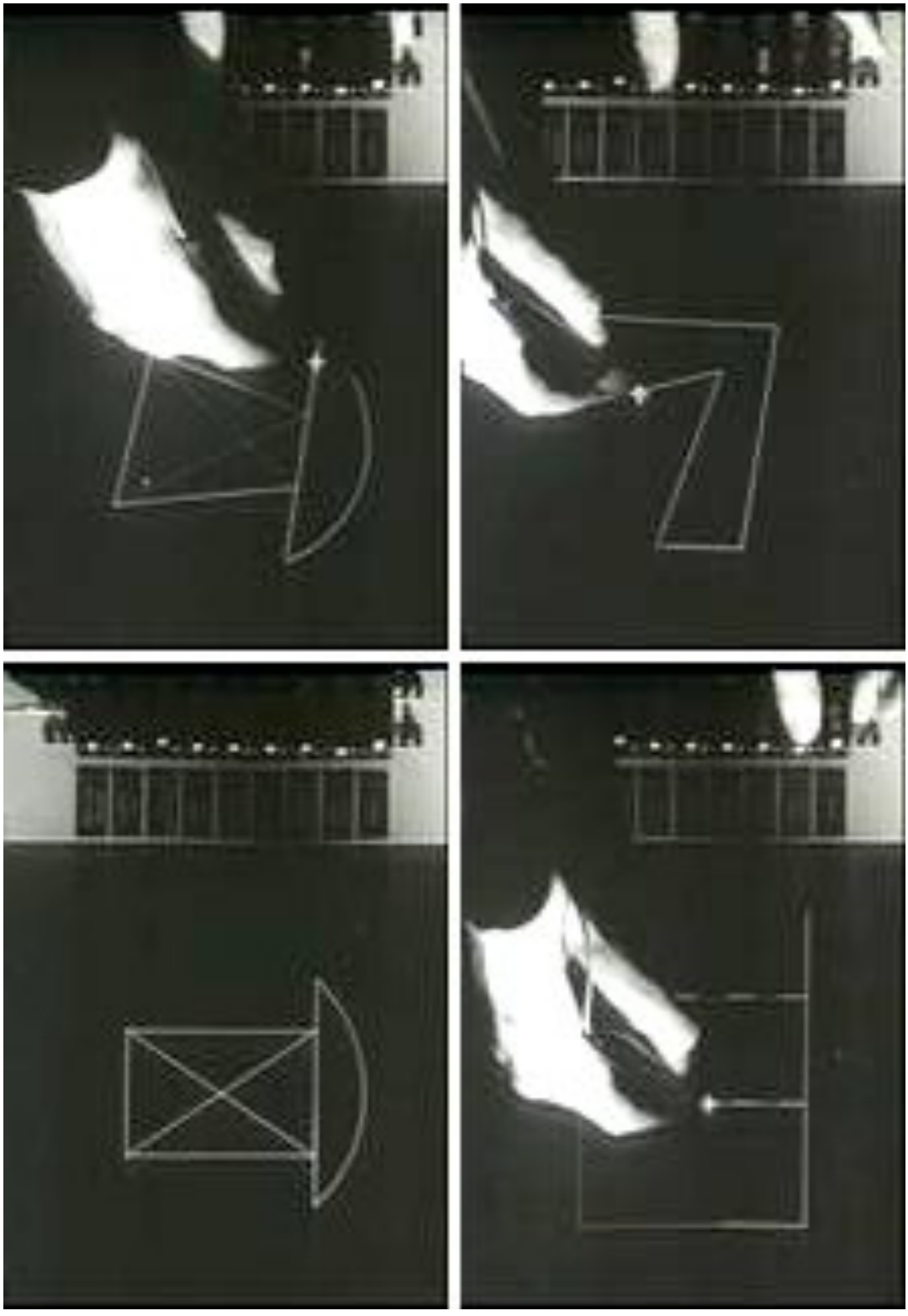
ENIAC - 1945

# Le temps-réel : projet Whirlwind MIT, 1950



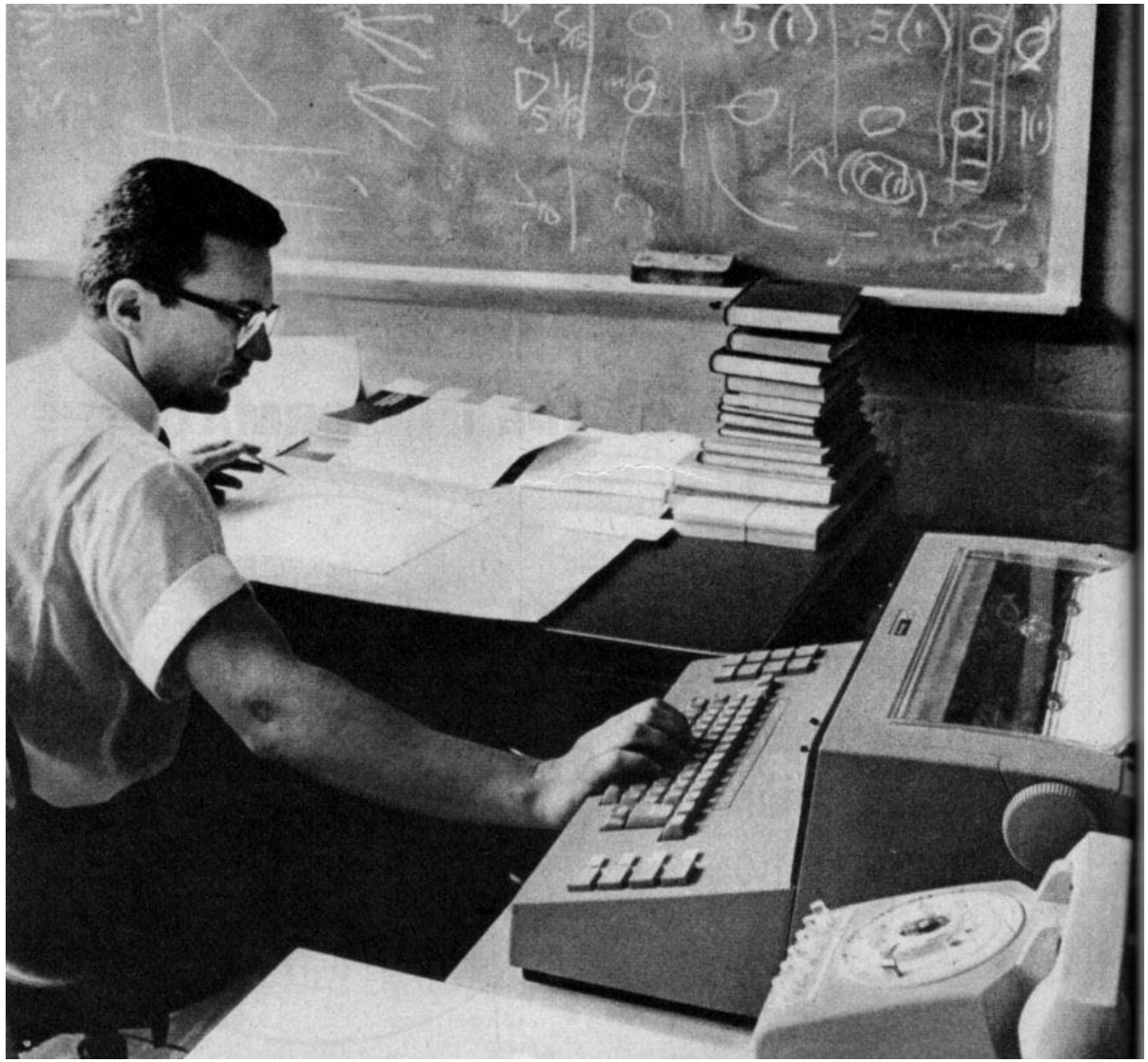
défense aérienne (SAGE)

1961 : Ivan Sutherland sur TX1 (MIT)



**J.C.R. Licklider (1960)**
**“man-computer symbiosis”**

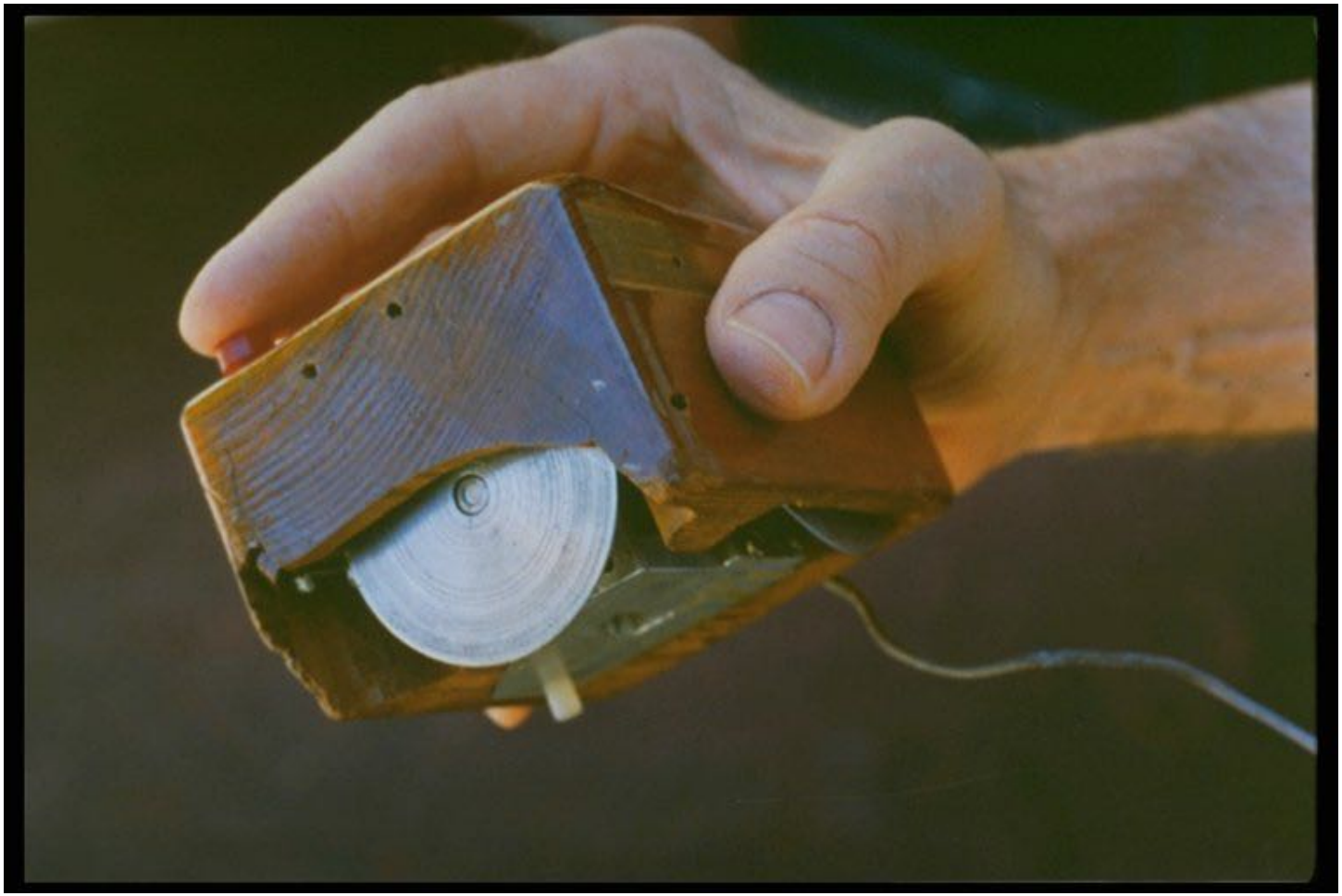
“The hope is that, in not too many years, human brains and computing machines will be coupled together very tightly and that the resulting partnership will think as no human brain has ever thought and process data in a way not approached by the information-handling machines we know today.”



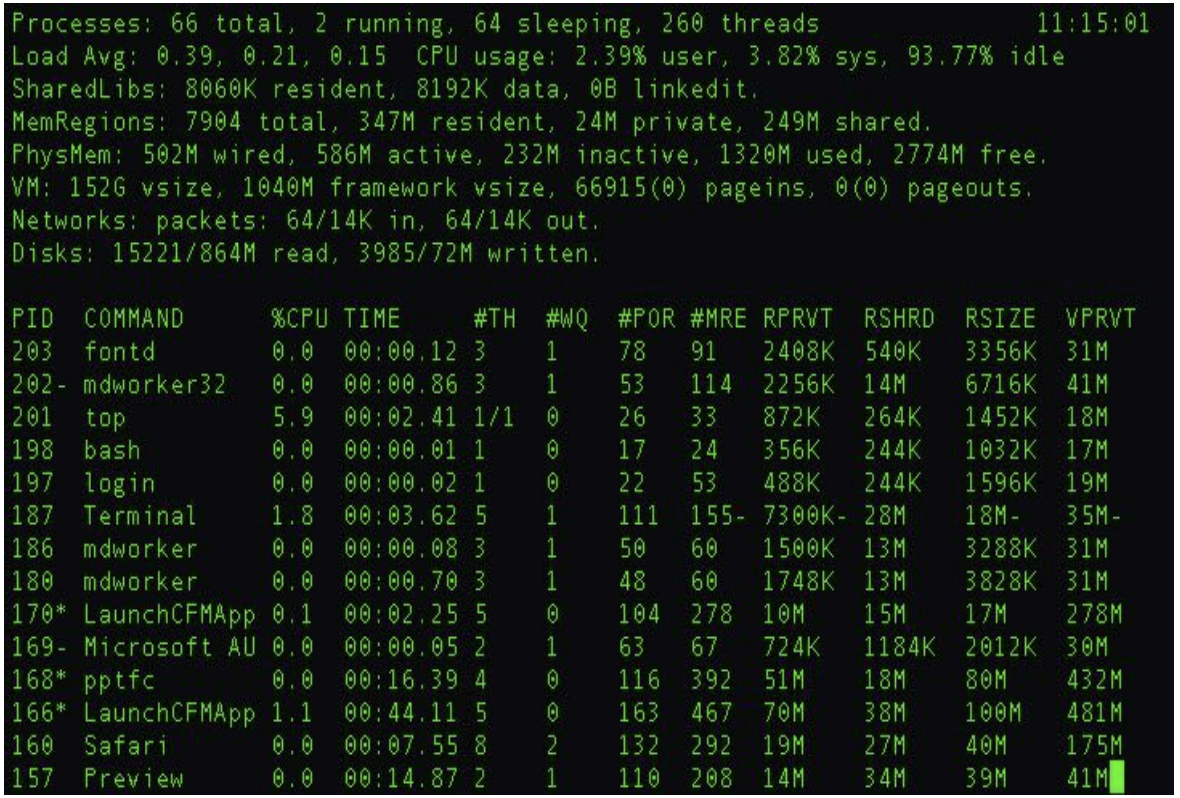
Le temps partagé (time sharing) :
MIT, 1959-64

# D. Engelbart : "augmenting human intellect" (SRI, 1963)

"A Research Center for Augmenting Human Intellect," Douglas C. Engelbart, and William K. English, AFIPS Conference Proceedings of the 1968 Fall Joint Computer Conference, San Francisco, CA, December 1968, Vol. 33, pp. 395-410

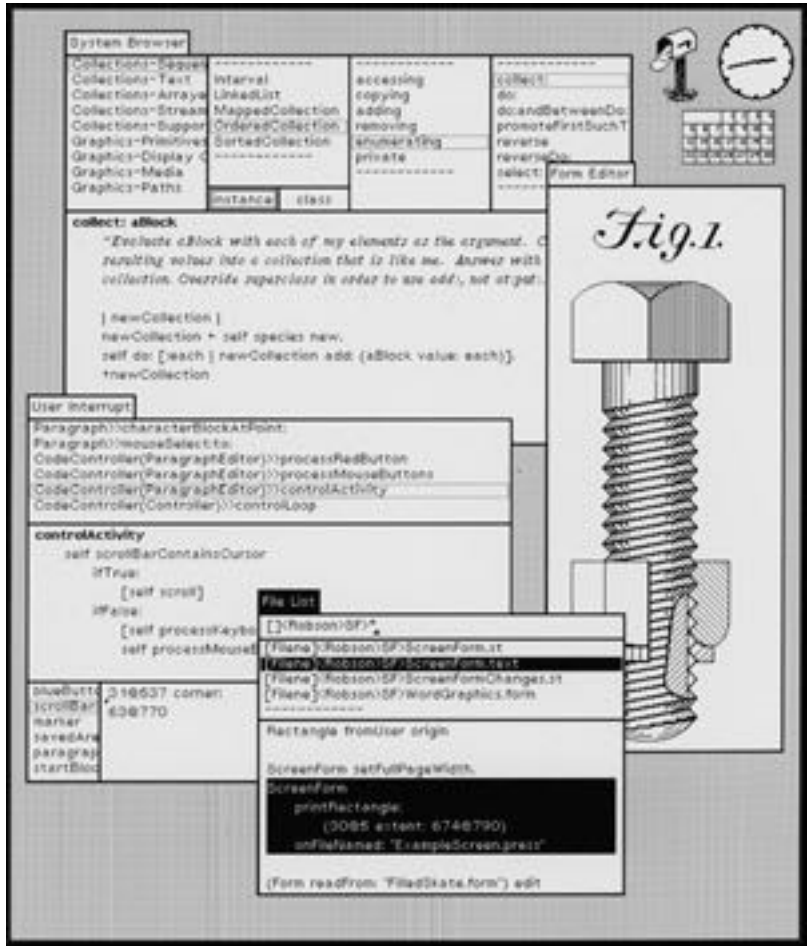


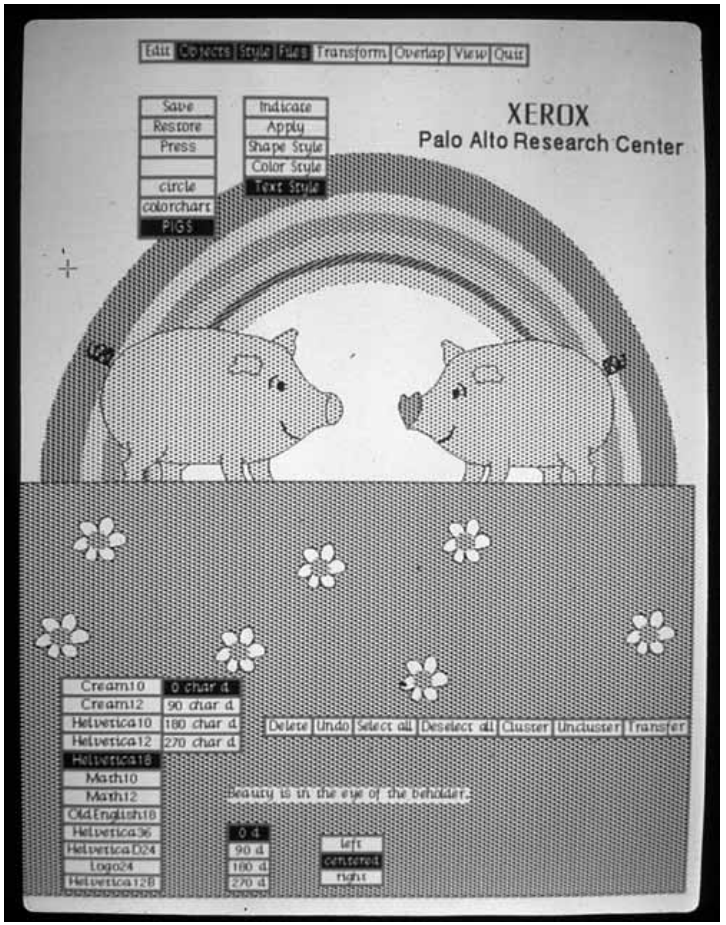
Douglas Engelbart et sa souris de 1963 (Stanford), 40 ans après




ecran type VT100 24 lignes * 80 colonnes
ici la commande UNIX top

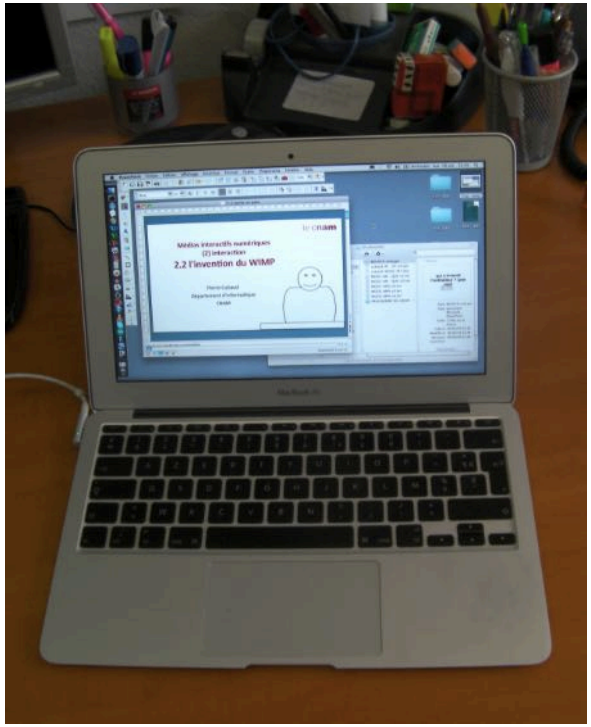
# 70's : XEROX PARC machine Alto : cut copy & paste



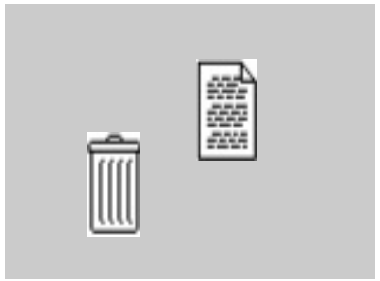

http://news.squeak.org/2007/12/29/old-smalltalk-pics-from-parc-place/
À voir aussi :
http://www.nomodes.com/tesler-resume.htm

- Ecran N&B 606 x 808 pixels (80 ppi)
- Clavier séparé, reconfigurable,
mesure de force et durée
- Souris 3 boutons
- 2 disques durs de 3 Mo pour le stockage local
- Ethernet
- Imprimante laser




mon portable

- "métaphore" du bureau ( desktop)

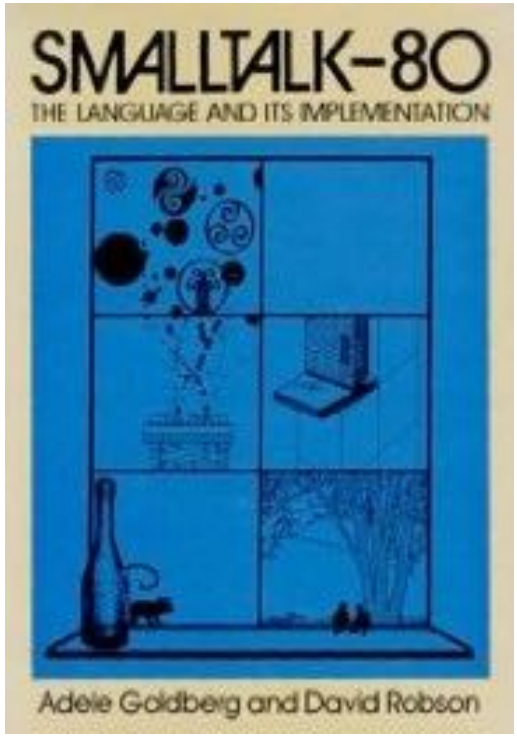



- le copier/coller ( copy/paste)

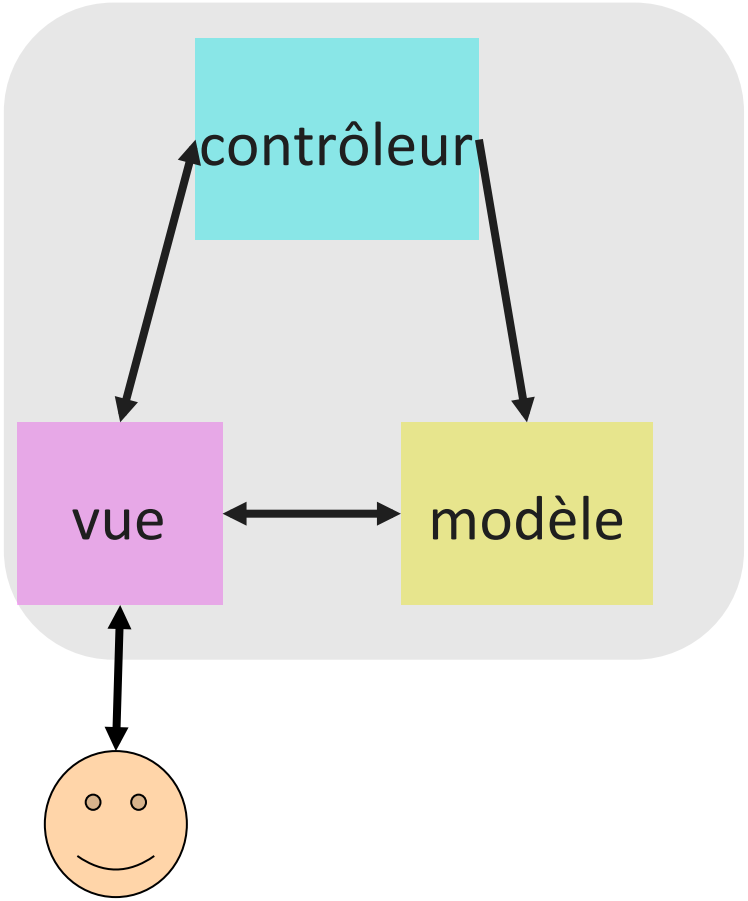
- l'annulation ( undo)

⇒"manipulation directe" (Schneidermann, 1983) :
des actions rapides, incrémentales, réversibles

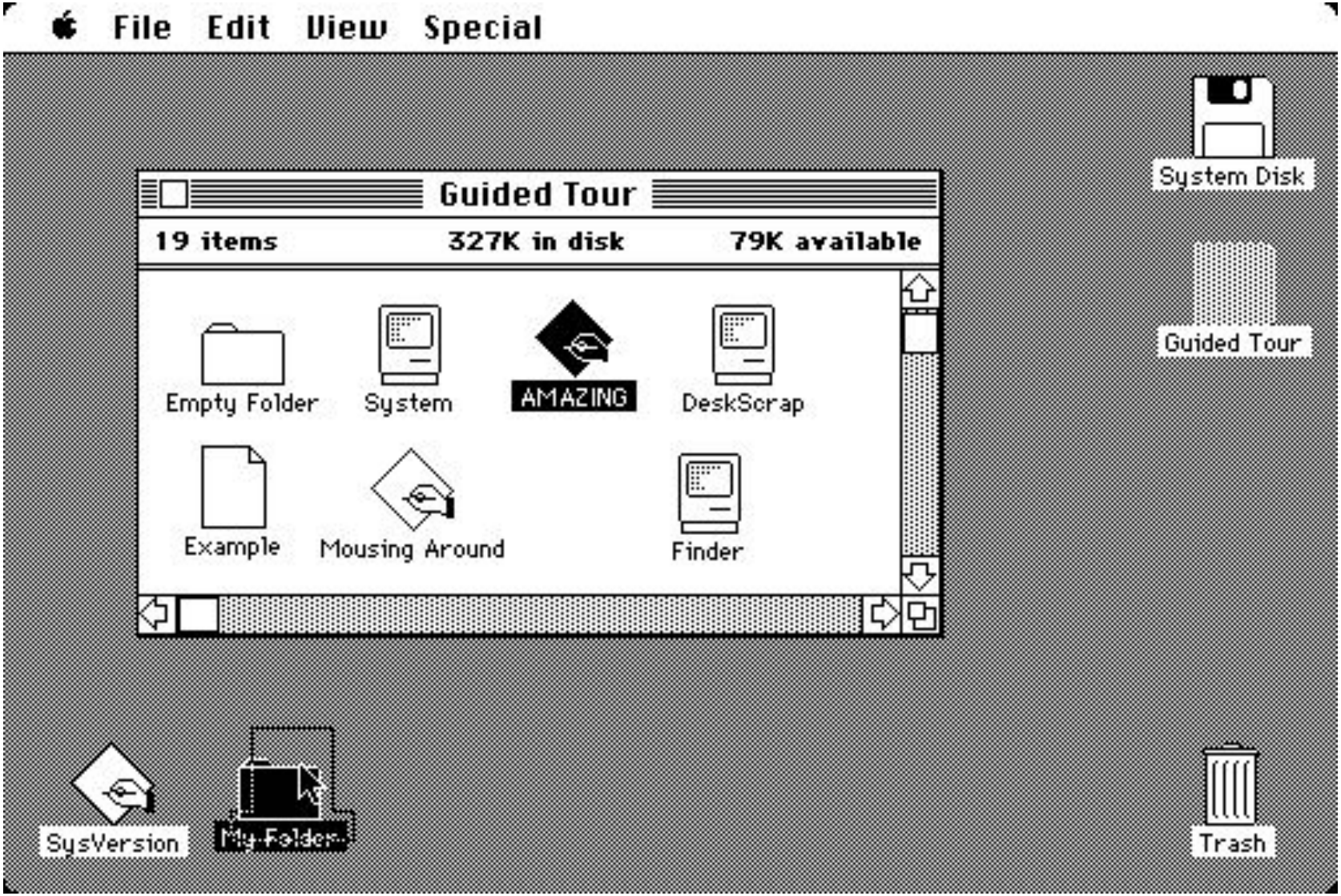
- langage de programmation "objet"
- modèle MVC




(wikipedia)

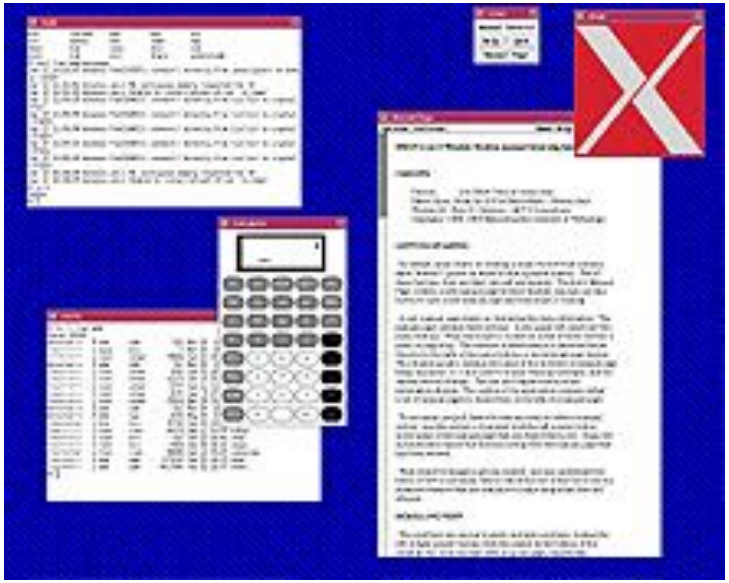


# Apple : MacIntosh (1/1984)

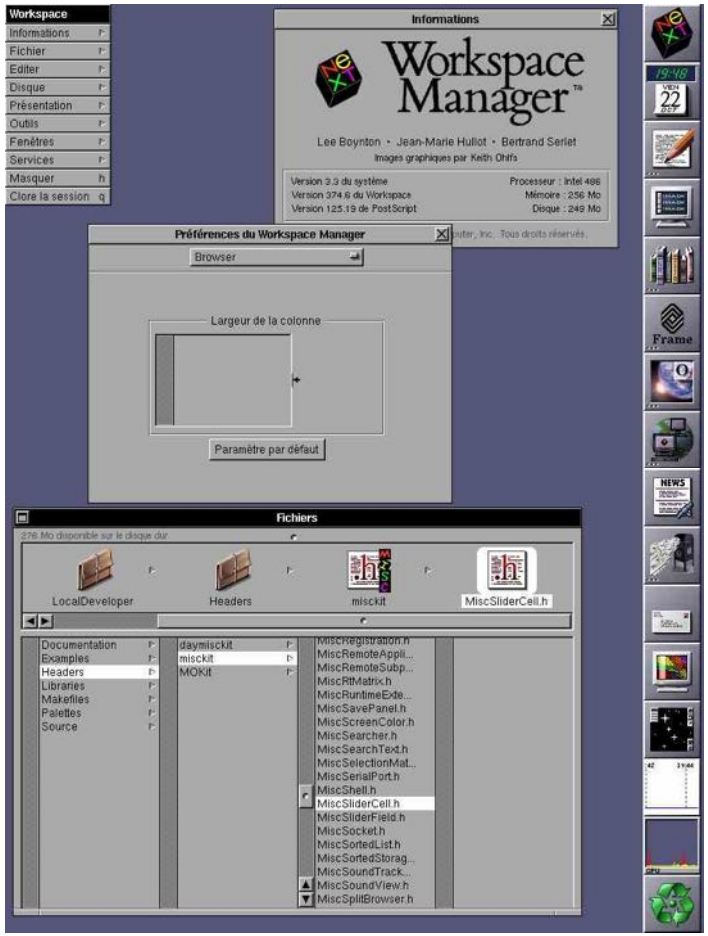



http://toastytech.com/guis/

# X Window (X11.1 : 9/1987)



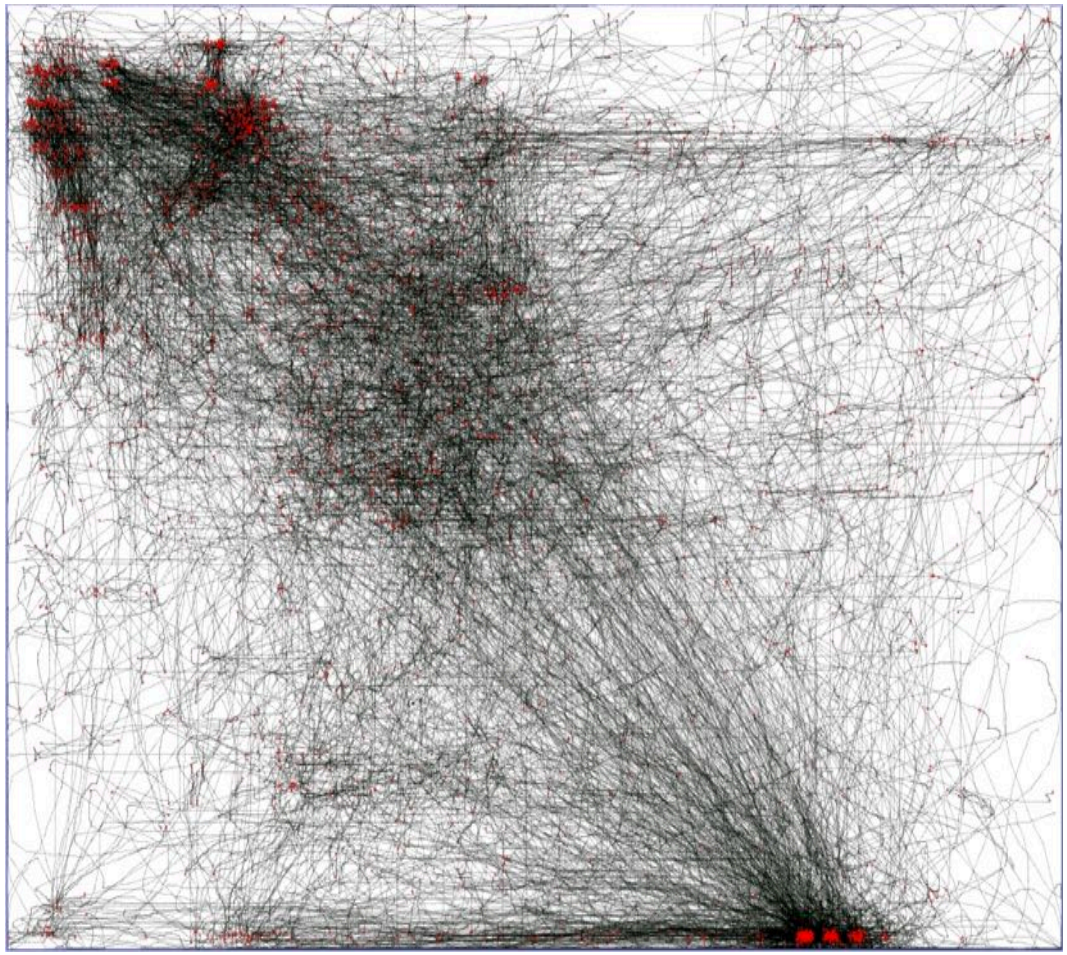
# NeXTSTEP (0.8 : 10/1988)





Apple Aqua (1/2000)

# IHM vu du côté ordinateur…

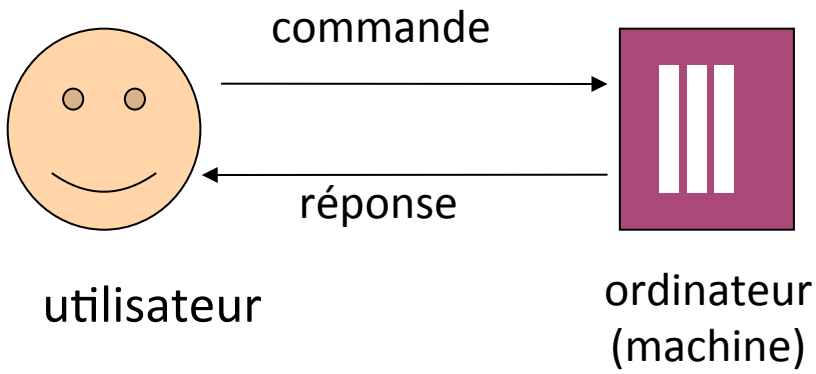


O. Chapuis, R. Blanch, M. Beaudouin-Lafon
Fitts' Law in the Wild: A Field Study of Aimed Movements
LRI tech. report 1480, dec. 2007

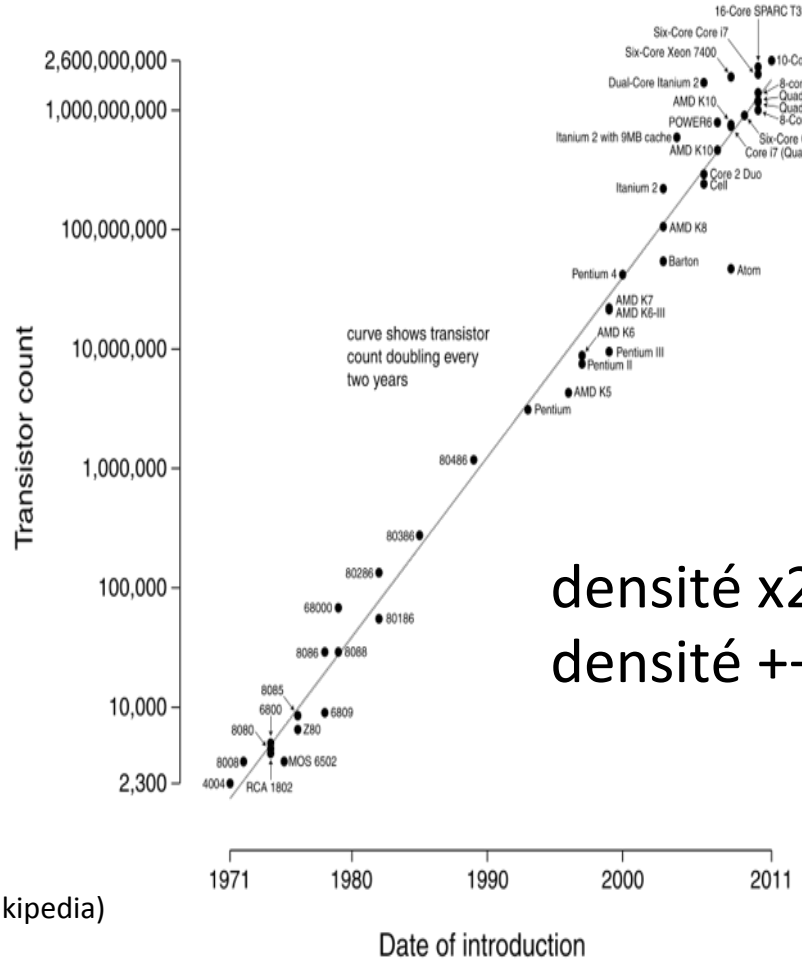
# (2) Au-delà du WIMP

• les domaines d'applications de l'ordinateur ont considérablement changé en un demi-siècle, pour beaucoup grâce à la "loi" de Moore

• mais c'est toujours pénible de donner des ordres à un ordinateur : "gulf of execution" de D. Norman



# La "loi" de Gordon Moore pour les circuits intégrés (1965)




(wikipedia)

densité x2 tous les 2 ans

densité ++ => prix vente --

# 1 : A coût égal, croissance exponentielle de puissance


ma TI-57 (1980) et mon téléphone (2010)

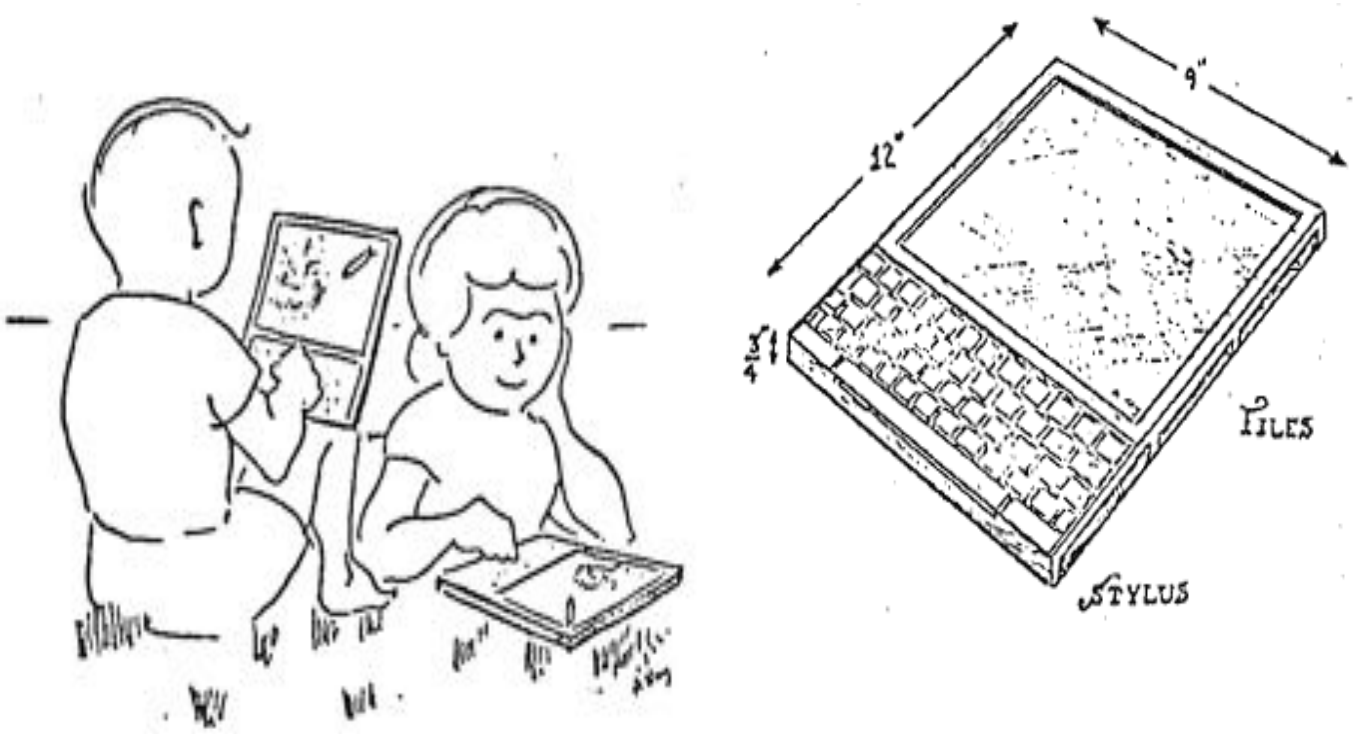
# 2: à puissance égale, décroissance exponentielle du coût




1er processeur dédié 3D pour PC (1995-97)


Etiquettes électroniques (e-ink)

# Etape 1 : l'ordinateur personnel (et pour tous ?)



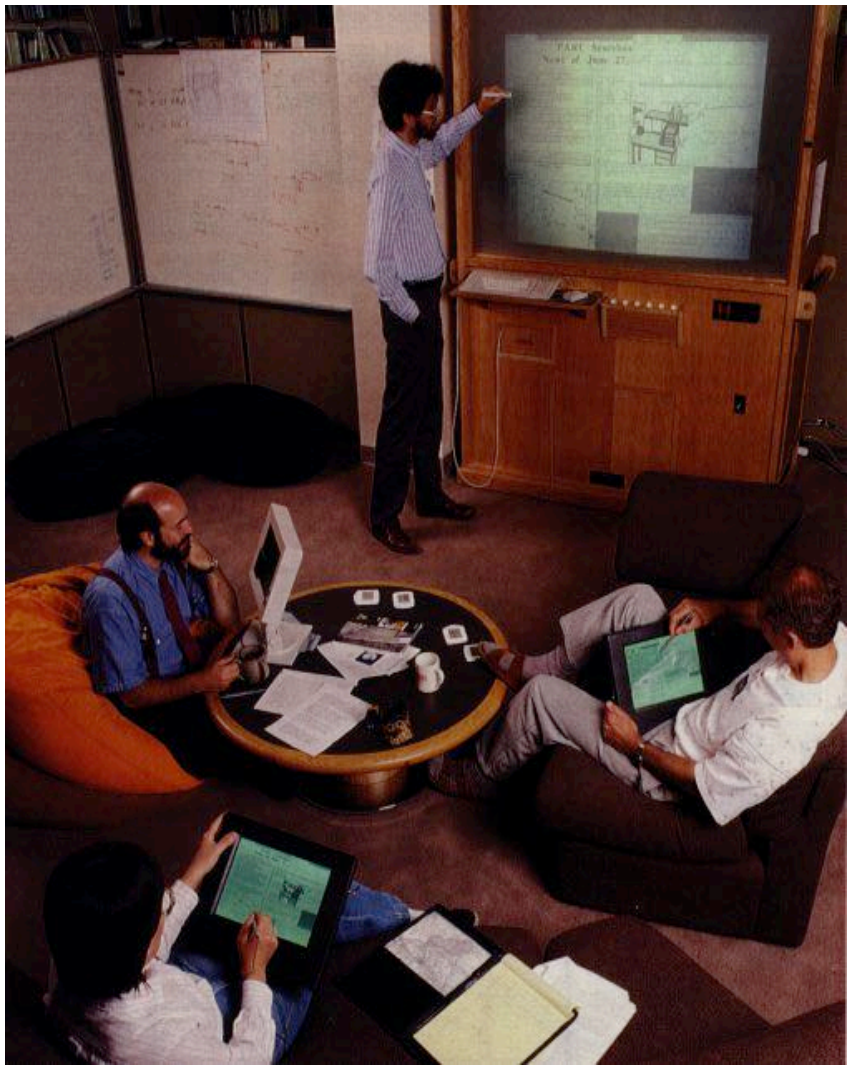

http://en.wikipedia.org/wiki/
File:Dynabook.png

## Le "dynabook" d'Alan Key (PARC, 1972)


(2010)

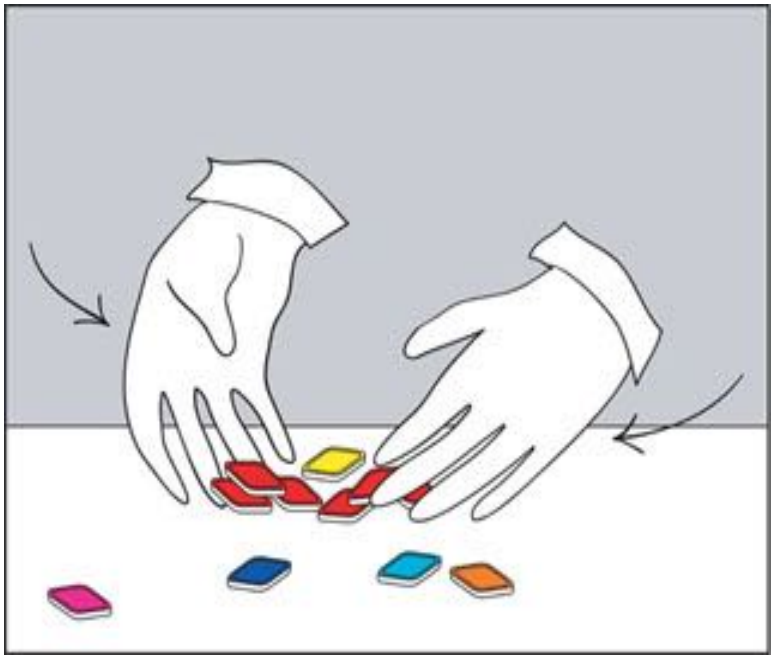
## Etape 2 : l'information tout le temps

Ubiquitous computing
M. Weiser
PARC, ca. 1990



(wikipedia)

# Etape 3 : l'information dans tout



Siftables (Merill, MIT, 2009)

PhotoCubes (S.H. Hsu, CNAM, 2010)

# (3) La captation

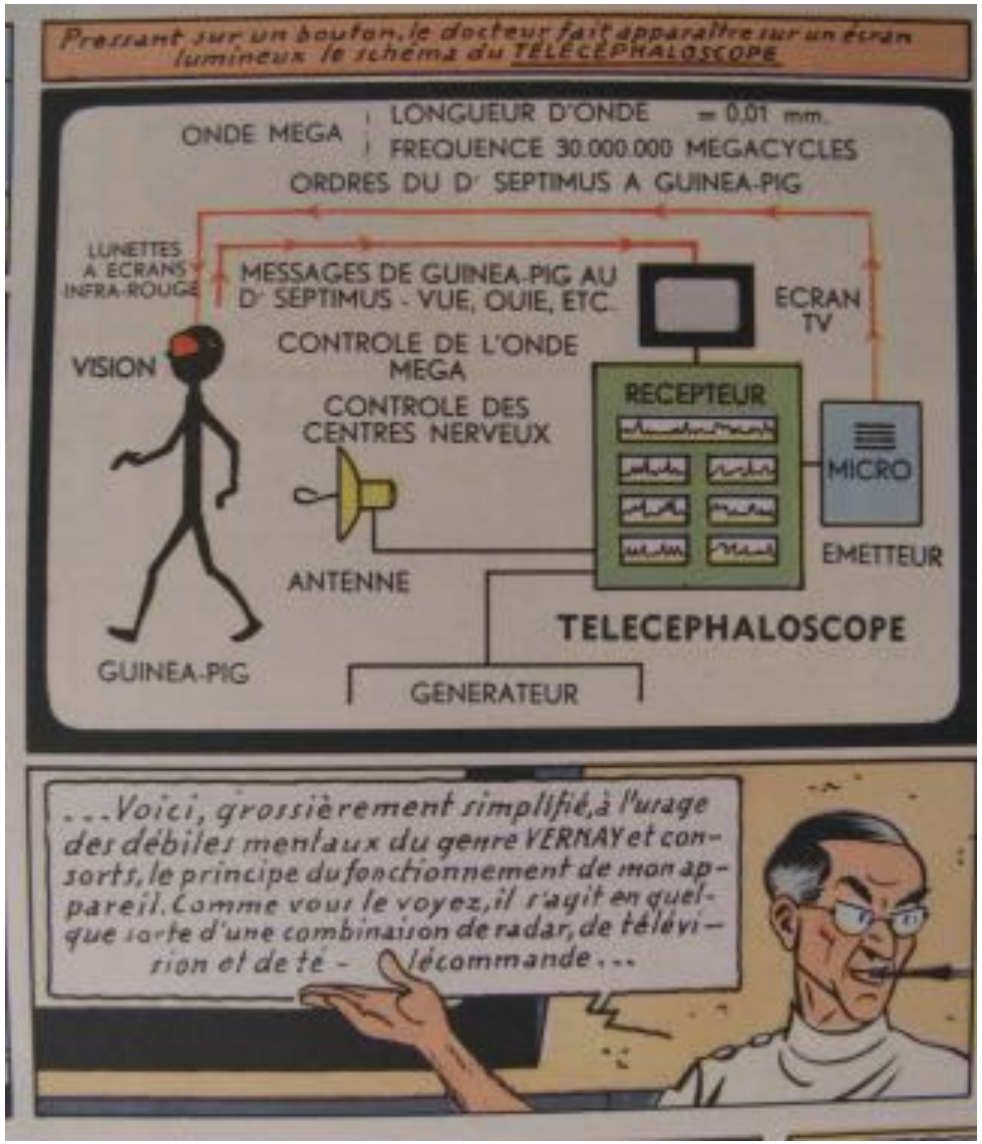
**ce qu'on capte pour l'IHM :**

- position
- mouvement, déplacement
- geste

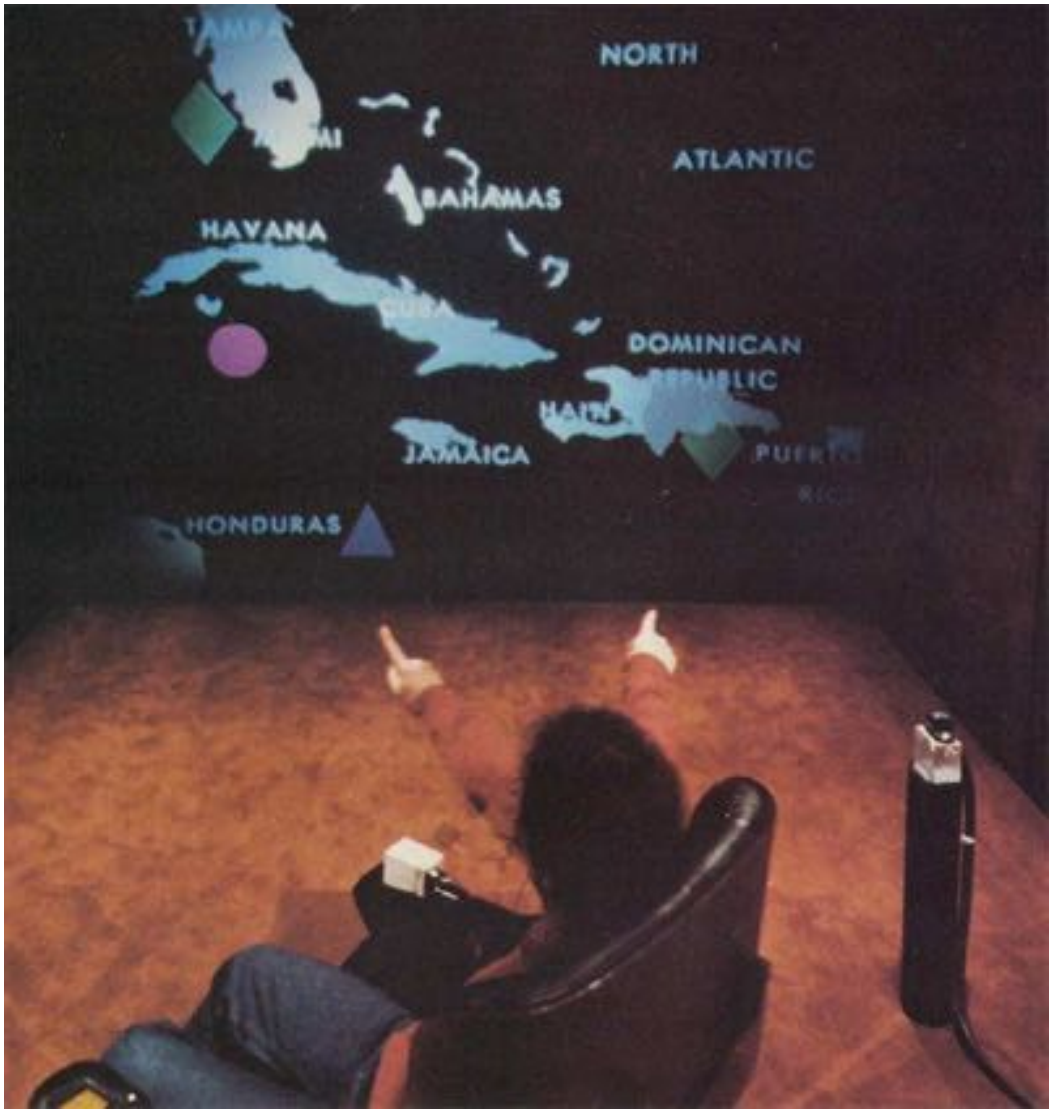
- voix : parole, chant
- attitude
- regard

- physiologie (temperature, rythme cardiaque, sudation ...)
- ondes cérébrales

# Capter pourquoi ? boucle de rétro-action (feedback)

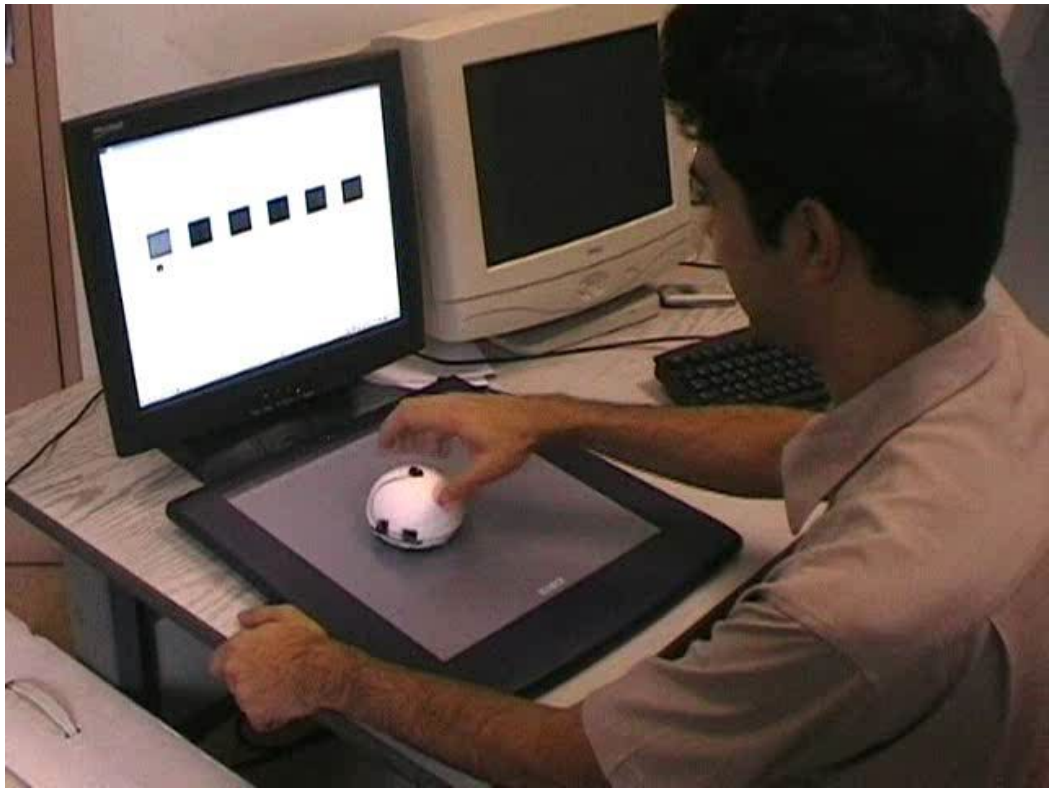



https://www.youtube.com/watch?v=7GVXqNLLH7Q



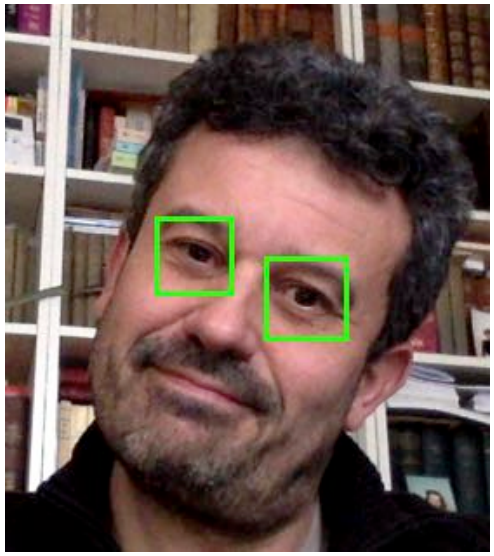

**R. Bolt - "put that there" (MIT, 1980)**

# Souris à 3 DDL, Rodrigo Almeida, CNAM/CEDRIC



procontrol & promidi pour Processing, OSC,  etc

# En octobre avec les ¬progs:

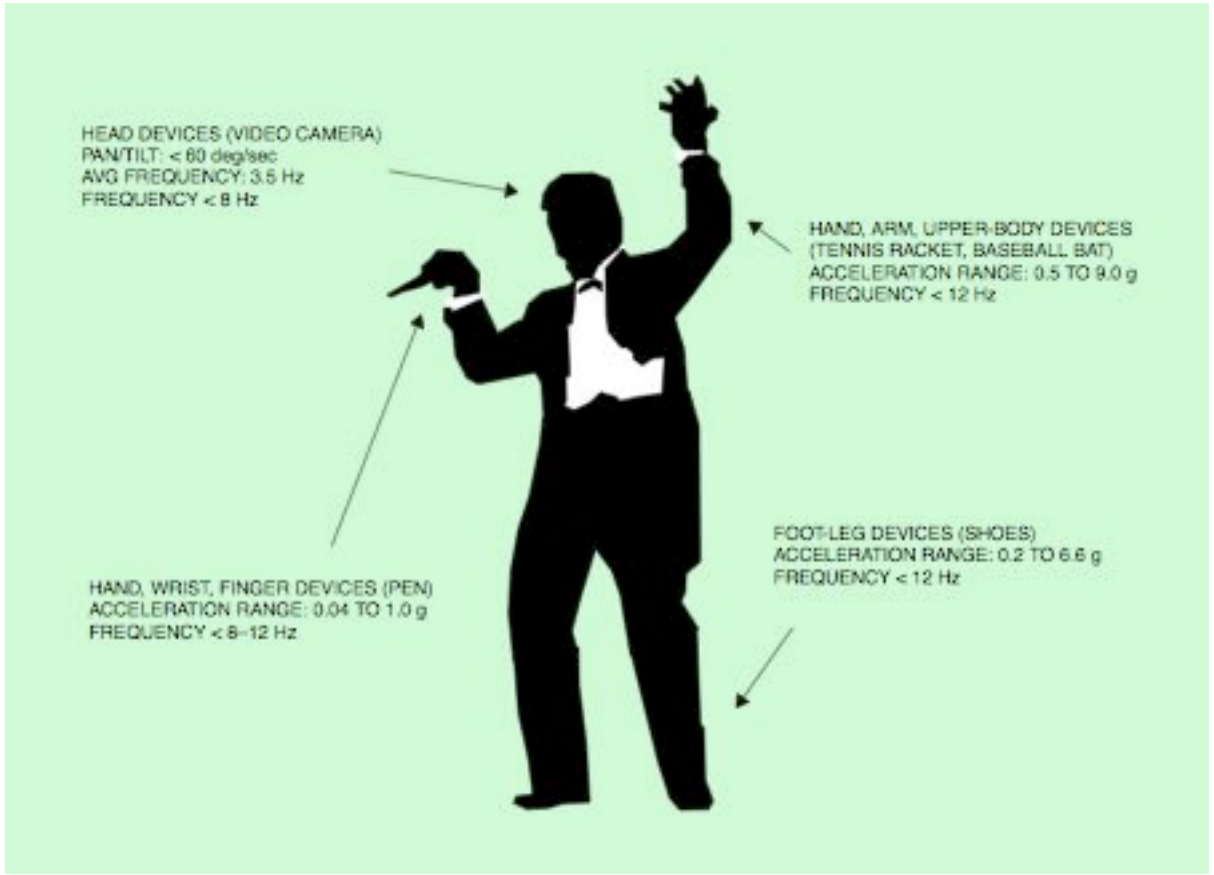


captation video, opencv

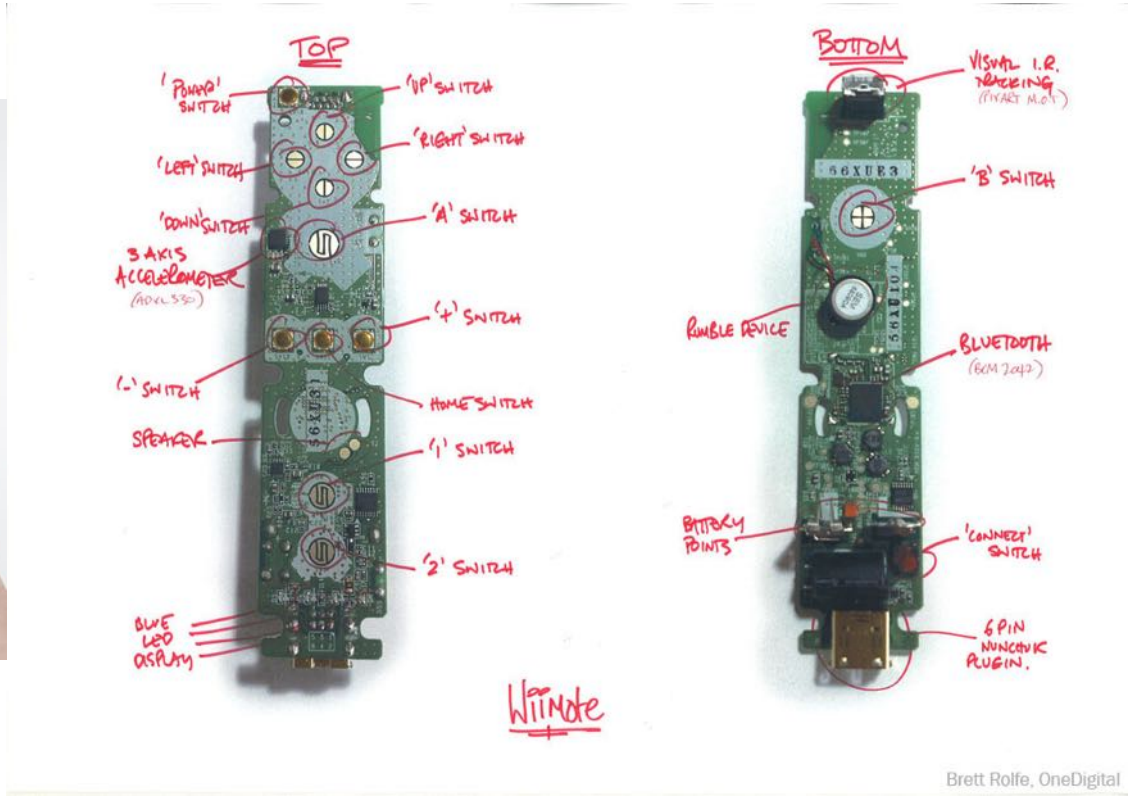
C. Verplaetse IBM Systems Journal 35(3-4) **1996** !!

## Inertial proprioceptive devices: Self-motion-sensing toys and tools

by C. Verplaetse



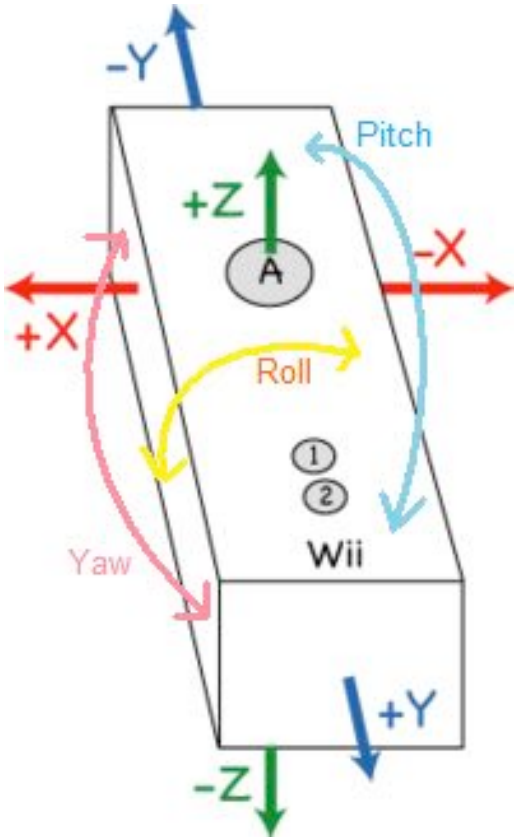
# La Wiimote de Nintendo (2006)




40 € wiimote + 20 €nunchuck
-accelerometre 3axes
-Camera IR + rec. Blobs
-HP, vibreur
-Plein de boutons + joysticks
-Bluetooth (et i2c avec le nunchuck)

Totalement « hacké »
=> www.wiili.com

# Utilisation de l'accéléromètre




On pose la wiimote de manière à avoir successivement les trois axes X Y Z à la verticale et on collecte les valeurs renvoyées.

+Z : x1, y1, z1
+Y : x2, y2, z2
+X : x3, y3, z3

d'où les coordonnées du point origine:

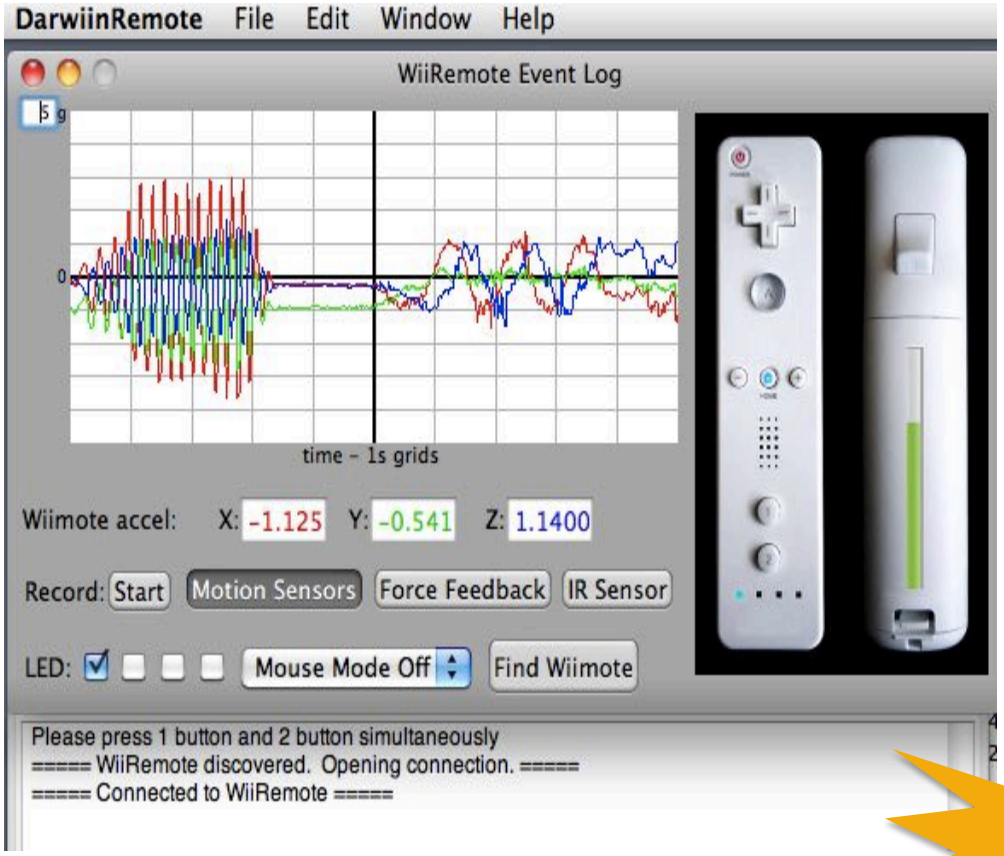
x0 = (x1 +x2)/2
y0 = (y1 + y3)/2
z0 = (z2 + z3) /2

On obtient alors les coordonnées du vecteur force (exprimées en g) :

ax = (xraw -x0)/(x3-x0)
ay = (yraw - y0)/(y2-y0)
az = (zraw - z0)/(z1-z0)

http://www.wiili.org/index.php/Motion_analysis

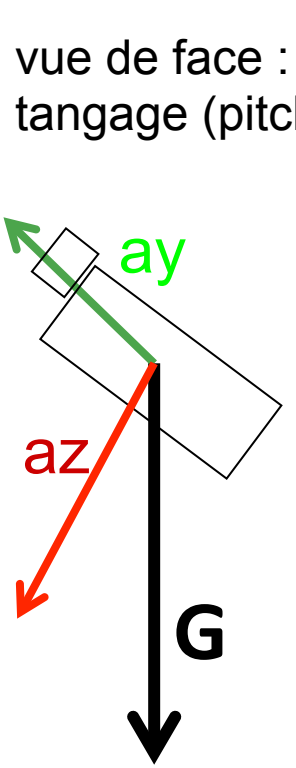
# Utilisation de l'accéléromètre

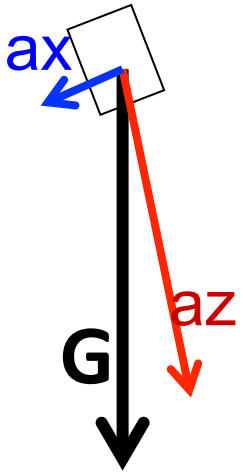



démo

# application à la mesure d'angles

ma (belle) lunette astronomique




vue de l'arrière
roulis (roll)

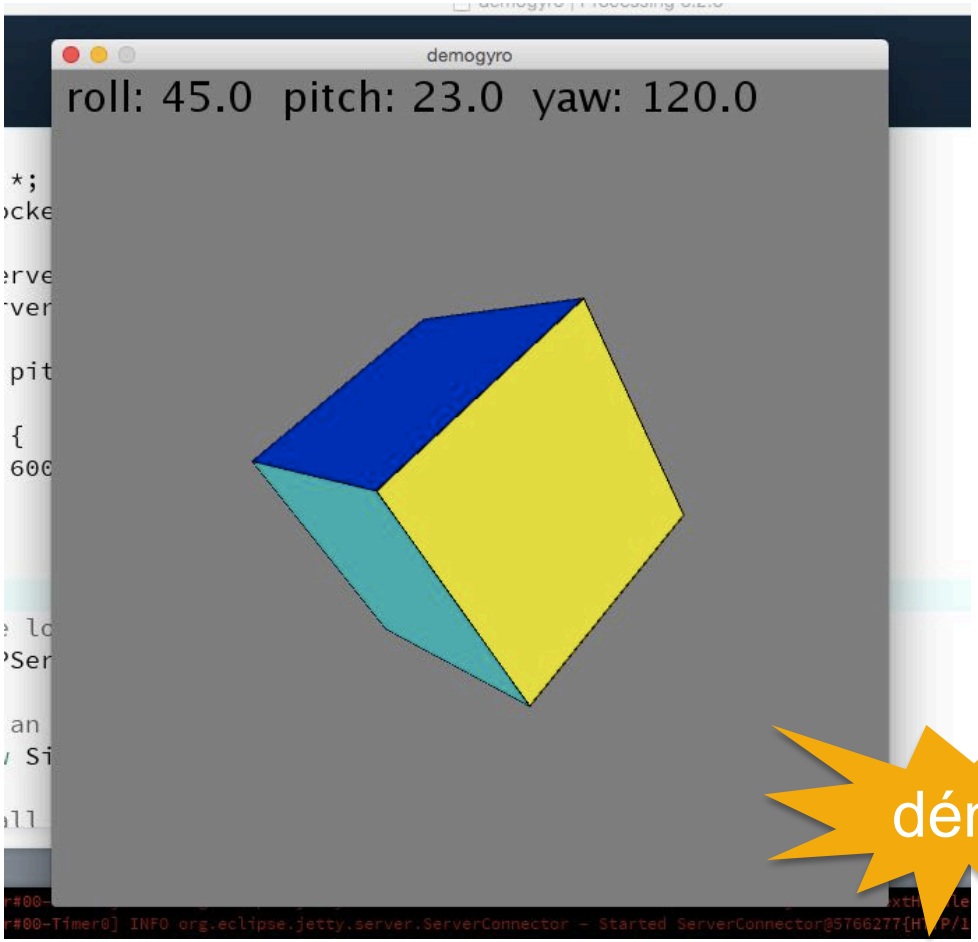
tg(pitch) = ay/az
tg(roll) = ax/az

# Centrales inertielles : les 3 angles d'Euler

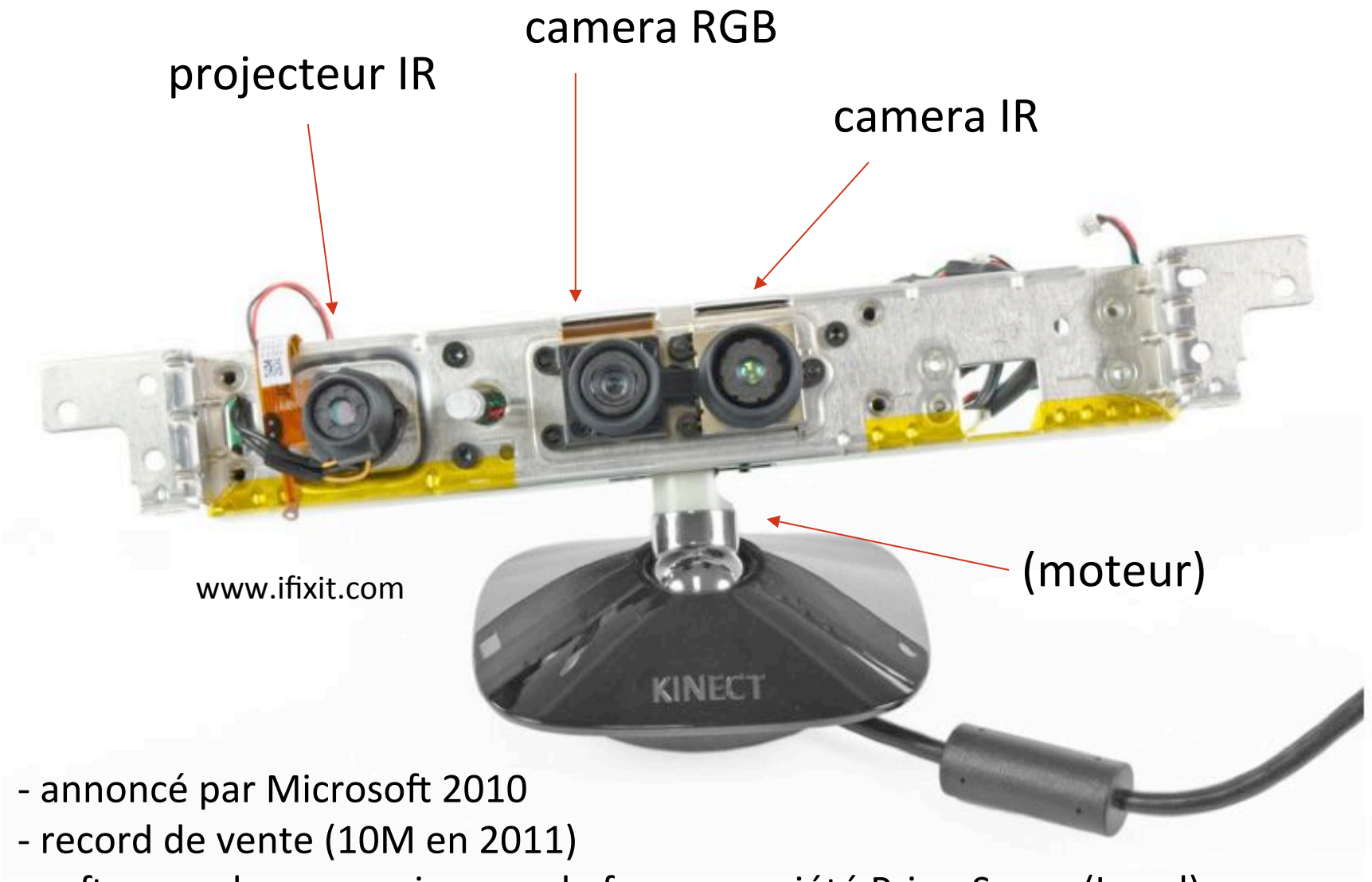
Xsense

Sparkfun

# Centrale inertielle du smartphone



# Kinect




- annoncé par Microsoft 2010
- record de vente (10M en 2011)
- soft+puce de reconnaissance de forme : société PrimeSense (Israel)

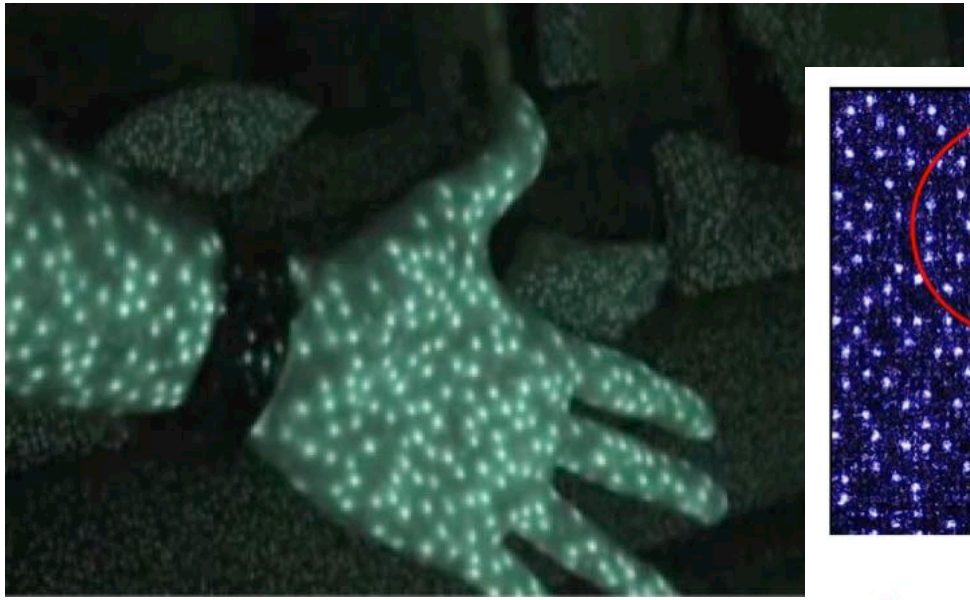
**Principe de la reconstruction 3D** :

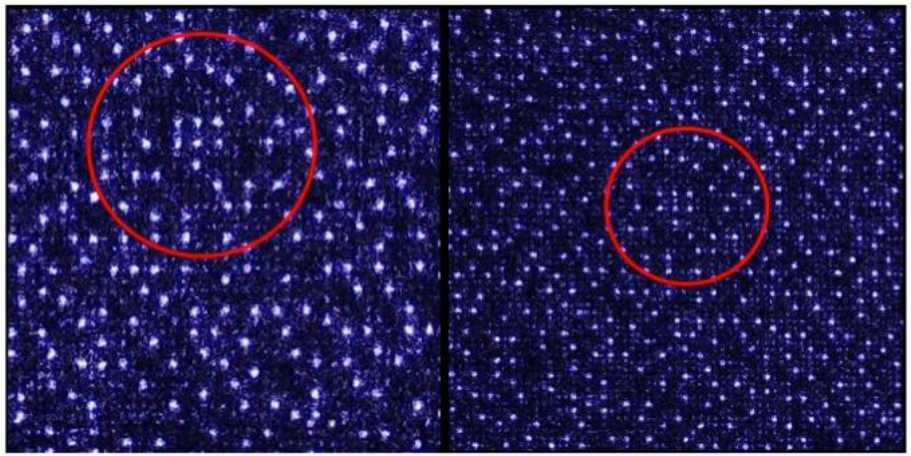
-le projecteur IR diffuse un semis de point sur les surfaces à analyser

-la caméra IR récupère l'image

-la position 3D est déduite en mixant 2 méthodes

(1) la dimension des points (2) la triangulation



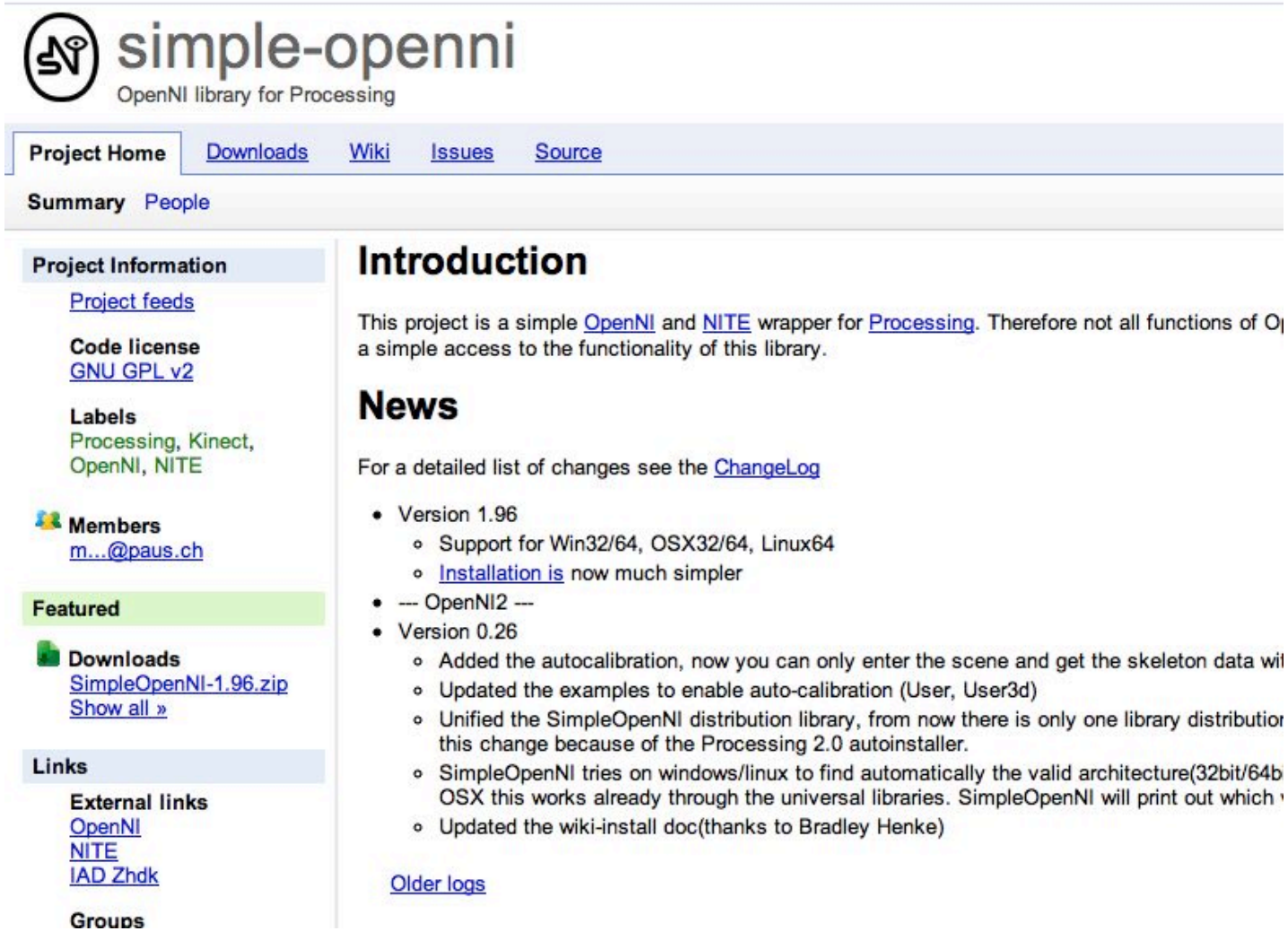


Pas tout à fait aléatoire !

il y a 3 types de motifs, adaptés aux distances

=> bon topo en ligne: H. Wannous, Telecom Lille

# Installation du wrapper Processing de OpenNI



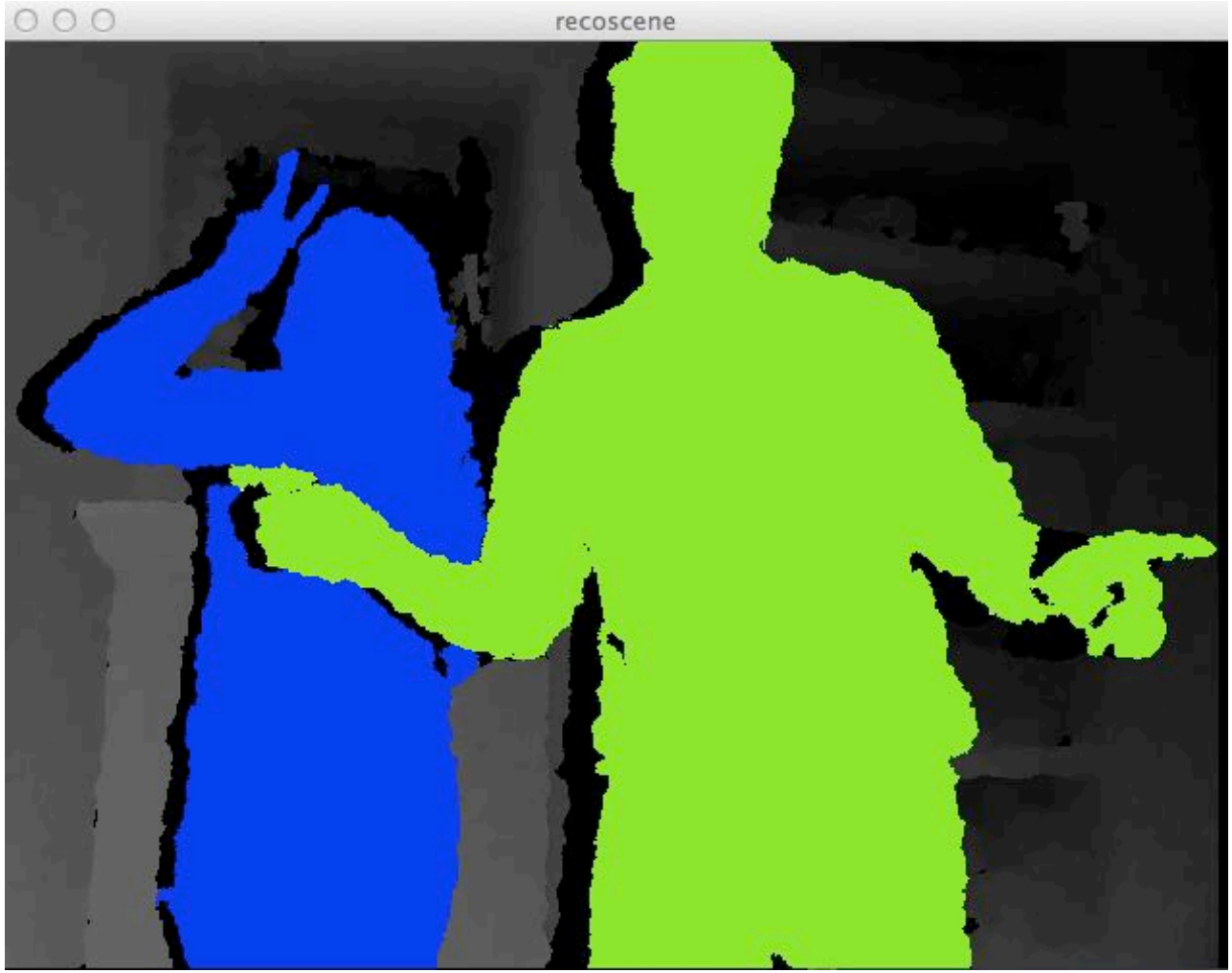

http://code.google.com/p/simple-openni/

# La carte de profondeur (depthmap et depthimage)

esssaiKinect1

```
import SimpleOpenNI.*;
SimpleOpenNI kinect;
void setup() {
  size(640*2, 480);
  kinect = new SimpleOpenNI(this);
  kinect.enableDepth();
  kinect.enableRGB();
  kinect.alternativeViewPointDepthToImage();
}
void draw() {
  background(0,255,0);
  kinect.update();
  image(kinect.depthImage(), 0, 0);
  image(kinect.rgbImage(), 640, 0);
}
```

- séparation fond/humains
- identifications des humains



**Favrication d'un pointeur**

avec le point le plus proche dans la depthmap comme pointeur


G. Borensten "Making things see" O'Reilly

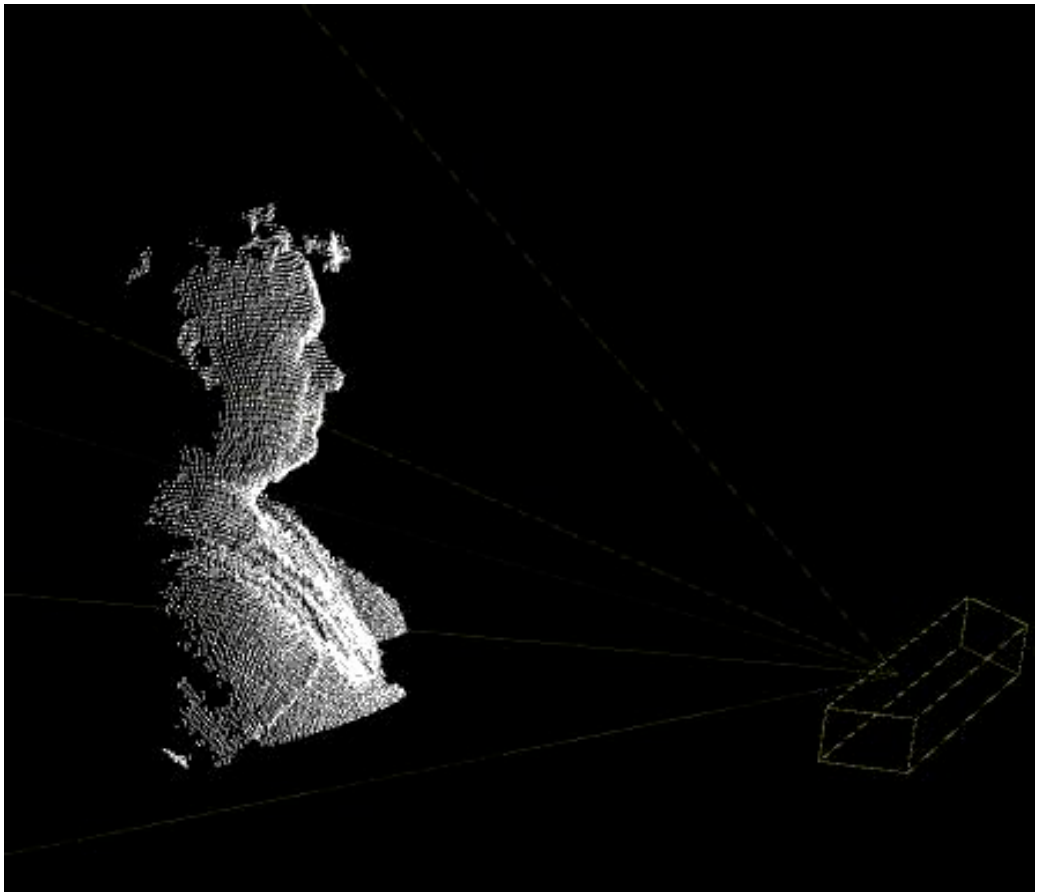
## Code du livre

```
import SimpleOpenNI.*;
SimpleOpenNI kinect;

int closestValue;
int closestX;
int closestY;

void setup() {
  size(640, 480);
  kinect = new SimpleOpenNI(this);
  kinect.enableDepth();
}
```

```
void draw() {
  closestValue = 8000;
  kinect.update();

  // get the depth array from the kinect
  int[] depthValues = kinect.depthMap();

  for(int y = 0; y < 480; y++){
   for(int x = 0; x < 640; x++){
      int i = x + y * 640;
      int currentDepthValue = depthValues[i];
      if(currentDepthValue > 0 && currentDepthValue < closestValue){
        closestValue = currentDepthValue;
        closestX = x;
        closestY = y;
      }
    }
   }

  //draw the depth image on the screen + le point le plus proche
  image(kinect.depthImage(),0,0);
  fill(255,0,0);
  ellipse(closestX, closestY, 25, 25);
}
```

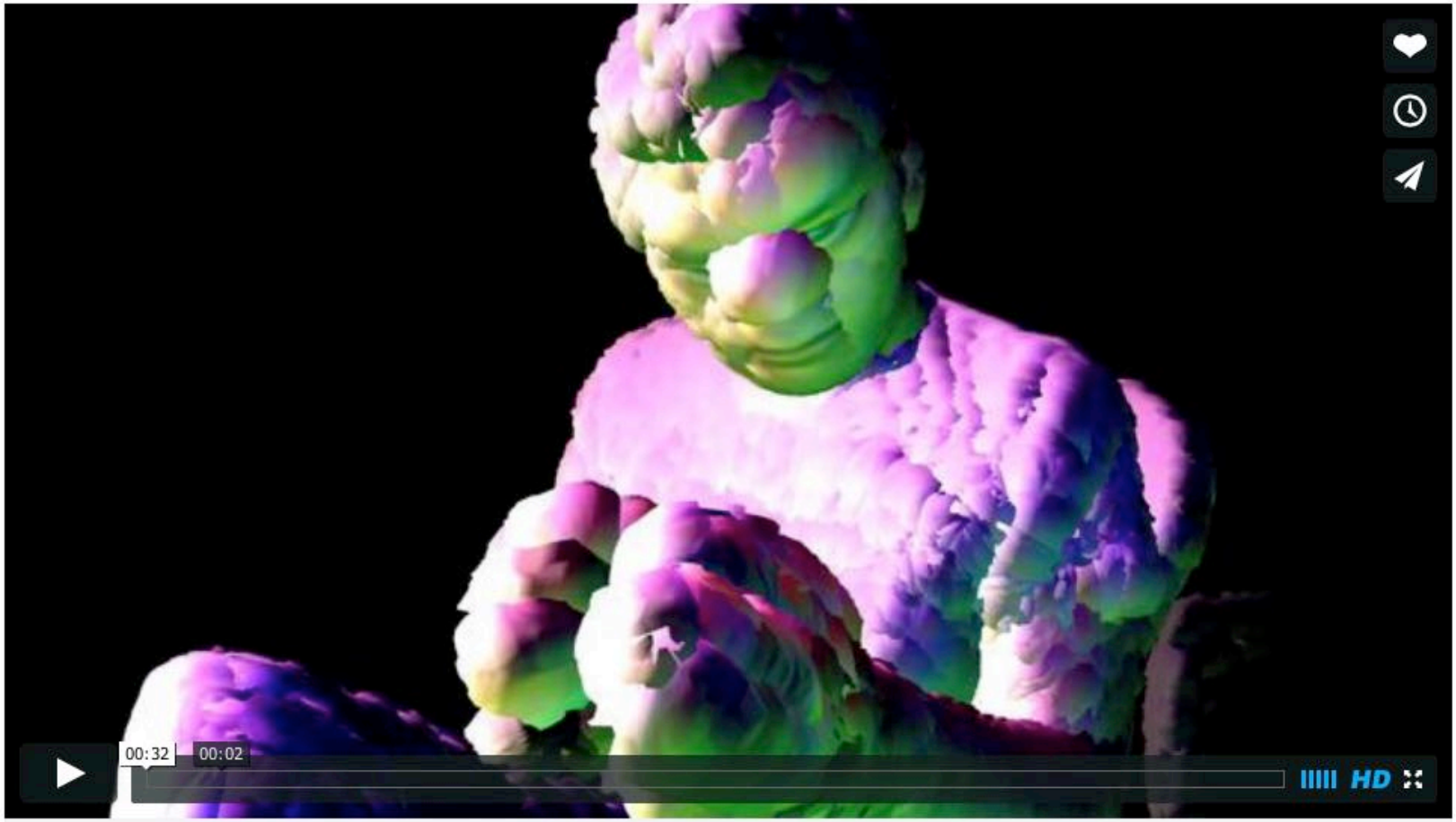
il faudra
filtrer le point

Reconstruction 3D basée sur la depthmap



demo "DepthMap3d" de SimpleOpenNI

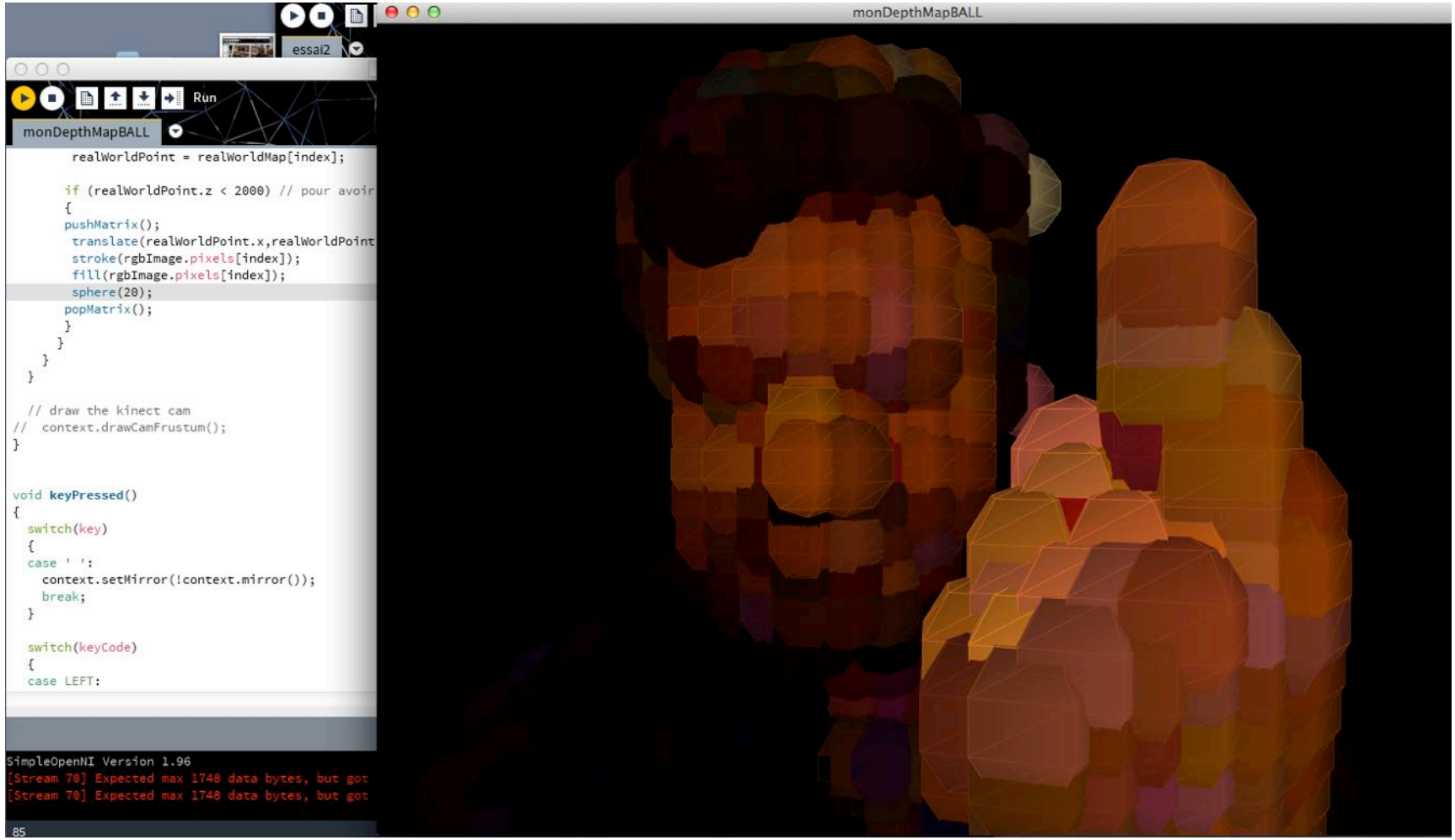
vimeo Join Log In Create Watch Upload Search VIDEOS




# Body Dysmorphic Disorder

from **flight404** PLUS 3 years ago NOT YET RATED

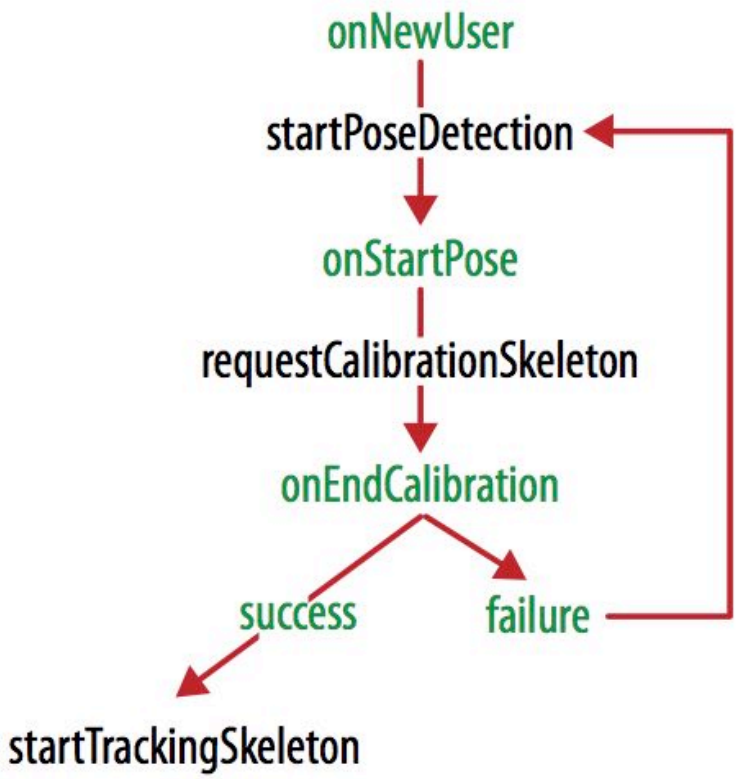
Made with Cinder and the Kinect sensor. Runs in realtime.
**flight404.com/blog/?p=472**


essai2
Run
monDepthMapBALL
realWorldPoint = realWorldMap[index];
if (realWorldPoint.z < 2000) // pour avoir
{
pushMatrix();
translate(realWorldPoint.x,realWorldPoint
stroke(rgbImage.pixels[index]);
fill(rgbImage.pixels[index]);
sphere(20);
popMatrix();
}
}
}
}
// draw the kinect cam
// context.drawCamFrustum();
}
void keyPressed()
{
switch(key)
{
case ' ':
context.setMirror(!context.mirror());
break;
}
switch(keyCode)
{
case LEFT:
SimpleOpenNI Version 1.96
[Stream 70] Expected max 1748 data bytes, but got
[Stream 70] Expected max 1748 data bytes, but got
85
monDepthMapBALL

```
// ici variables globales comme dans
// le code de "depthmap3d"

void setup(){
 // ici debut  comme dans code depthmap3d
  sphereDetail(5);
}
```

```
void draw() {
 // debut  comme dans code depthmap3d

 PVector[] realWorldMap = context.depthMapRealWorld();

 // draw pointcloud`
 for(int y=0;y < context.depthHeight();y+=steps)  {
  for(int x=0;x < context.depthWidth();x+=steps)   {
   index = x + y * context.depthWidth();
   if((depthMap[index] > 0))     {     // draw the projected point
    realWorldPoint = realWorldMap[index];

     if (realWorldPoint.z < 2000) {     // pour avoir juste moi
      pushMatrix();
      translate(realWorldPoint.x,realWorldPoint.y,realWorldPoint.z);
      stroke(rgbImage.pixels[index]);
      fill(rgbImage.pixels[index]);
      sphere(20);
     popMatrix();
     }
   }
  }
 }

 // draw the kinect cam
//  context.drawCamFrustum();
}
```

# Suivi du corps : demo "User" de simpleNI

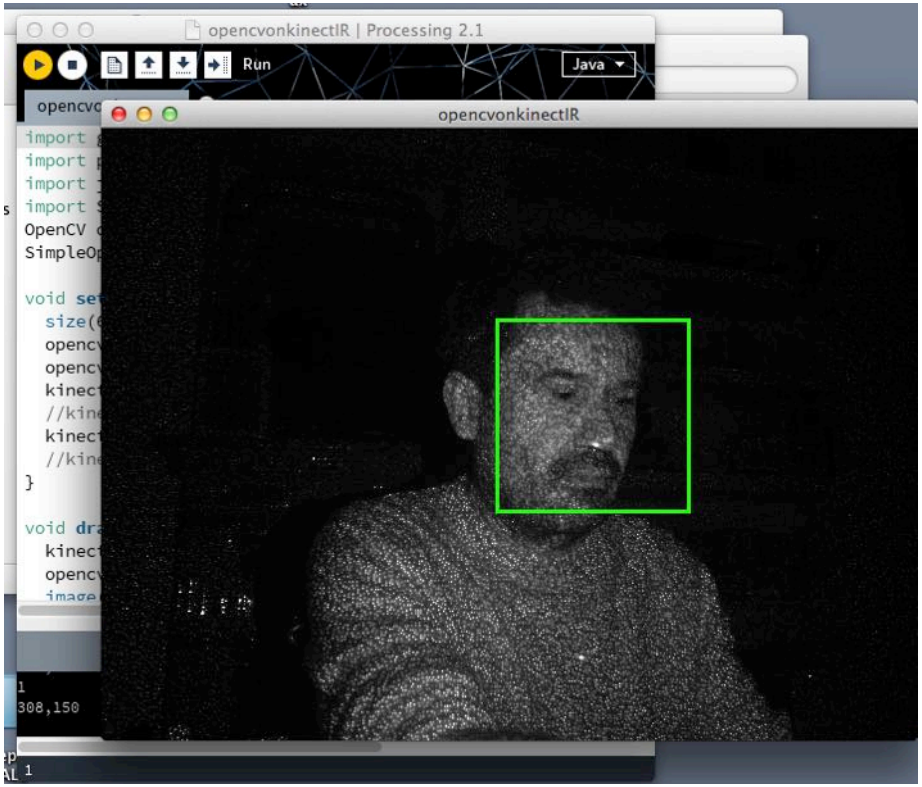




G. Borensten "Making things see" O'Reilly

# Couplage Kinect - openCV

avec la depthmap

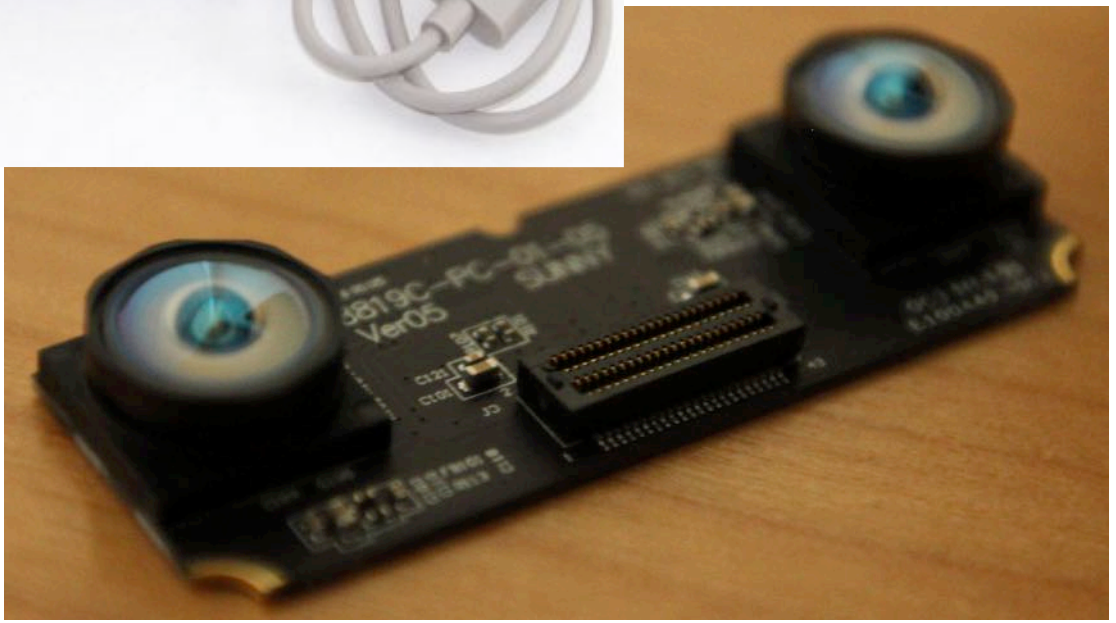



avec la camera IR

**sur la kinect :**

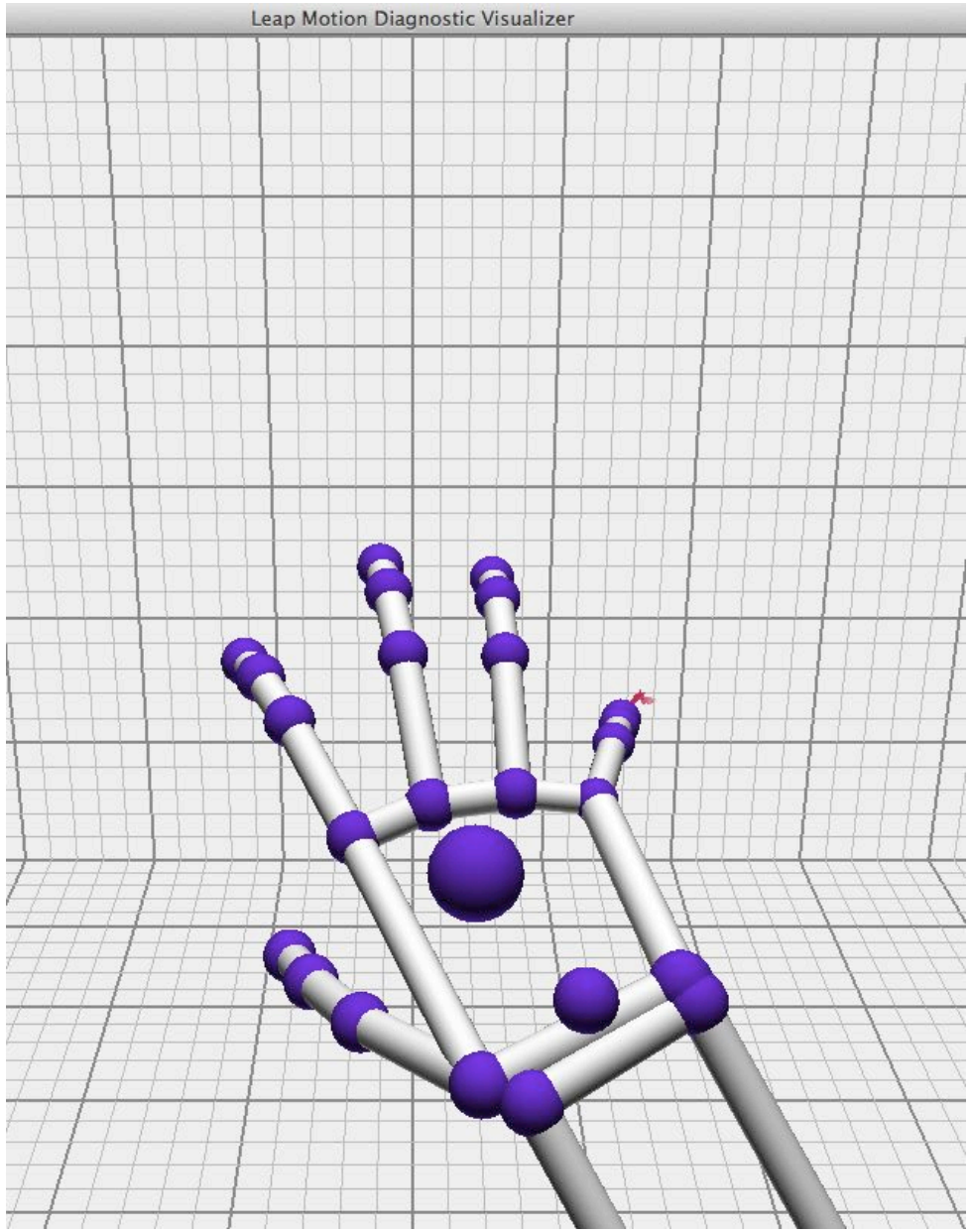
---

# Leap Motion

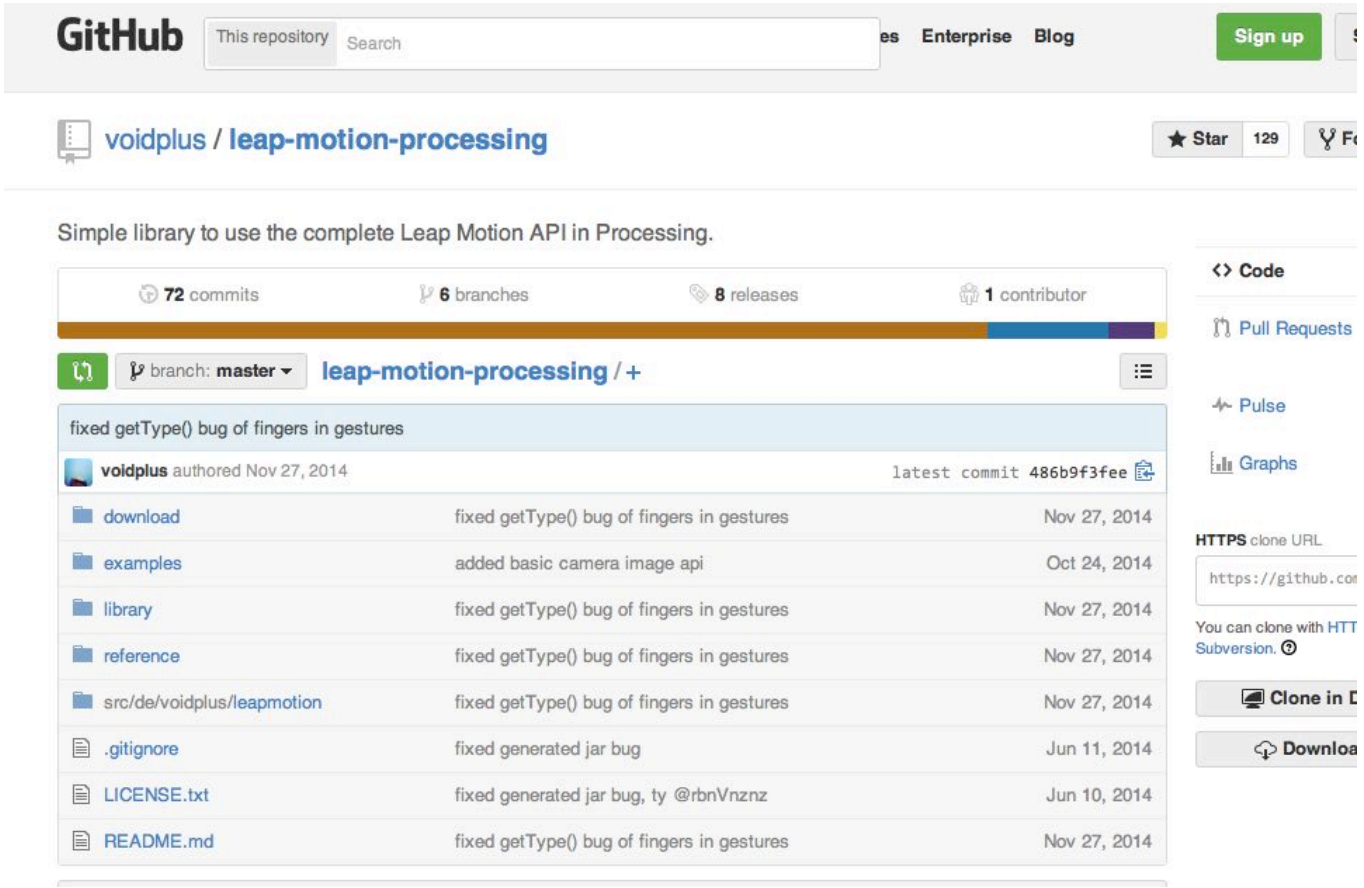



www.ifixit.com

Application
de test



# installer la librairie Processing




https://github.com/voidplus/leap-motion-processing

# la demo "e1_basic"

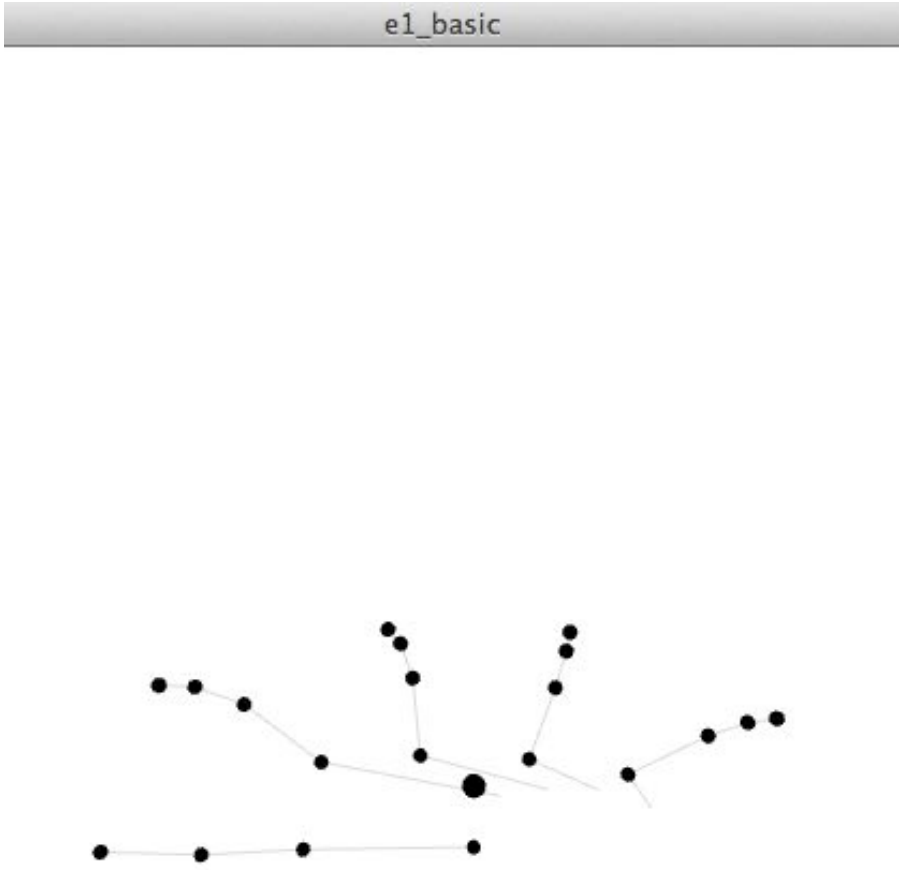
e1_basic | Processing 2.1

Run

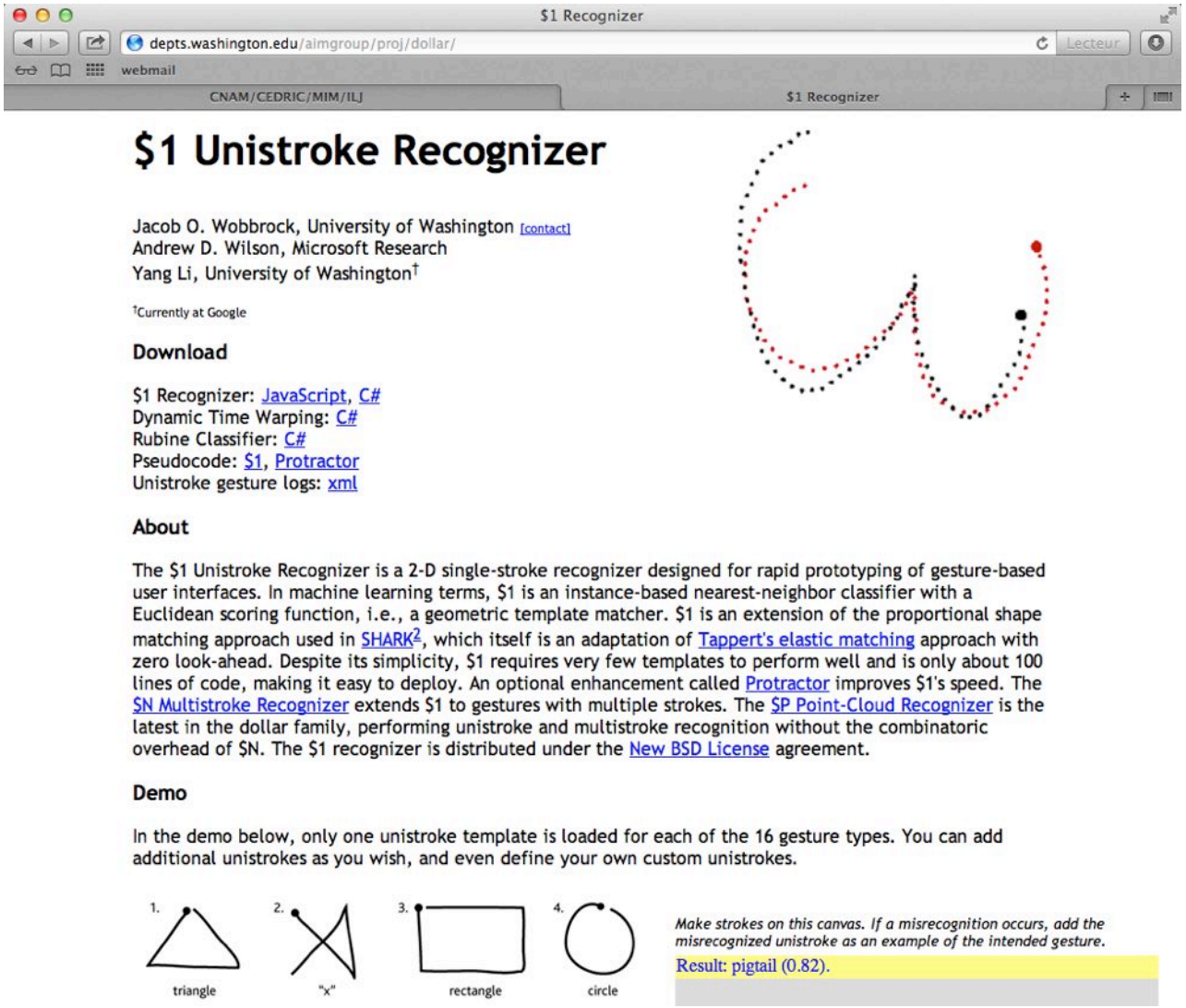
e1_basic

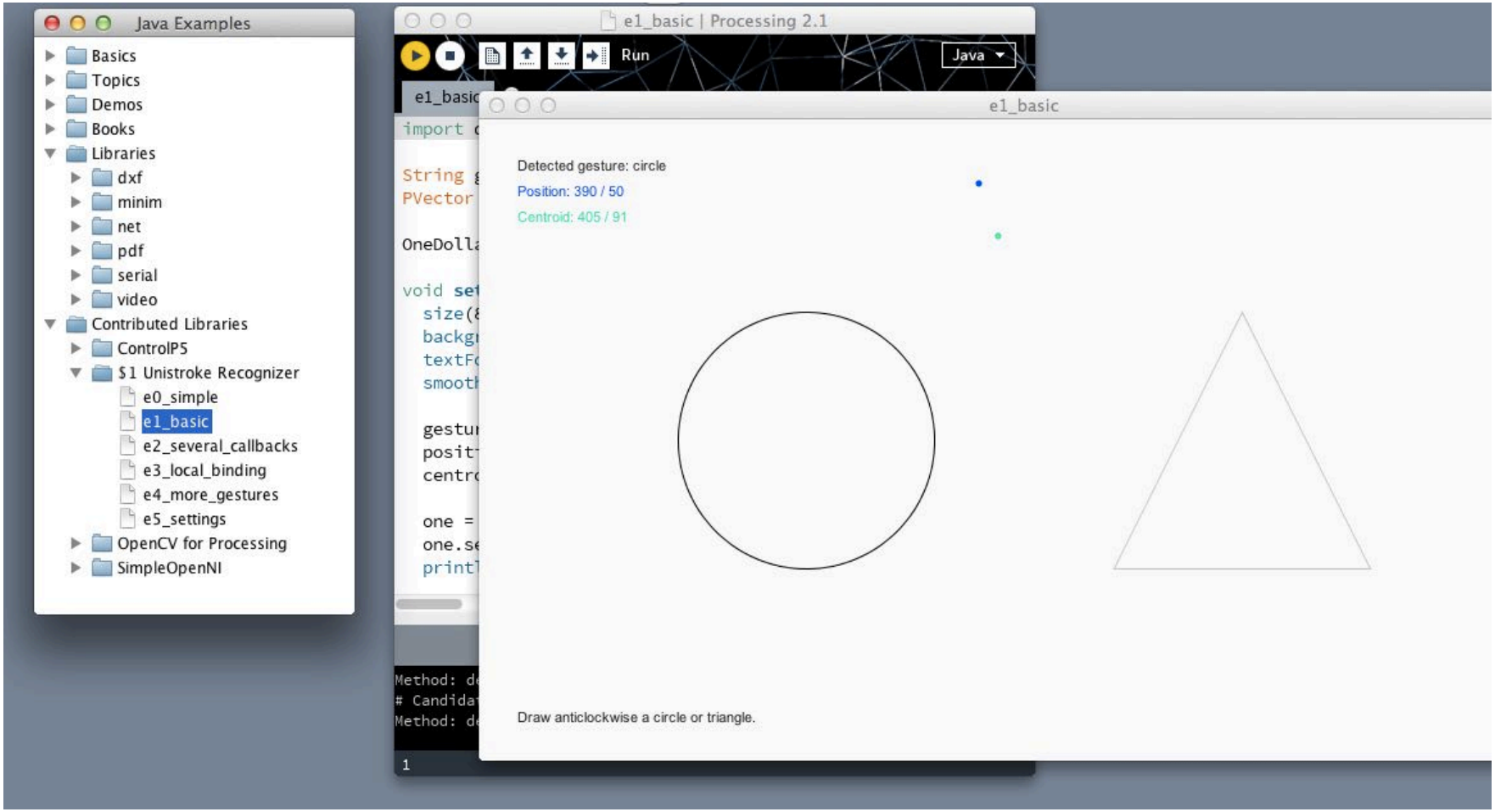
```
import de.voidplus.leapmotion.*;

LeapMotion leap;

void setup(){
  size(800, 500, P3D);
  background(255);
  noStroke(); fill(50);
  // ...

  leap = new LeapMotion(this);
}

void draw(){
  background(255);
  // ...
  int fps = leap.getFrameRate();

  // HANDS
  for(Hand hand : leap.getHands()){

    hand.draw();
    int     hand_id          = hand.getId();
    PVector hand_position    = hand.getPosition();
```

```
# LeapMotion-Library v1.1.2 - LeapMotion-SDK v0.8.1.6221 -
https://github.com/voidplus/leap-motion-processing

1
```



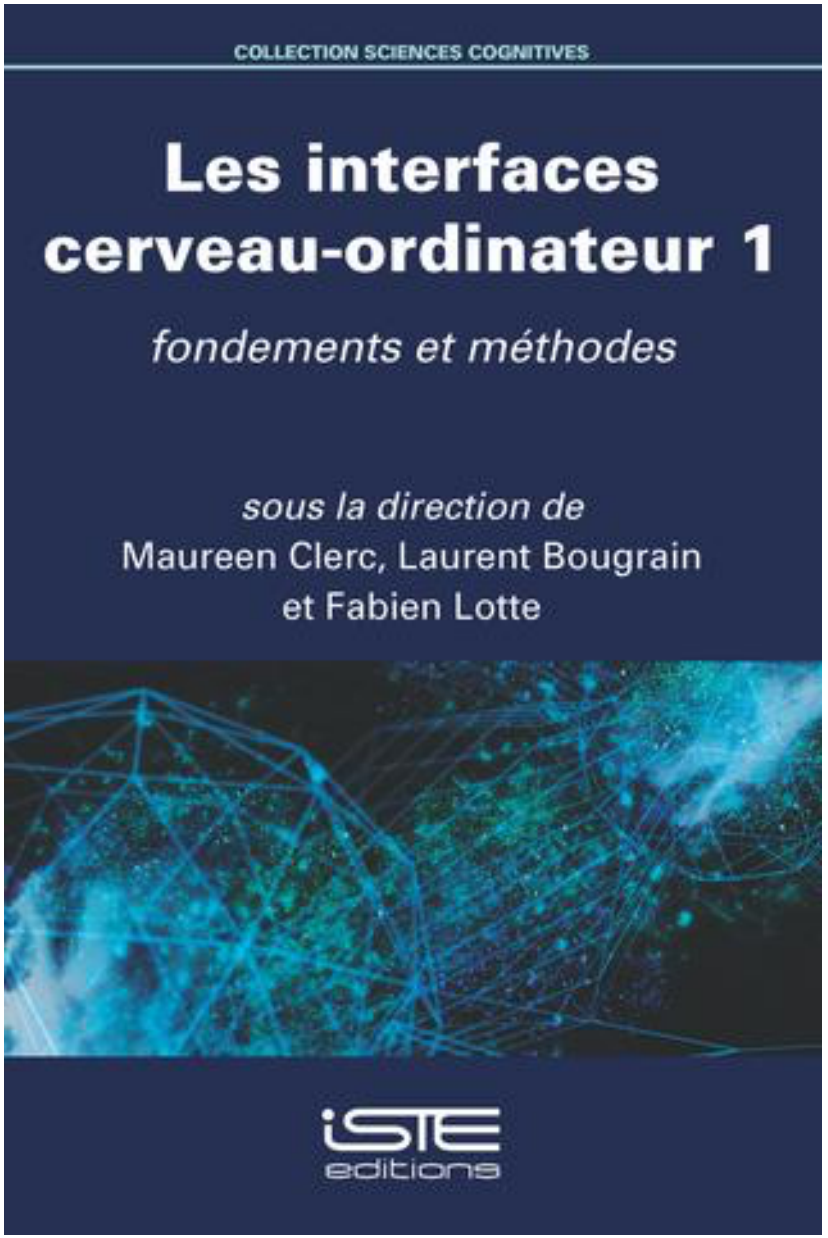
# ET ENCORE : La reconnaissance de tracés simples





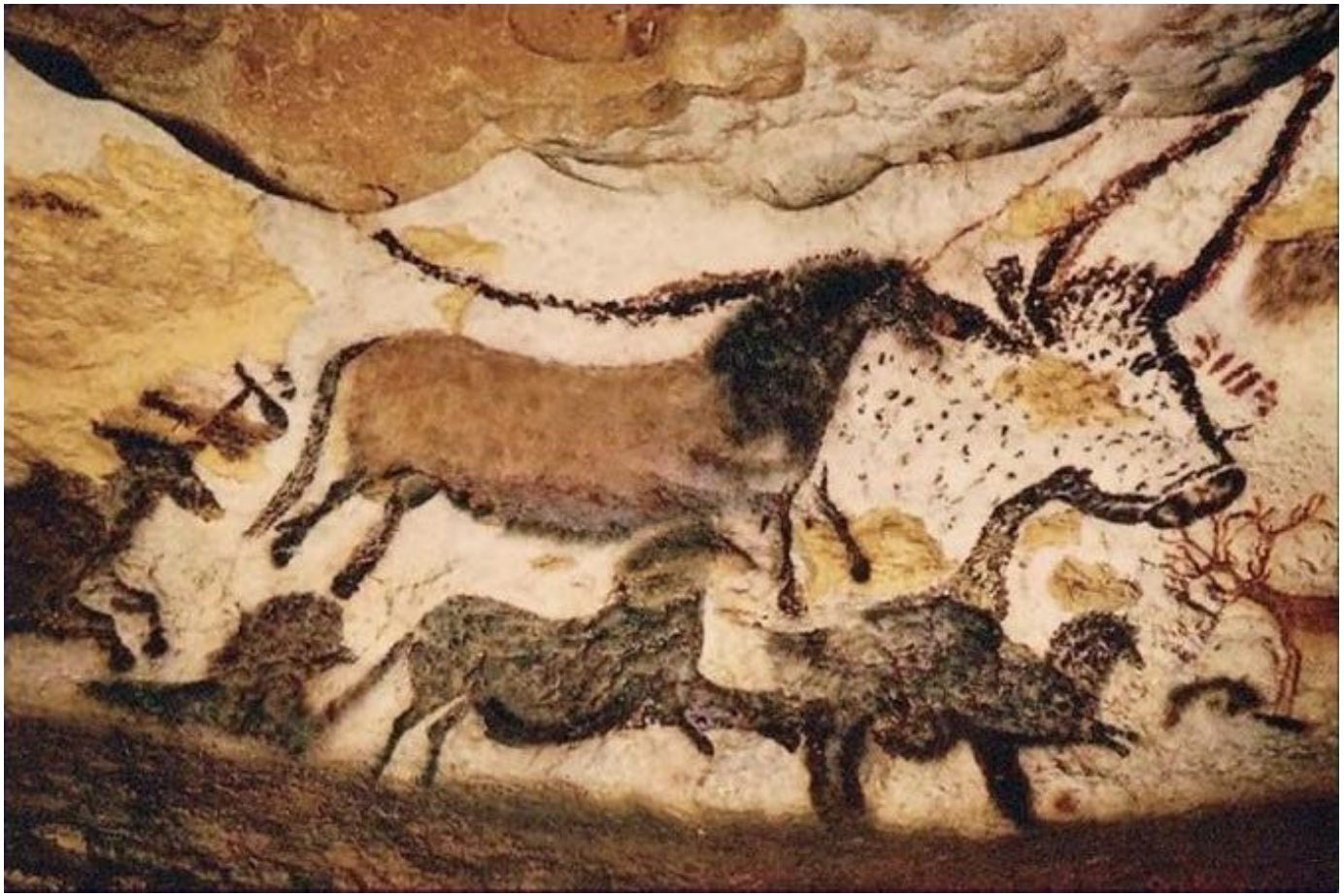

Prendre le temps de l'évaluer !

mais après ?

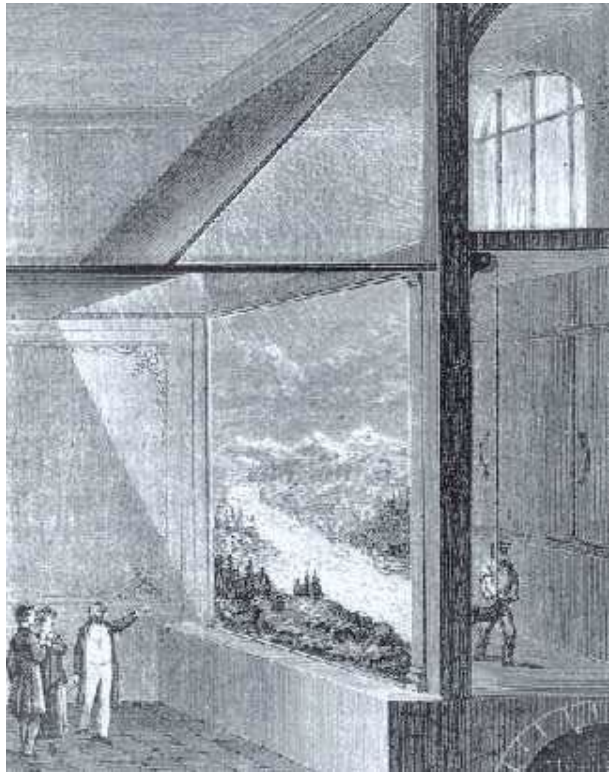

COLLECTION SCIENCES COGNITIVES
Les interfaces cerveau-ordinateur 1
fondements et méthodes
sous la direction de
Maureen Clerc, Laurent Bougrain
et Fabien Lotte
iSTE
editions

# (3) L'immersion


**Occulus rift**



**Lascaux -15000**



## Le diorama de Daguerre (1822)

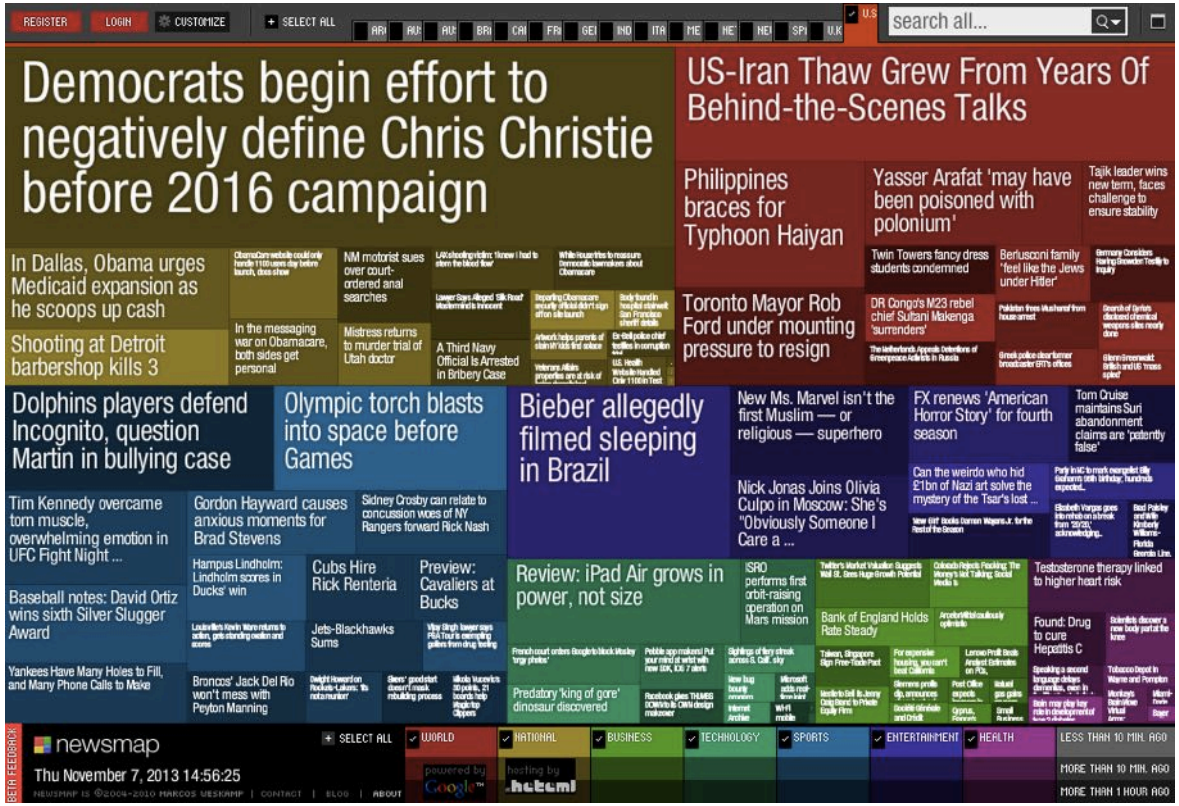
http://www.digischool.nl/ckv2/romantiek/romantiek/panorama/


## Rue Léon Jouhaux (Xème)

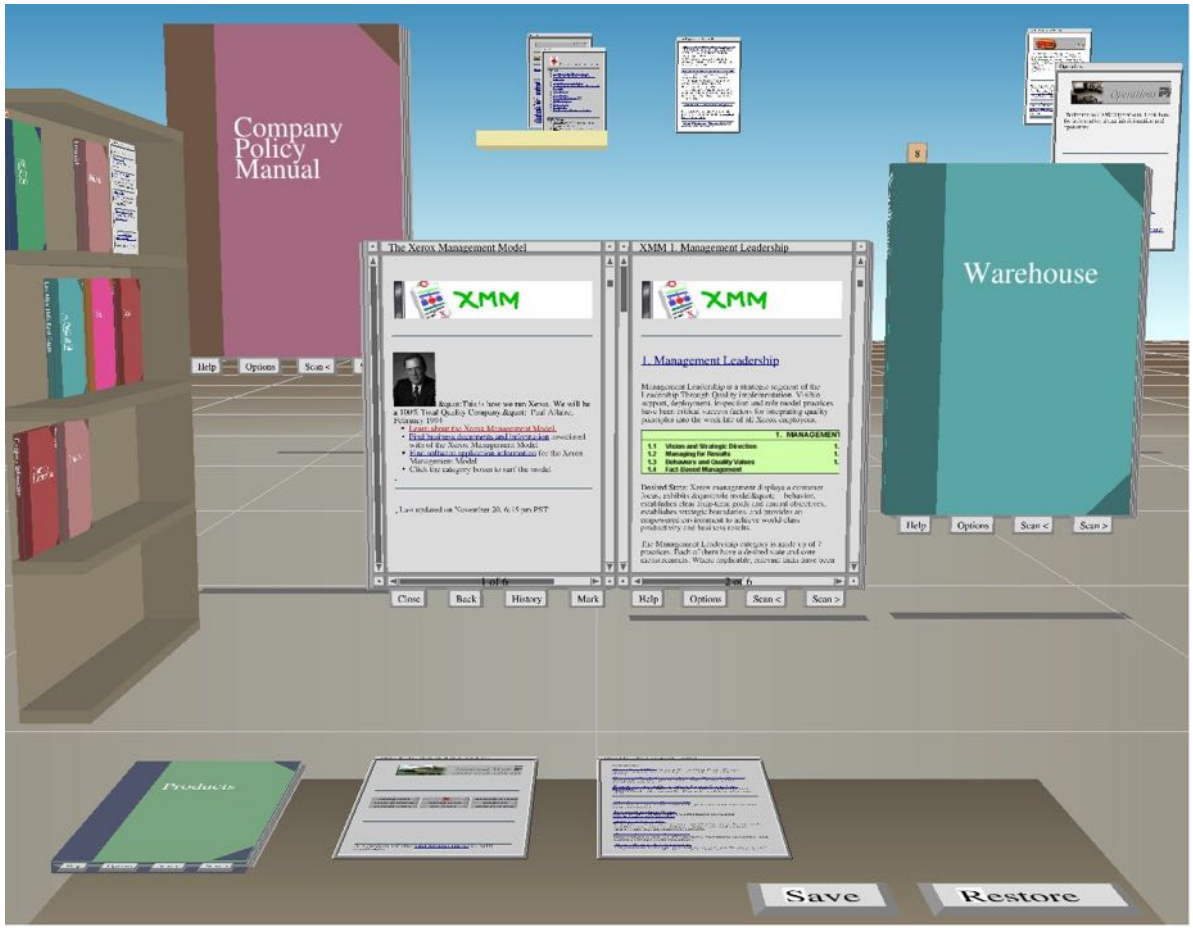
# Multiplication des écrans

http://www.stocktradingtogo.com/2007/09/25/are-20-monitors-enough-for-one-trader-you-decide/

# Immersion dans les données




http://newsmap.jp




**Stuart K. Card, George G. Robertson, and William York . *The WebBook and the Web Forager: An Information Workspace for the World-Wide Web*  proc. ACM CHI'96**

Perception
du relief :

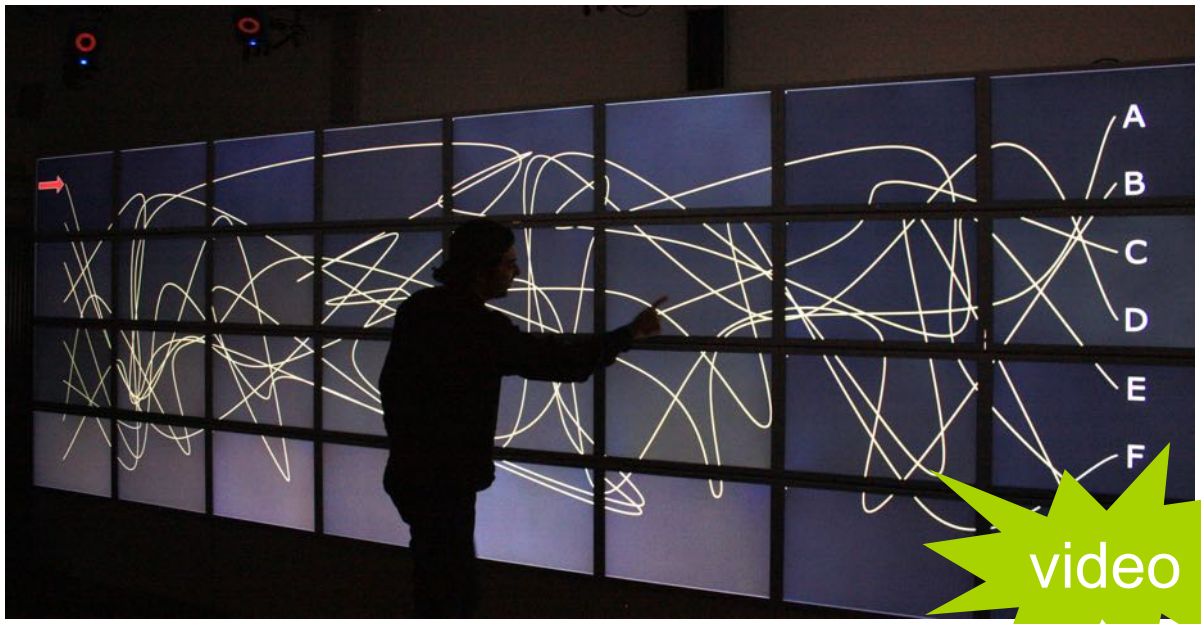
Nombreux
Indices
- Monoculaires
- Binoculaires

## Les expériences de J.C. Lee (HCII, Carnegie Mellon Univ., 2008)


video

<= 11M en 2015

# Reprise sur mur d'écrans (INRIA+CNAM, 2012)

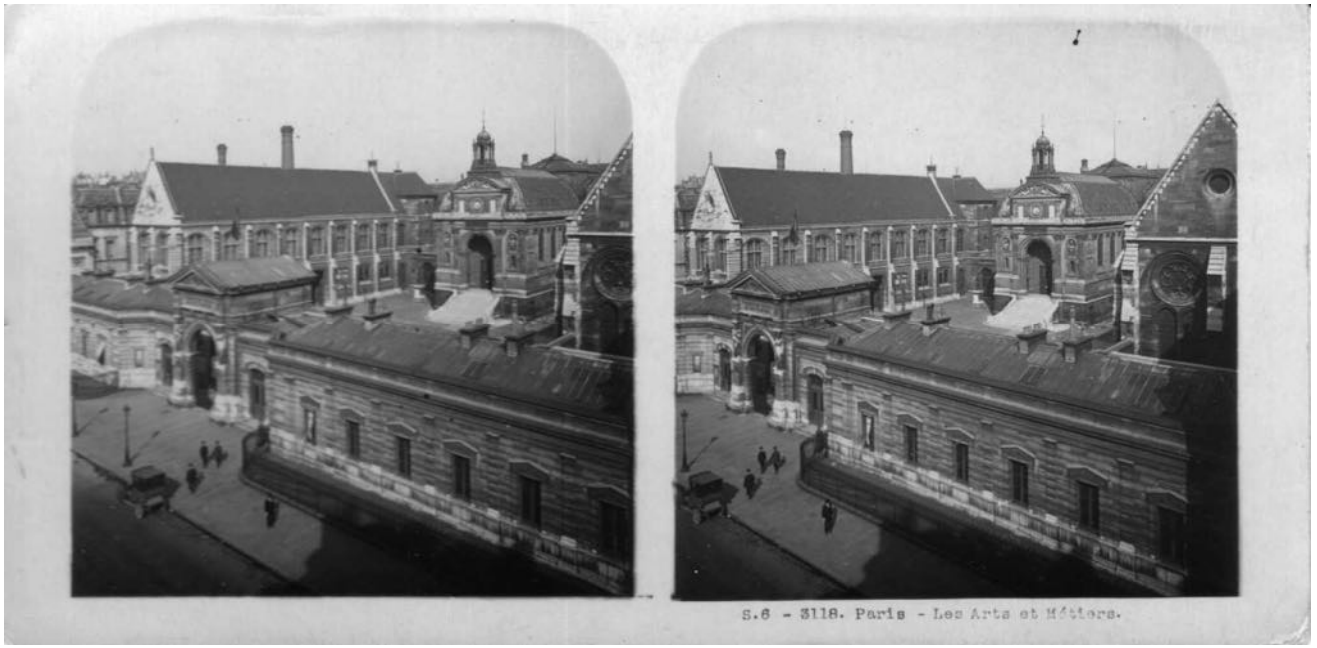



- 8 x 4 = 32 écrans LCD 30"  =>  5.5m x 1.8m and 131 Mpix
- cluster de 16 macpro avec 16 x 2 nvidia 8800GT
- capture mouvements video IR VICON (e<1mm, 200 Hz)

## Le stéréoscope

### Brewster (18xx)

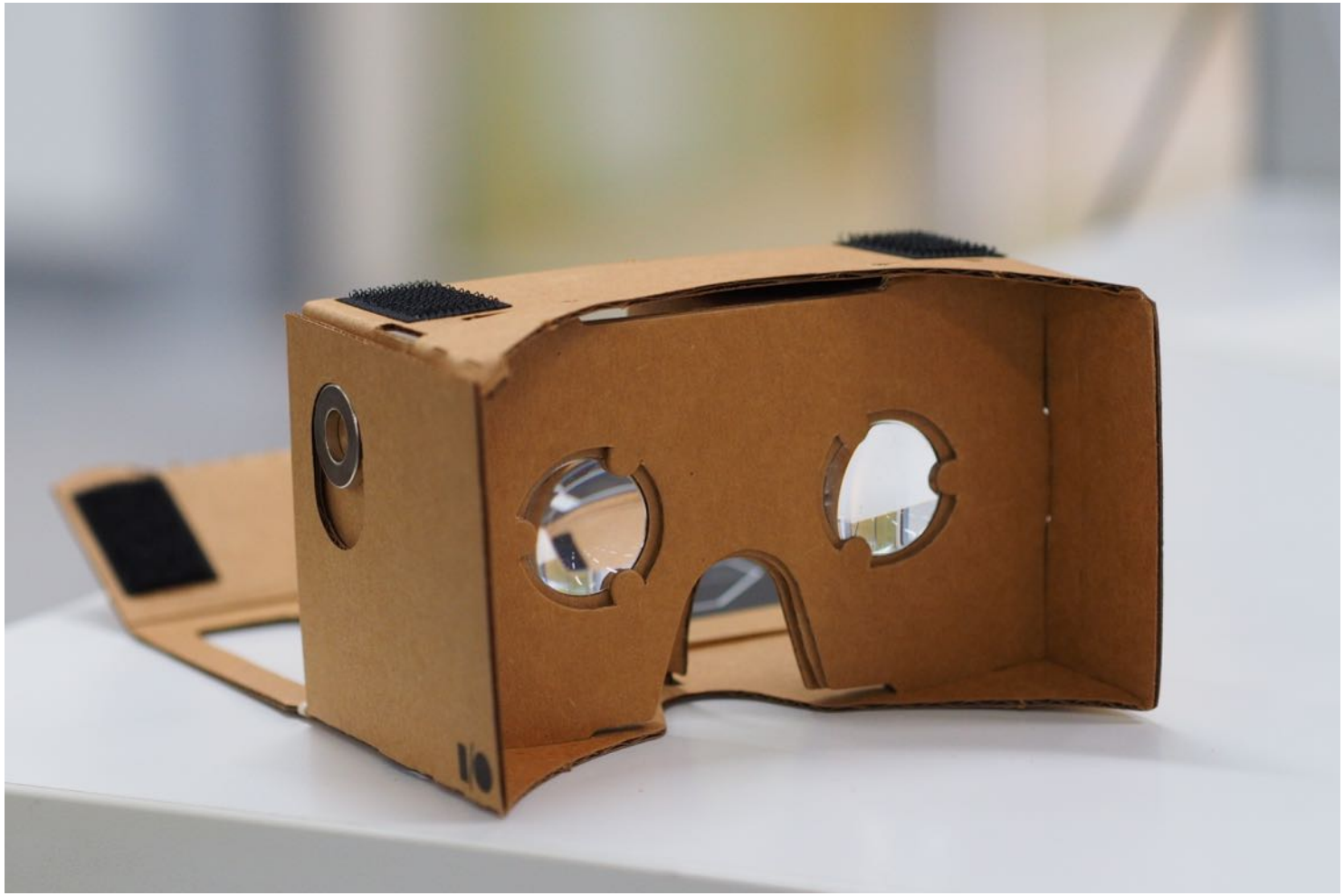
### Wheatstone (1830)




# Le "mexicain"

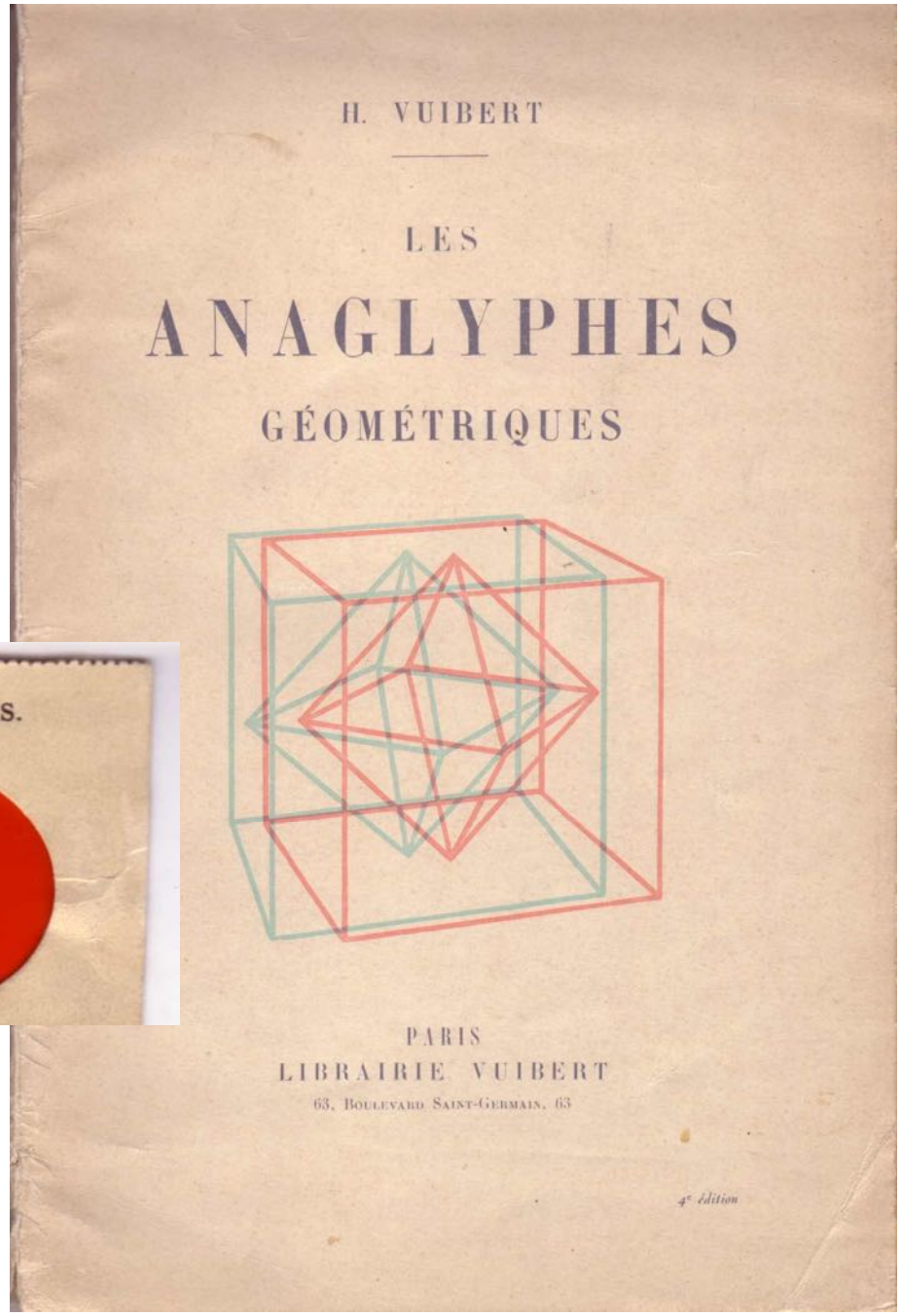
http://www.berezin.com/3d/holmes.htm (en kit 45€)

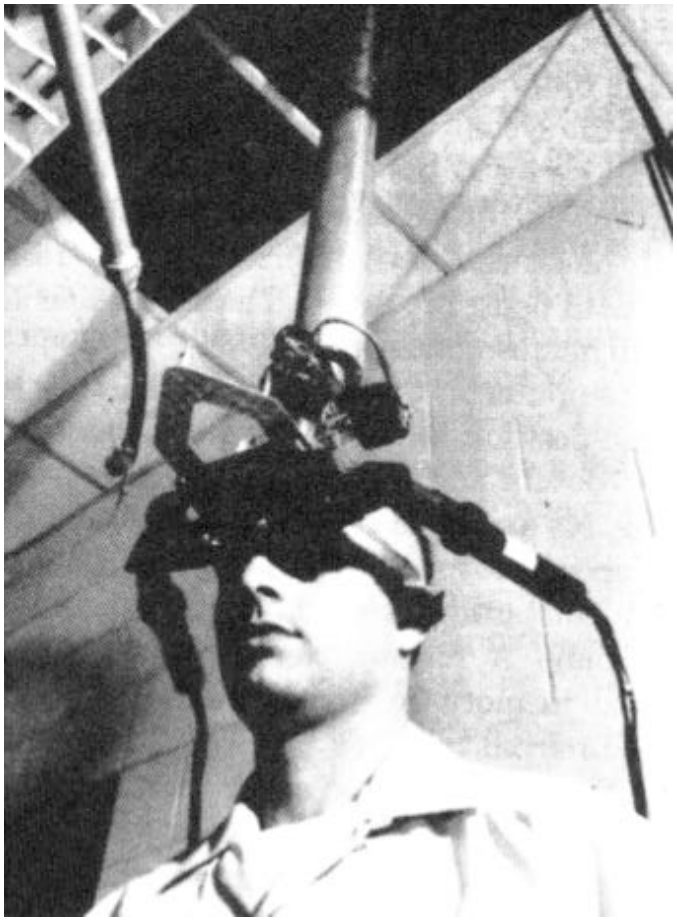
# Google cardboard

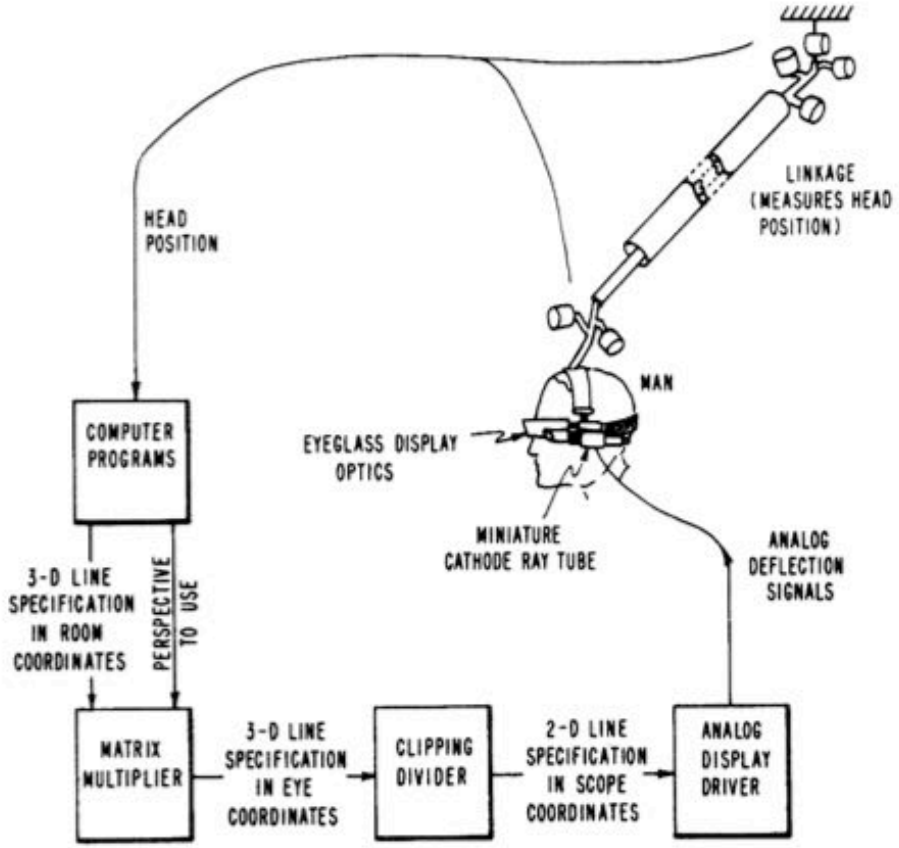


# Les anaglyphes

**d'Almeida (1858)**
**Ducos du Hauron (1891)**






# I. Sutherland (1968)

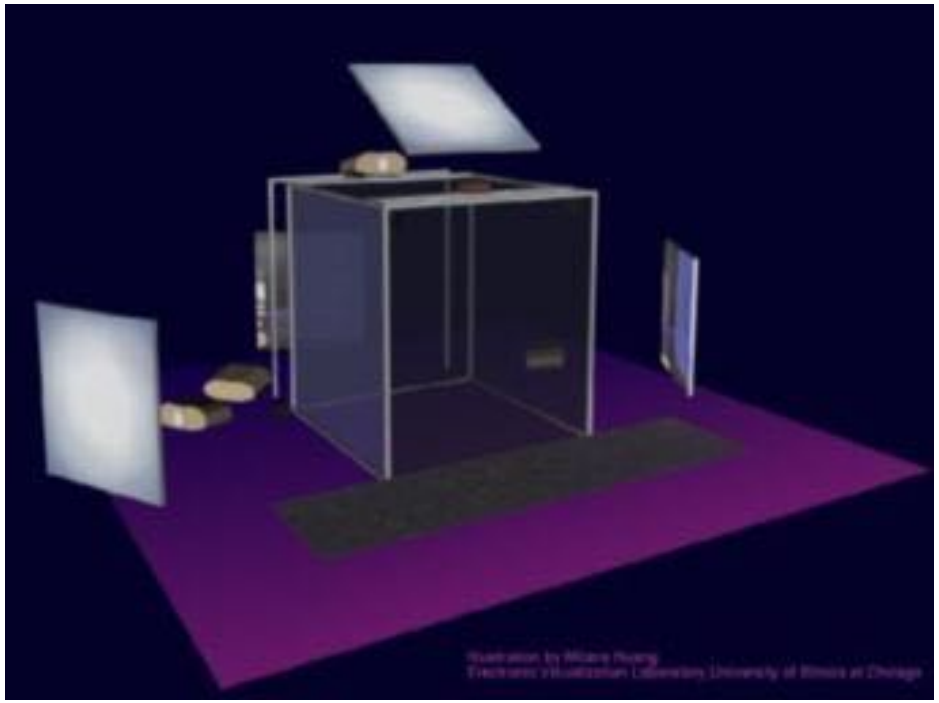
## Ivan Sutherland - The ultimate display, 1965

The ultimate display would, of course, be a room within which the computer can control the existence of matter. A chair displayed in such a room would be good enough to sit in. Handcuffs displayed in such a room would be confining, and a bullet displayed in such a room would be fatal. With appropriate programming such a display could literally be the Wonderland into which Alice walked.

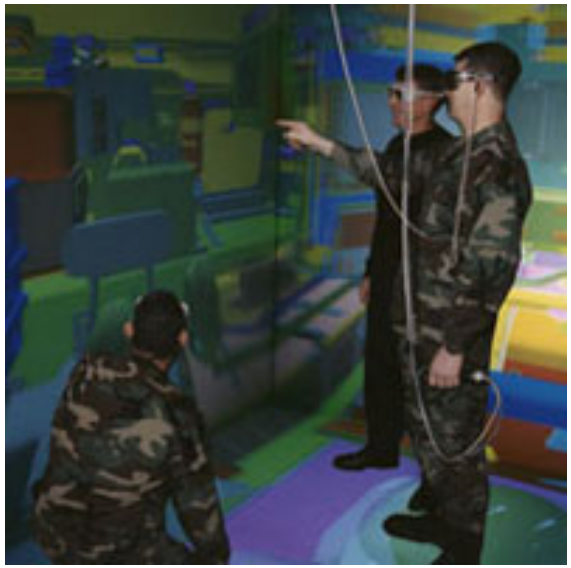
http://www.eng.utah.edu/~cs6360/Readings/UltimateDisplay.pdf

## CAVE : Univ. Illinois Chicago (1992)

Cruz-Neira,C., Sandin, D.J., DeFanti, T.A., Kenyon, R.V., and Hart, J.C. "The CAVE: Audio Visual Experience Automatic Virtual Environment," Communications of the ACM, Vol. 35, No. 6, June 1992, pp. 65-72.



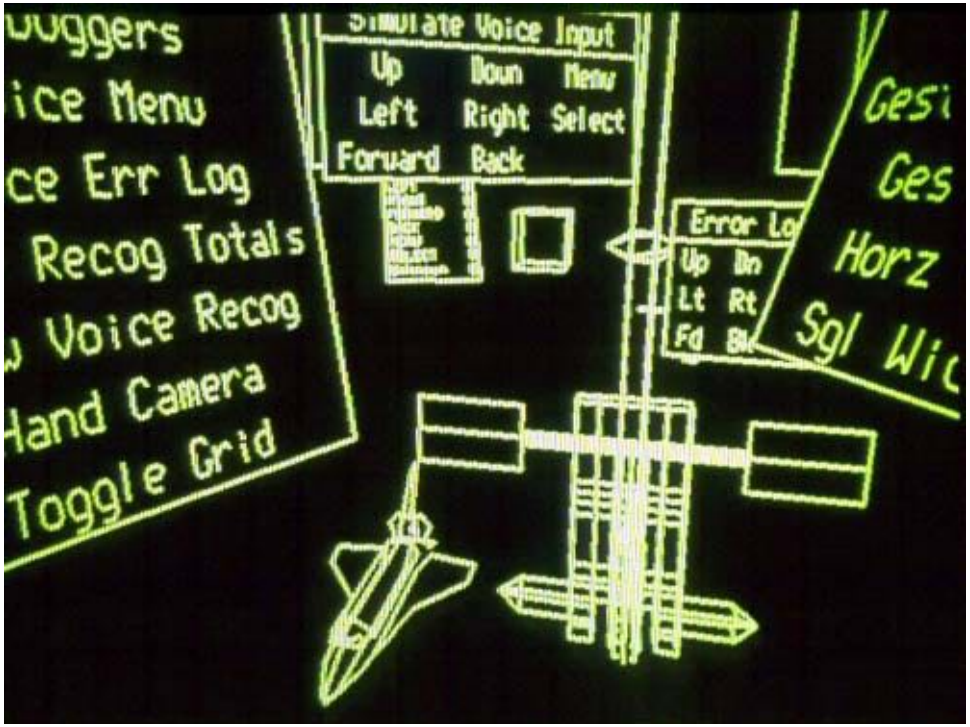
http://www.evl.uic.edu/pape/CAVE/



http://www.mechdyne.com/

16 Mpix / mur !

**La réalité virtuelle : Scott Fisher et al., Jaron Lanier (1985-7)**


http://itofisher.com/sfisher/

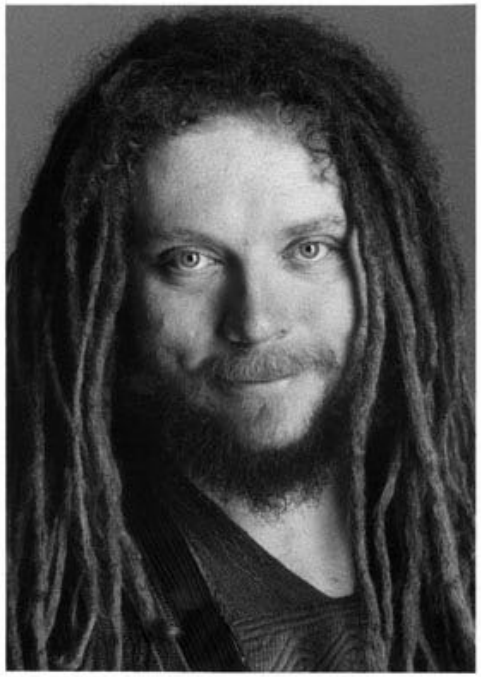
http://itofisher.com/sfisher/portfolio/files/viewlab.html

SCIENTIFIC AMERICAN

OCTOBER 1987
$2.50

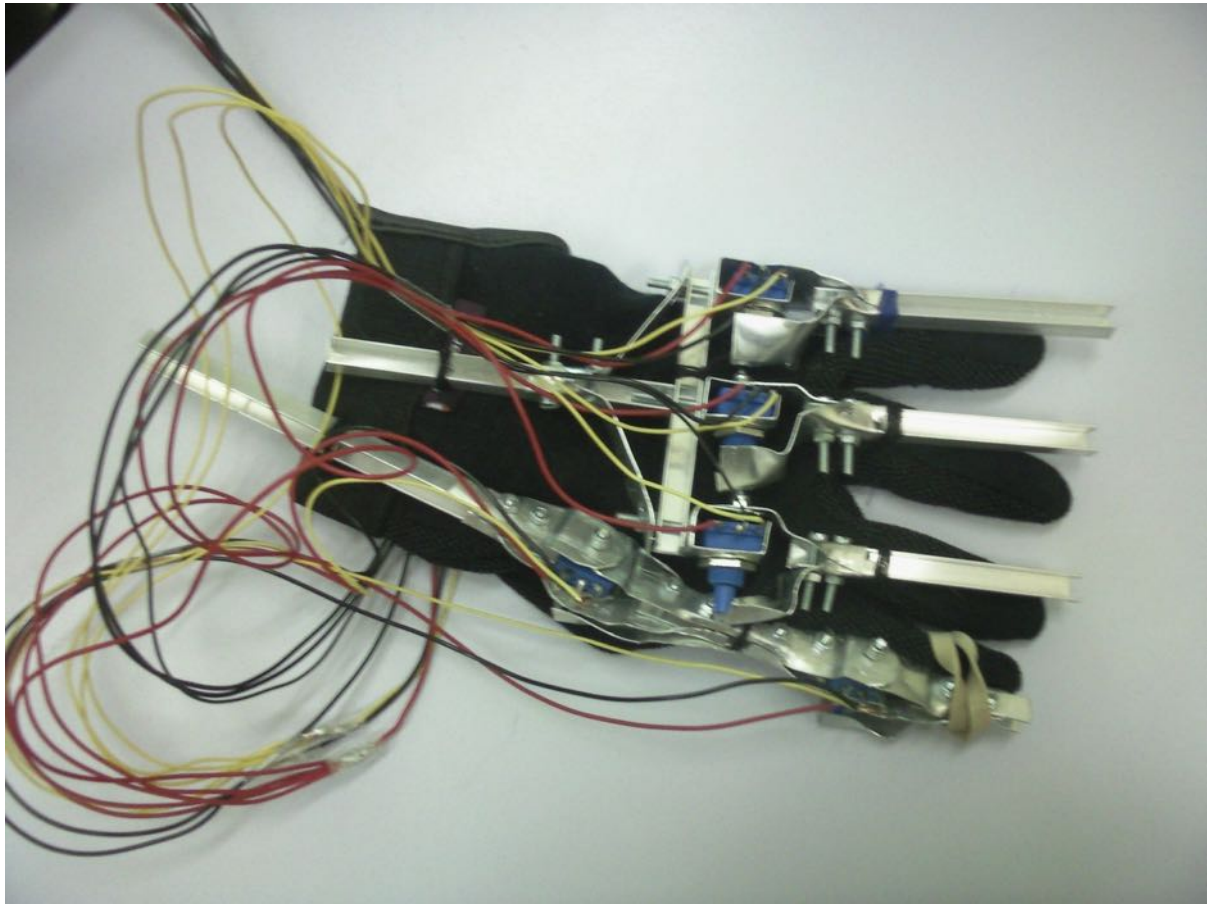
*The next revolution in computers, the subject of this issue, will see power increase tenfold in 10 years while networks and advanced interfaces transform computing into a universal intellectual utility.*

***Wired Glove** gives a computer user the sensation of handling objects on the screen; the image of the hand mimics the user's movements.*



http://www.jaronlanier.com/

A LIRE : http://www.jaronlanier.com/topeleven.html

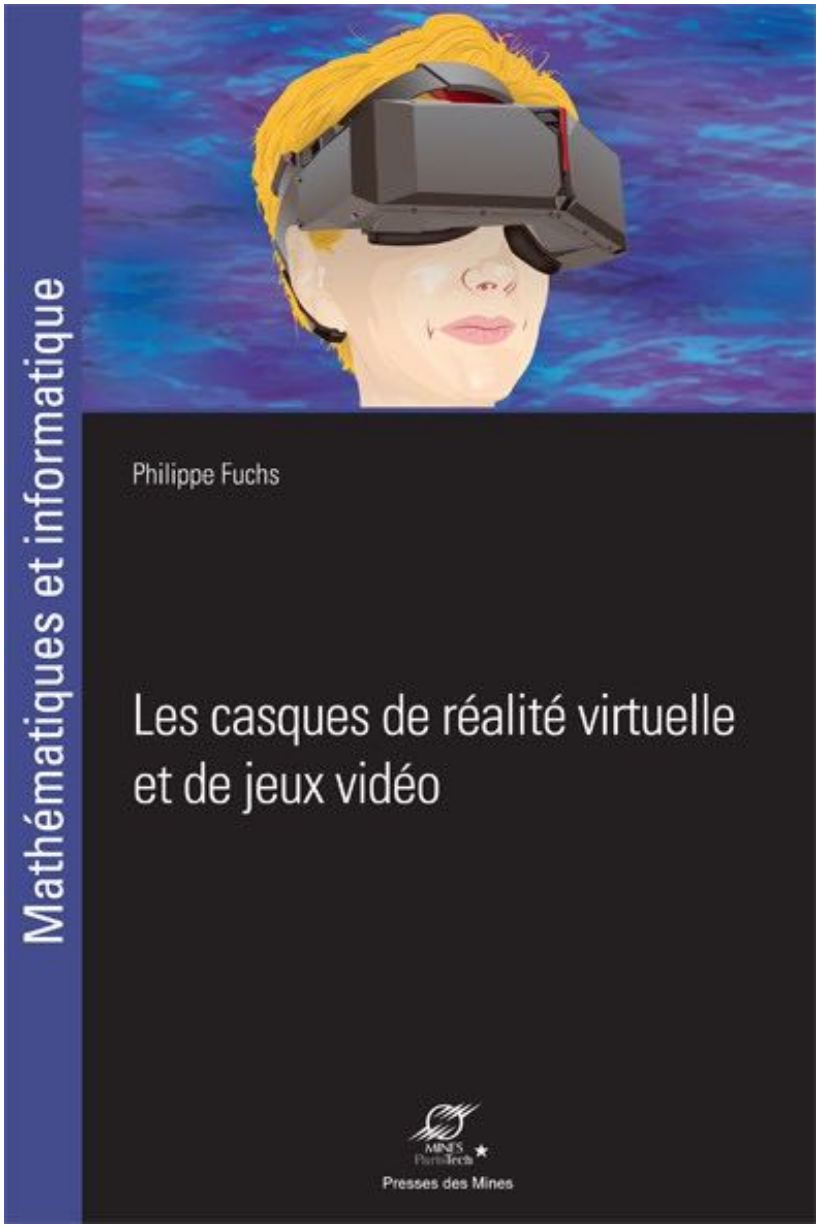


**gant de captation (élève ingénieur cnam paris, 2010)**

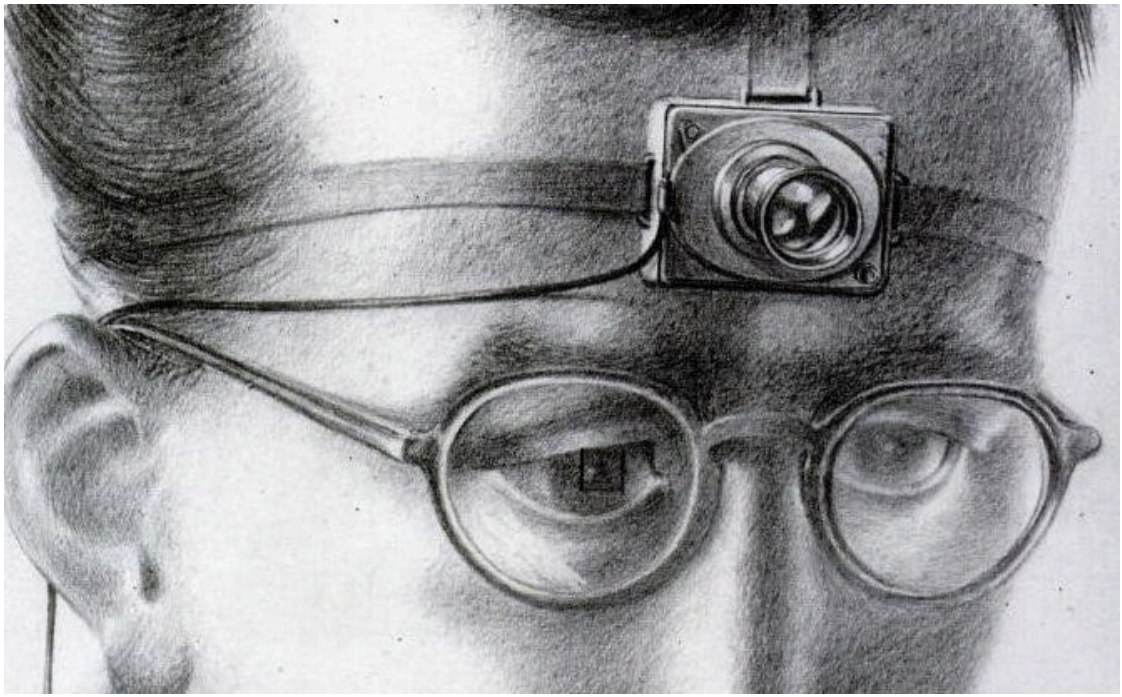
**... à suivre (cours de J. Dupire)**

paru en 2016

+ le traité de la RV
Fuchs et al.



# (4) L'augmentation



V. Bush. "As we may think" 1945

**réalité augmentée ?**

AFOSR-3223

*Summary Report*

AUGMENTING HUMAN INTELLECT: A CONCEPTUAL FRAMEWORK

*Prepared for:*

DIRECTOR OF INFORMATION SCIENCES
AIR FORCE OFFICE OF SCIENTIFIC RESEARCH
WASHINGTON 25, D.C.

CONTRACT AF 49(638)-1024

*By: D. C. Engelbart*

STANFORD RESEARCH INSTITUTE

MENLO PARK, CALIFORNIA

SRI

# D. Engelbart (1962)

# Augmenting human intellect (...)

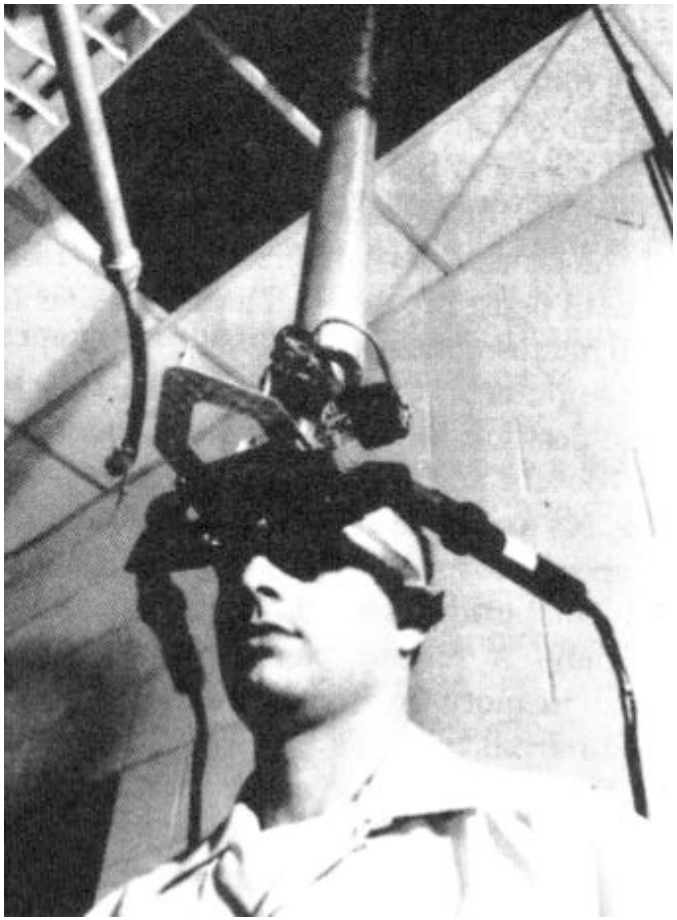

**ABSTRACT**

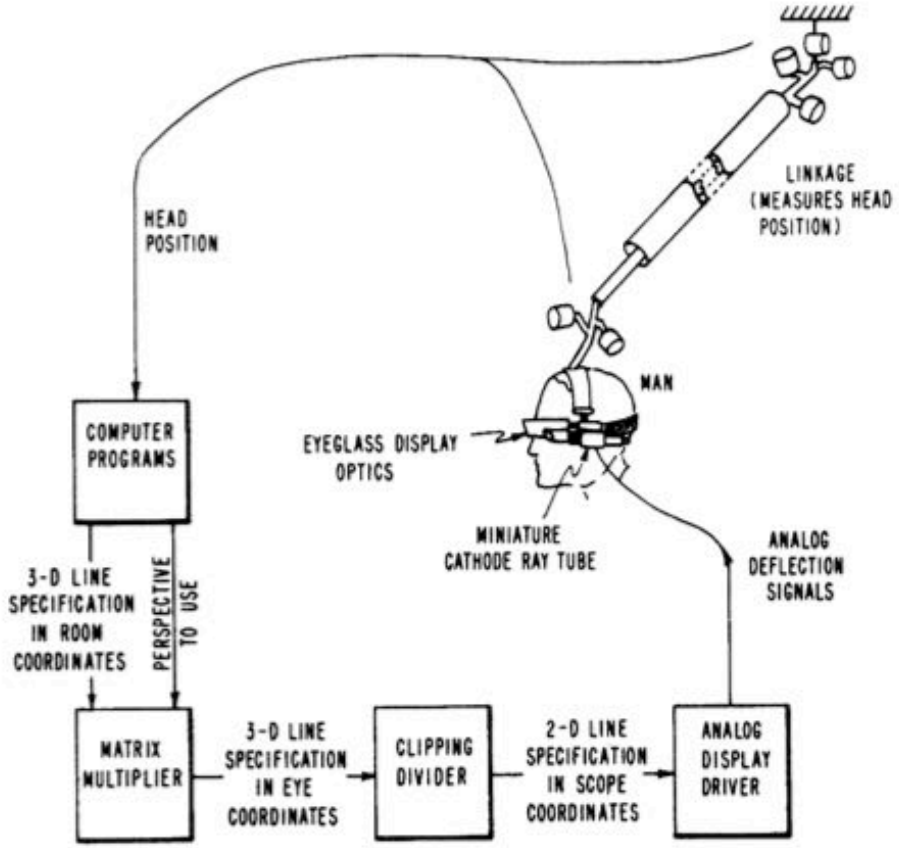
This is an initial summary report of a project taking a new and systematic approach to improving the intellectual effectiveness of the individual human being. A detailed conceptual framework explores the nature of the system composed of the individual and the tools, concepts, and methods that match his basic capabilities to his problems. One of the tools that shows the greatest immediate promise is the computer, when it can be harnessed for direct on-line assistance, integrated with new concepts and methods.

| Augment: | Approach | Technology | Applications |
|---|---|---|---|
| Users | Wear devices<br>on the body | VR helmets<br>Goggles<br>Data gloves | Medicine<br>Field service<br>Presentations |
| Physical objects | Imbed devices<br>within objects | Intelligent bricks<br>Sensors, receptors<br>GPS, electronic paper | Education<br>Office facilities<br>Positioning |
| Environment<br>surrounding objects<br>and users | Project images and<br>record remotely | Video cameras, Scanners<br>Graphics tablets<br>Bar code readers<br>Video Projectors | Office work<br>Film-making<br>Construction<br>Architecture |

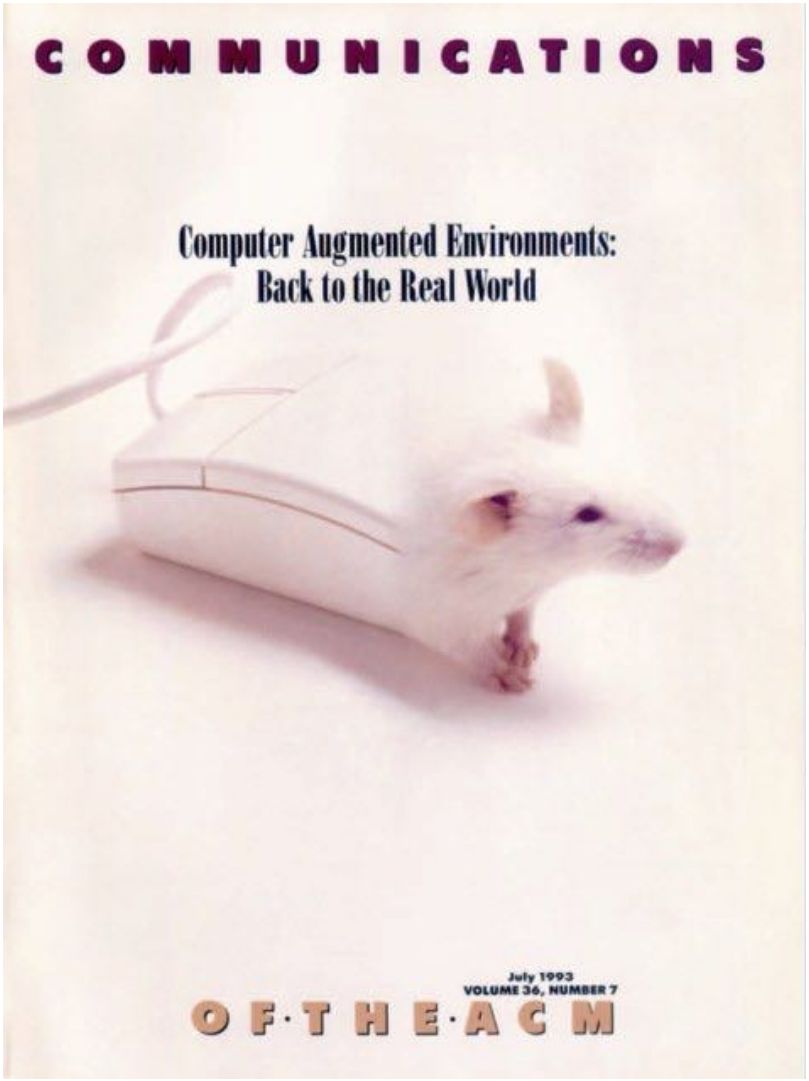
**Figure 1: Examples of augmented reality approaches, with relevant technologies and applications**

W.E. Mackay. Augmented reality : Linking real and virtual worlds. A new paradigm for interacting with computers. Proc. ACM AVI'1998

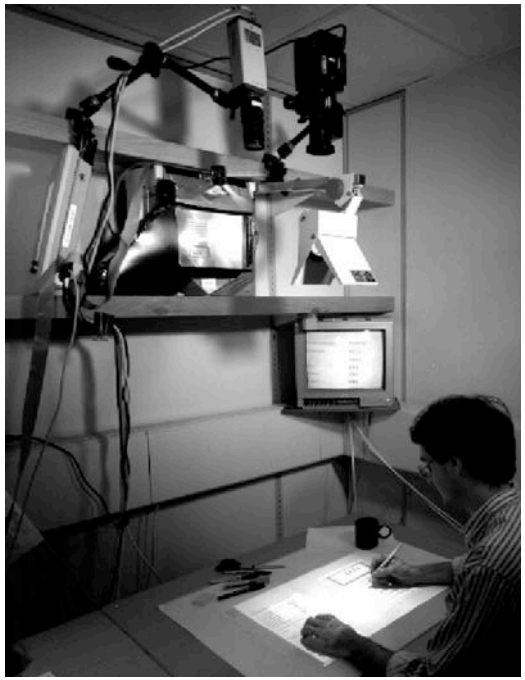





**... bis repetita**



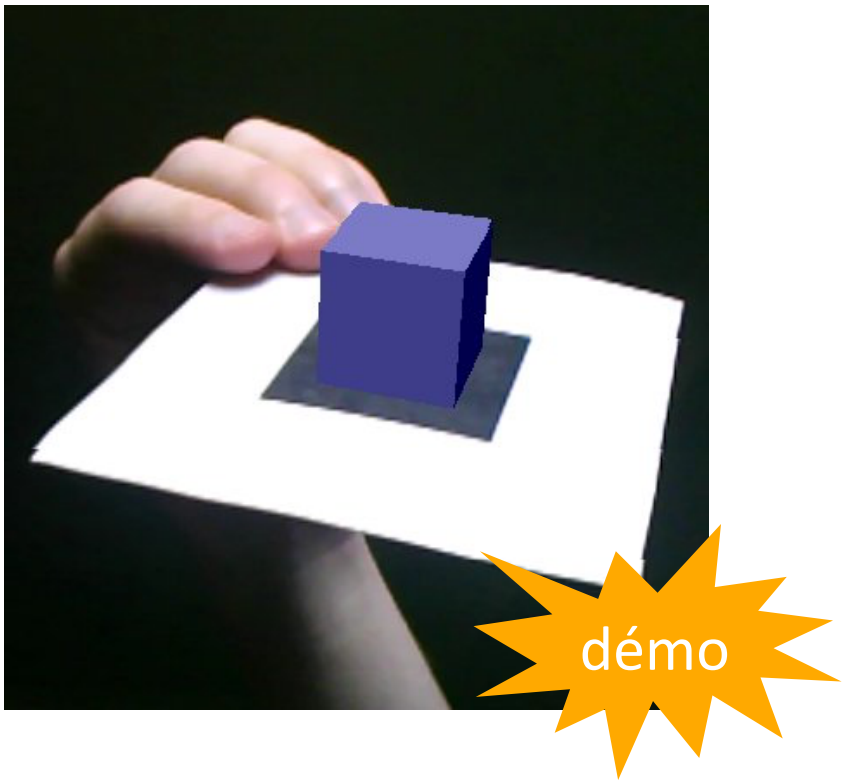

CACM July 1993



P. Wellner

W. Mackay et al.


**1997 : S. Feiner et al. : Columbia touring machine**



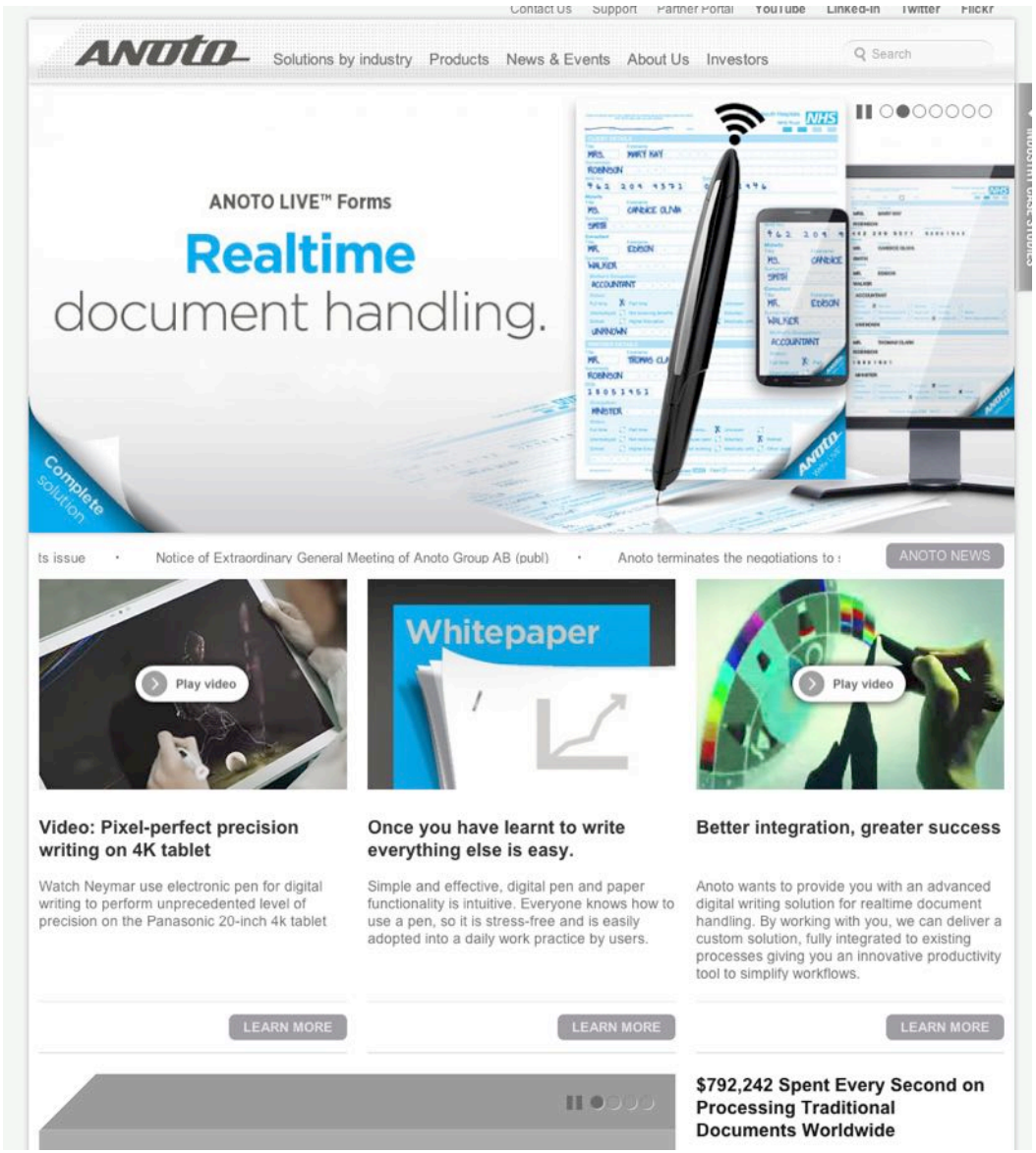

**ARToolkit**

**H. Kato + U. Washington + U. Canterbury, >1999**

couplage restitution stéreo et captation des mouvements

utilisation d'AR toolkit pour la captation


# Le stylo Anoto et les cahiers augmentés

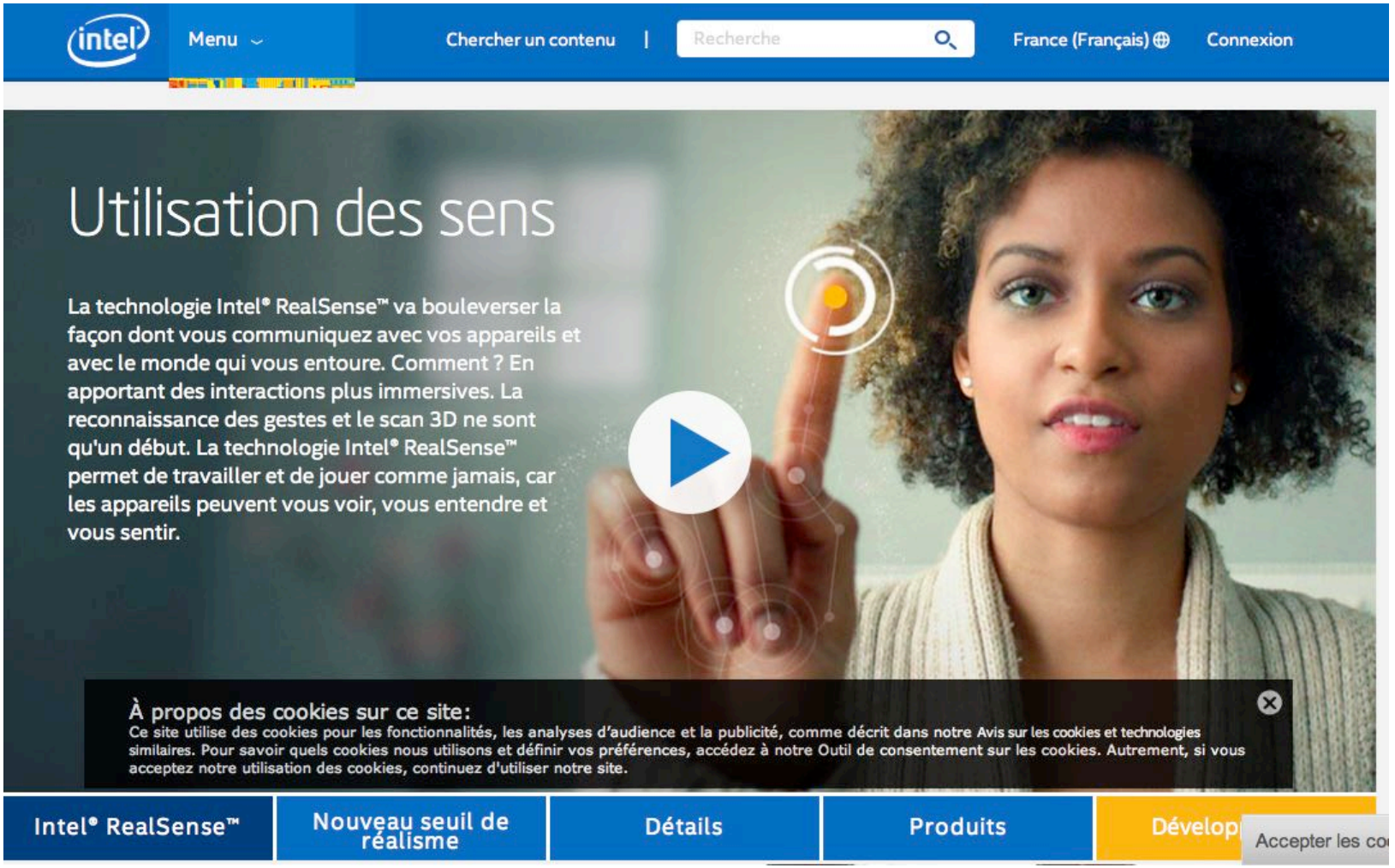


# 2014 : Google Glass

+ Aura (Optivent)
+ SpaceGlasses (Meta)
+ ReconJet (ReconInstrument)
+ Wrap 1200 DXAR (Vuzix)


nov. 2013

# Intel "RealSense » en 2014




http://www.intel.fr/content/www/fr/fr/architecture-and-technology/realsense-overview.html

# en 2016 : les premiers produits

# Introducing Intel® RealSense™ Smartphone Developer Kit

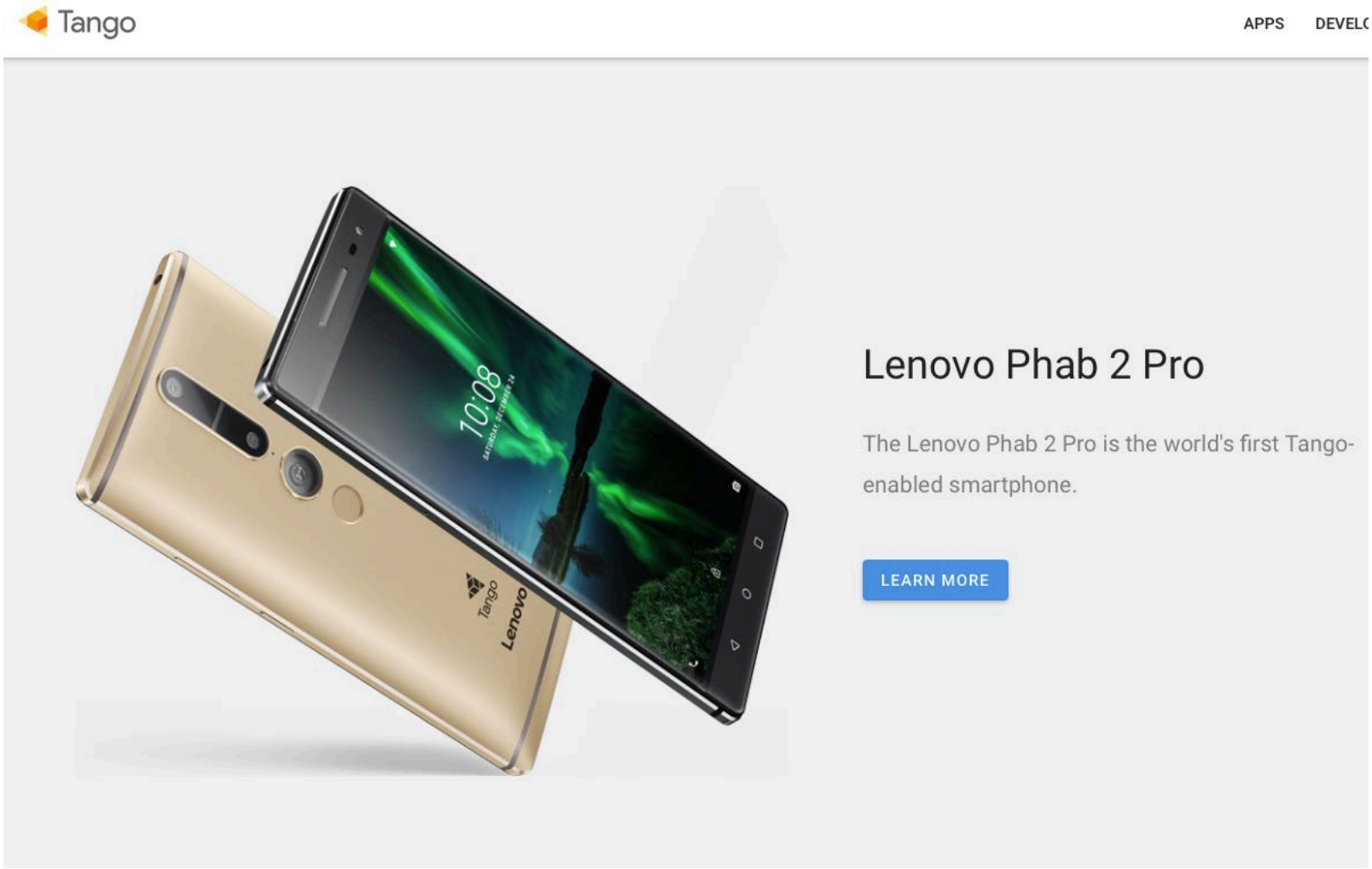
By Miao W. (Intel), Added February 22, 2016 Translate





During CES 2016 in Las Vegas in January, Intel announced the Intel RealSense Smartphone Developer Kit (SDK), an Android device with embedded Intel® RealSense™ Camera ZR300 and supports Google* Project Tango* developer ecosystem. Currently the developer kit is open for reservation.

The Intel® RealSense™ Smartphone Developer Kit is powered by the Intel® Atom™ x7-Z8700 SoC (formerly Cherry Trail), which features the 14nm Intel Architecture technology with 4 Cores / 4 Threads and Gen 8 Intel® HD Graphics, and the industry-leading Intel® RealSense™ Camera ZR300. The Developer Kit includes a 6" QHD (2560x1440) display. The device comes with 2GB of memory and 64GB of internal storage. It includes an 8MP rear camera and a 2MP front-facing camera. Figure 1 and Figure 2 show the front and back views of the Developer Kit, respectively.



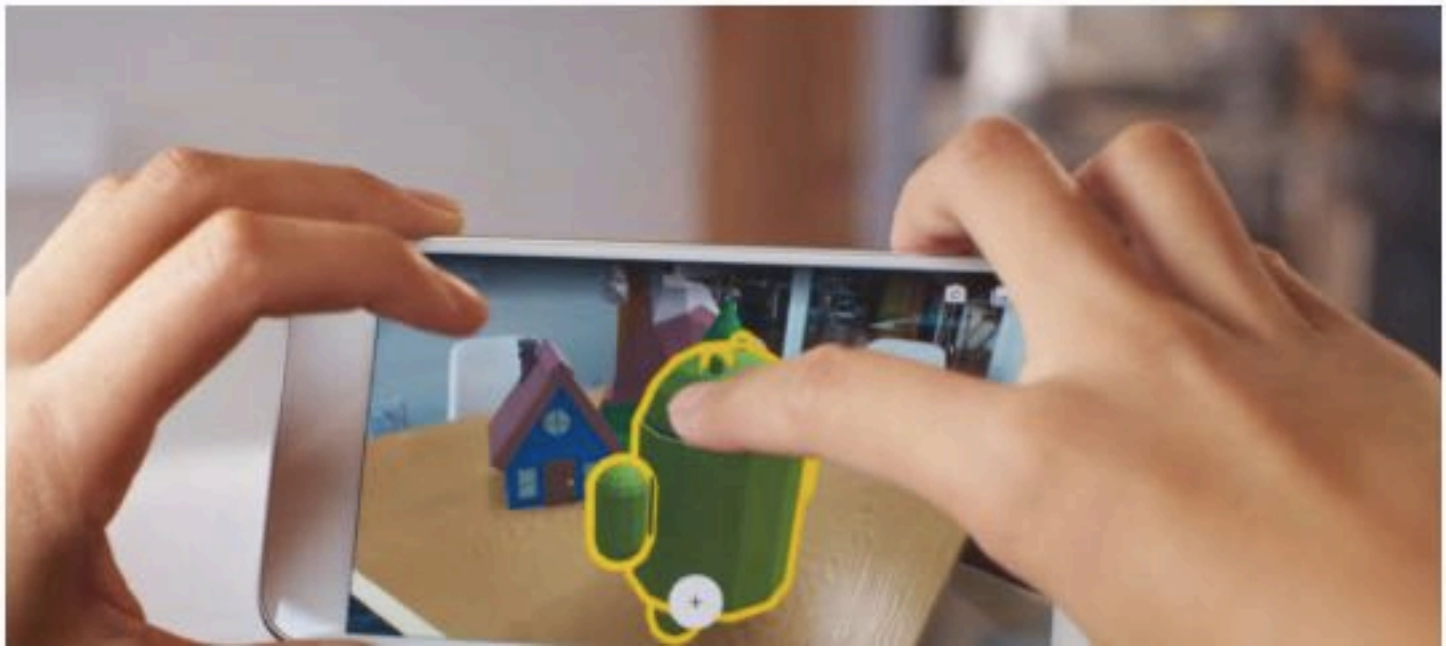

http:// get.google.com/tango/

# [Réalité augmentée] En réponse à Apple, Google annonce ARCore et arrête Tango

*JULIEN BERGOUNHOUX* | RÉALITÉ AUGMENTÉE, GOOGLE, SMARTPHONE |
PUBLIÉ LE 30 AOÛT 2017 À 11H12

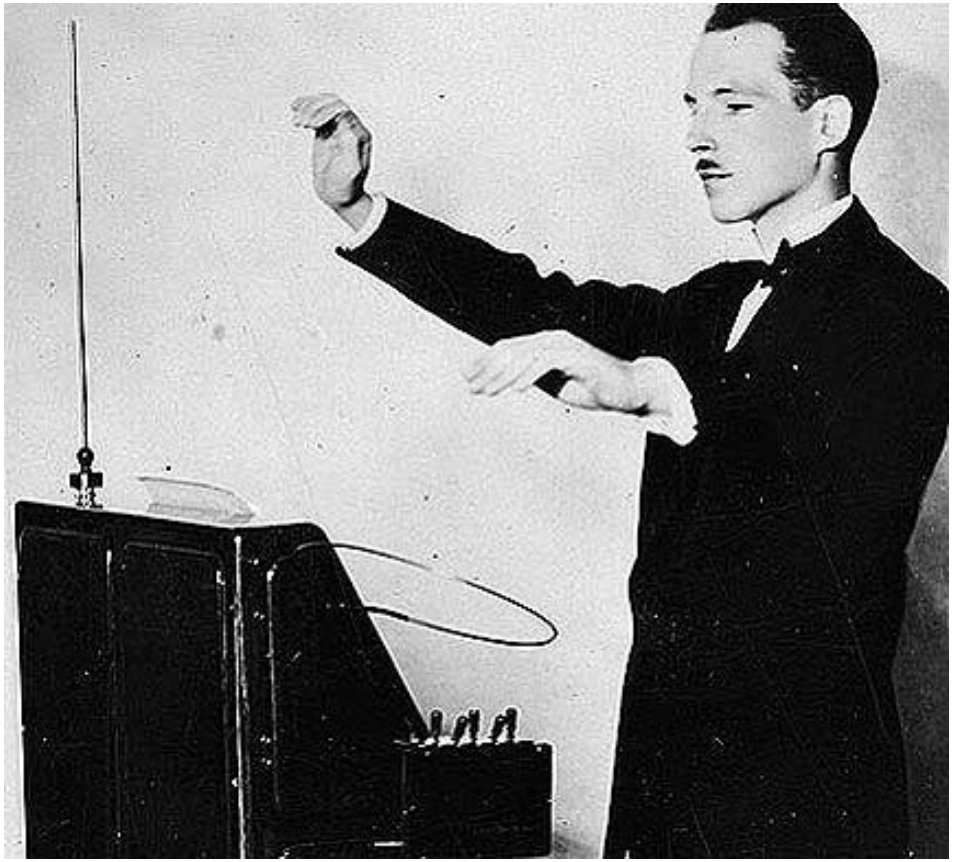


VIDÉO ANALYSE A deux semaines de la sortie des premières applications en réalité augmentée sur iPhone, Google annonce ARCore, un kit de développement logiciel pour démocratiser la réalité augmentée sur Android. La plate-forme Tango, sur laquelle il travaillait depuis 3 ans, est abandonnée au profit de cette nouvelle approche. Un changement de stratégie brutal forcé par la perspective de millions d'iPhone compatibles avec ARKit, alors que les ventes smartphones embarquant Tango ne se comptaient qu'en milliers.



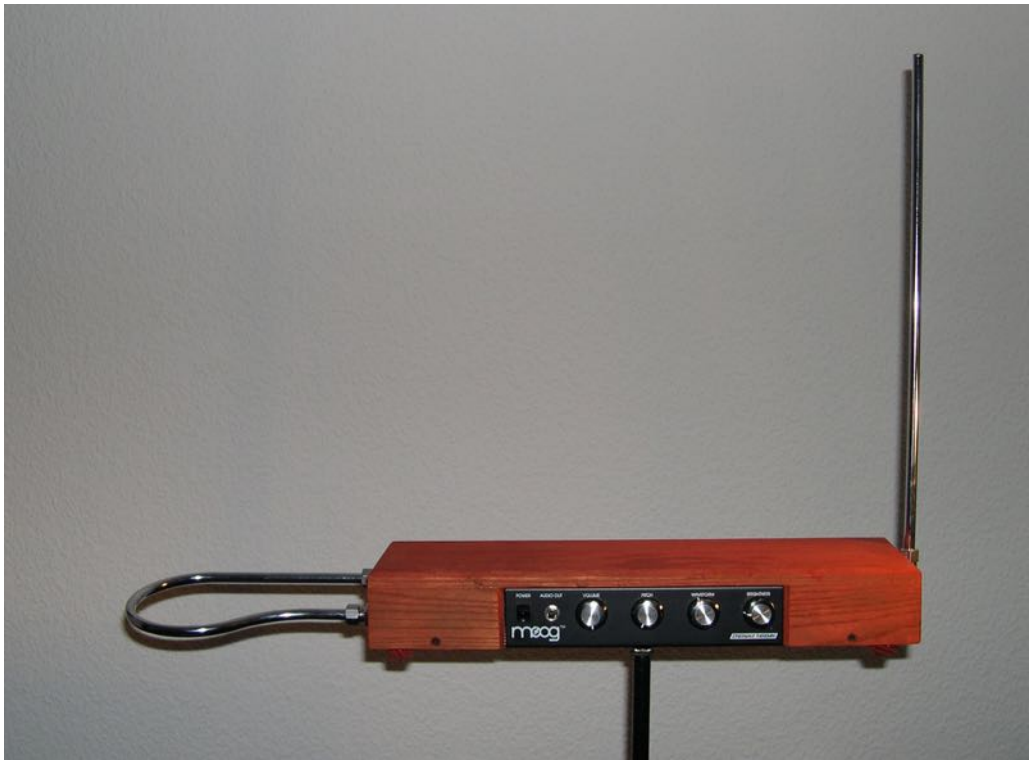

AR

# (5) Les objets malins



Theremine (1917)

# (existe encore : ex. de Moog)



# "Physical computing" ?

Physical computing
From Wikipedia, the free encyclopedia
• *Have questions?*
Find out how to ask questions and get answers. •Jump to: navigation, search

**Physical computing**, in the broadest sense, means building interactive physical systems by the use of software and hardware that can sense and respond to the analog world. While this definition is broad enough to encompass things such as smart automotive traffic control systems or factory automation processes, it is not commonly used to describe them. In the broad sense, physical computing is a creative framework for understanding human beings' relationship to the digital world. In practical use, the term most often describes handmade art, design or DIY hobby projects that use sensors and microcontrollers to translate analog input to a software system, and/or control electro-mechanical devices such as motors, servos, lighting or other hardware.

(Greenberg, UIST'01)

**INTRODUCTION**

In the last decade, various movements embraced human-computer interface designs that include physical user interfaces augmented by computing power. These include *ubiquitous computing* and *calm technology* [15], *pervasive computing* [1], *tangible user interfaces* [7], *information appliances* [12] and *context-aware computing* [3].

Researchers in these areas have demonstrated many simple but exciting examples of physical user interfaces. Ishii and

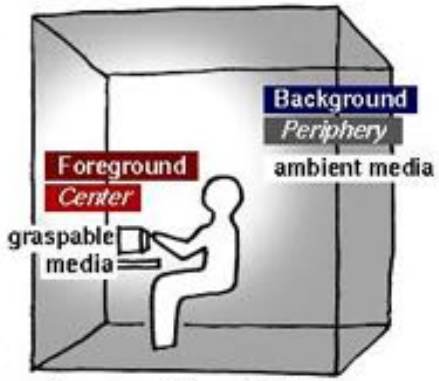
Physical Computing is an approach to learning how humans communicate through computers that starts by considering how humans express themselves physically. In this course, we take the human body as a given, and attempt to design computing applications within the limits of its expression.

(Interactive Telecom. Program ITP NYU)

# Les interfaces tangibles

**Tangible Bits** is our vision of Human Computer Interaction (HCI) which guides our research in the Tangible Media Group. People have developed sophisticated skills for sensing and manipulating our physical environments. However, most of these skills are not employed by traditional GUI (Graphical User Interface). Tangible Bits seeks to build upon these skills by giving physical form to digital information, seamlessly coupling the dual worlds of bits and atoms.

Guided by the Tangible Bits vision, we are designing "tangible user interfaces" which employ physical objects, surfaces, and spaces as tangible embodiments of digital information. These include foreground interactions with graspable objects and augmented surfaces, exploiting the human senses of touch and kinesthesia. We are also exploring background information displays which use "ambient media" -- ambient light, sound, airflow, and water movement. Here, we seek to communicate digitally-mediated senses of activity and presence at the periphery of human awareness. The goal is to change the "painted bits" of GUIs (Graphical User Interfaces) to "tangible bits," taking advantage of the richness of multimodal human senses and skills developed through our lifetime of interaction with the physical world.

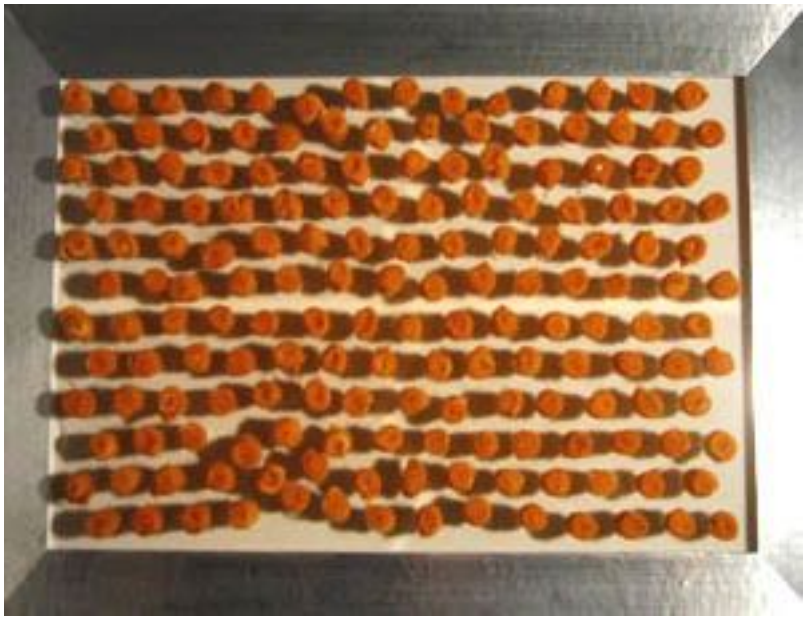


*drawing: Hiroshi Ishii*

Tangible Bits full paper presented at CHI 97

Prof. Hiroshi ISHII http://web.media.mit.edu/~ishii/

Ex. de projet de l'équipe : super cilia skin



# Les « phidgets » (S. Greenberg, C. Fitchett, U. Calgary, 2001)

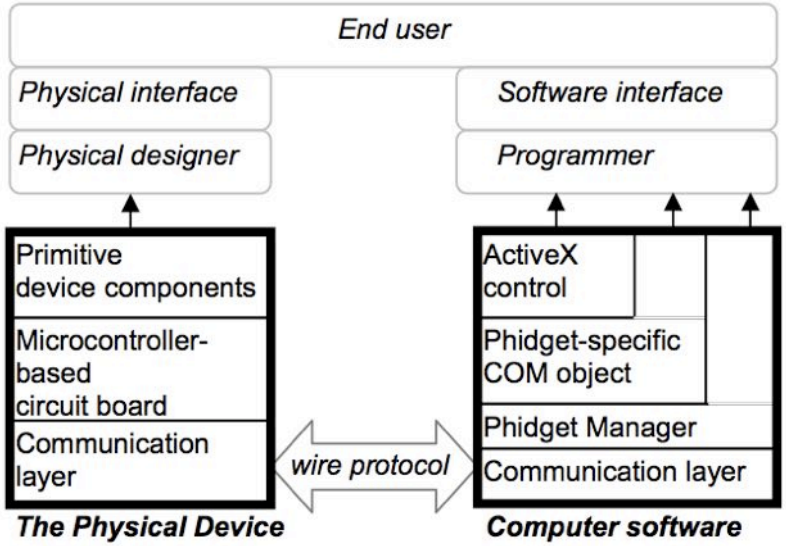
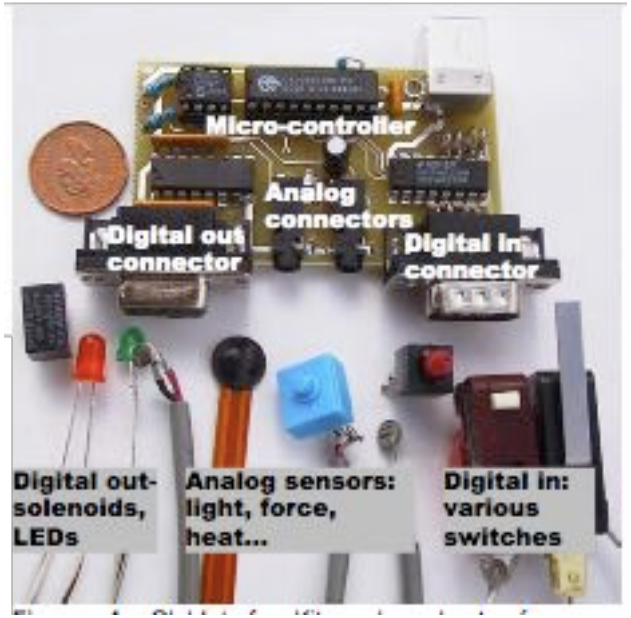
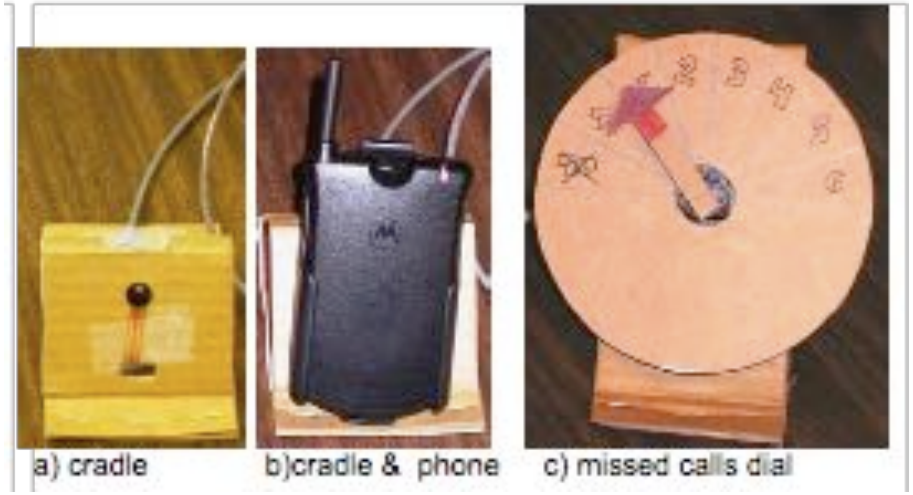



**Figure 5.** Phidget Architecture



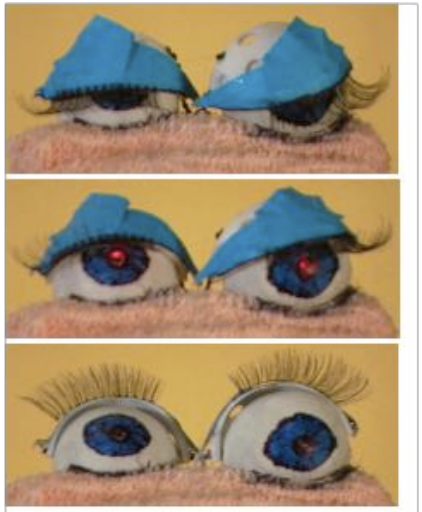
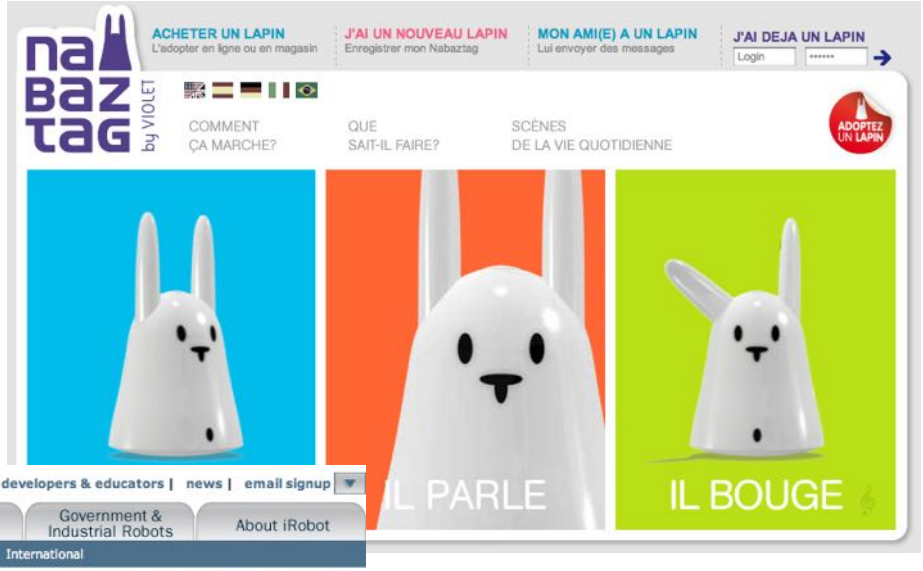
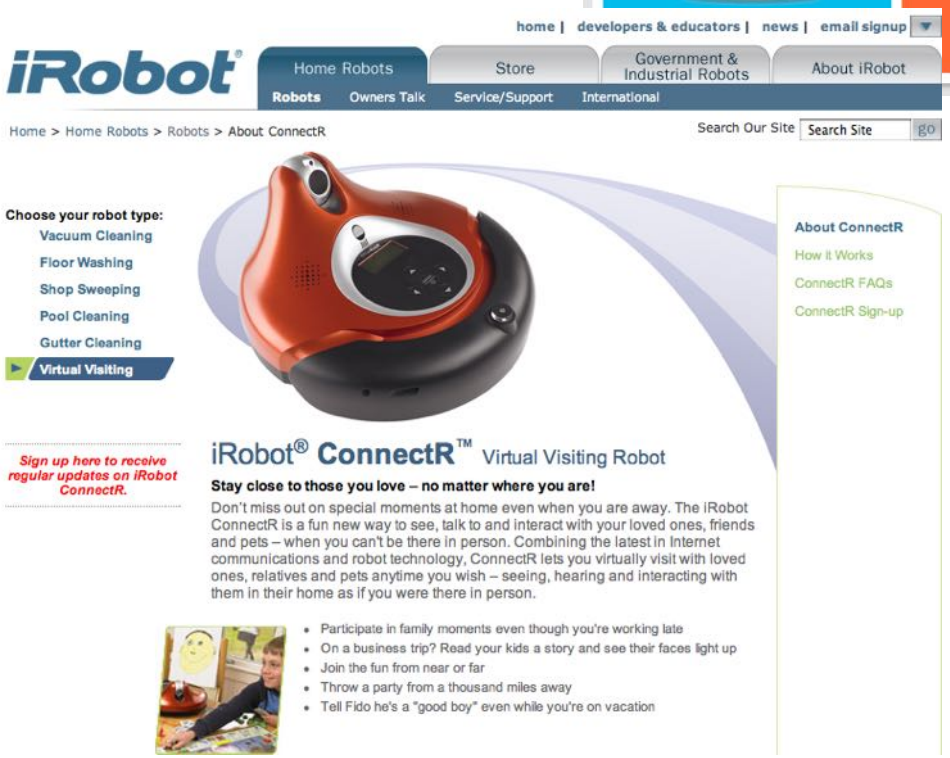



**Figure 11: Phidget Eyes:** closed, open & lit, fully open

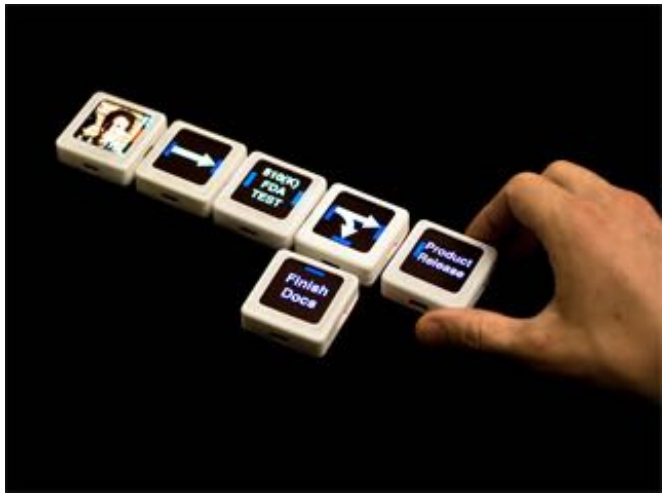
# Deja une industrie

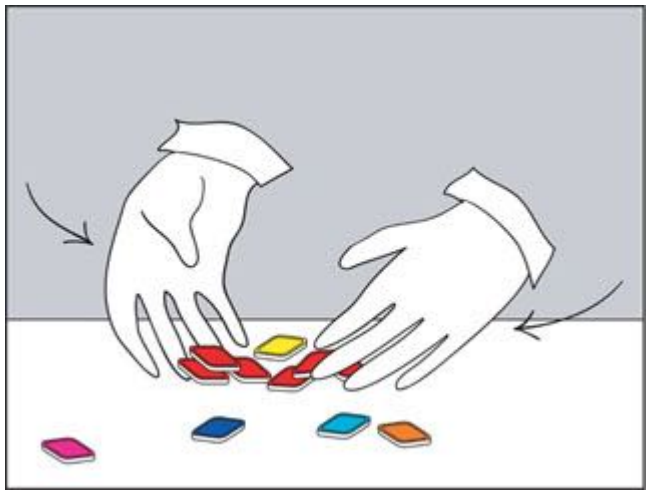


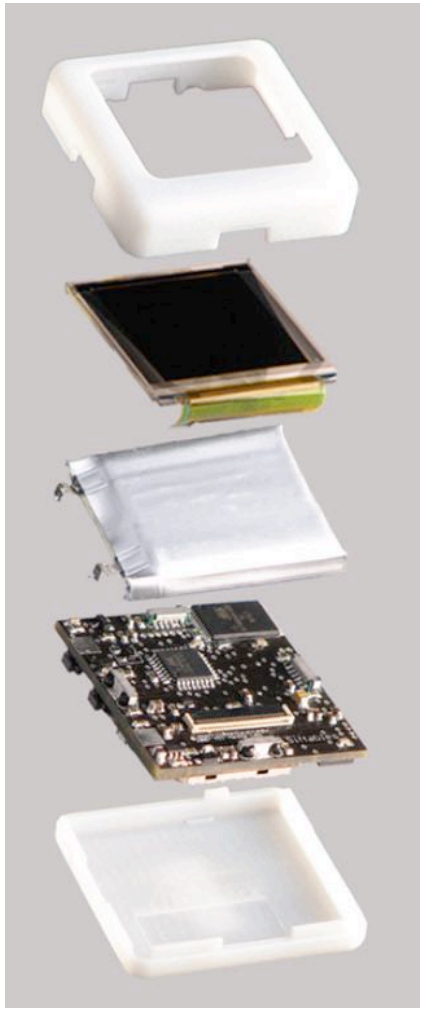




skyscout

# Le projet « siftables » (David Merril, MIT, 2007)





http://web.media.mit.edu/~dmerrill/siftables.html

LOGIN CART

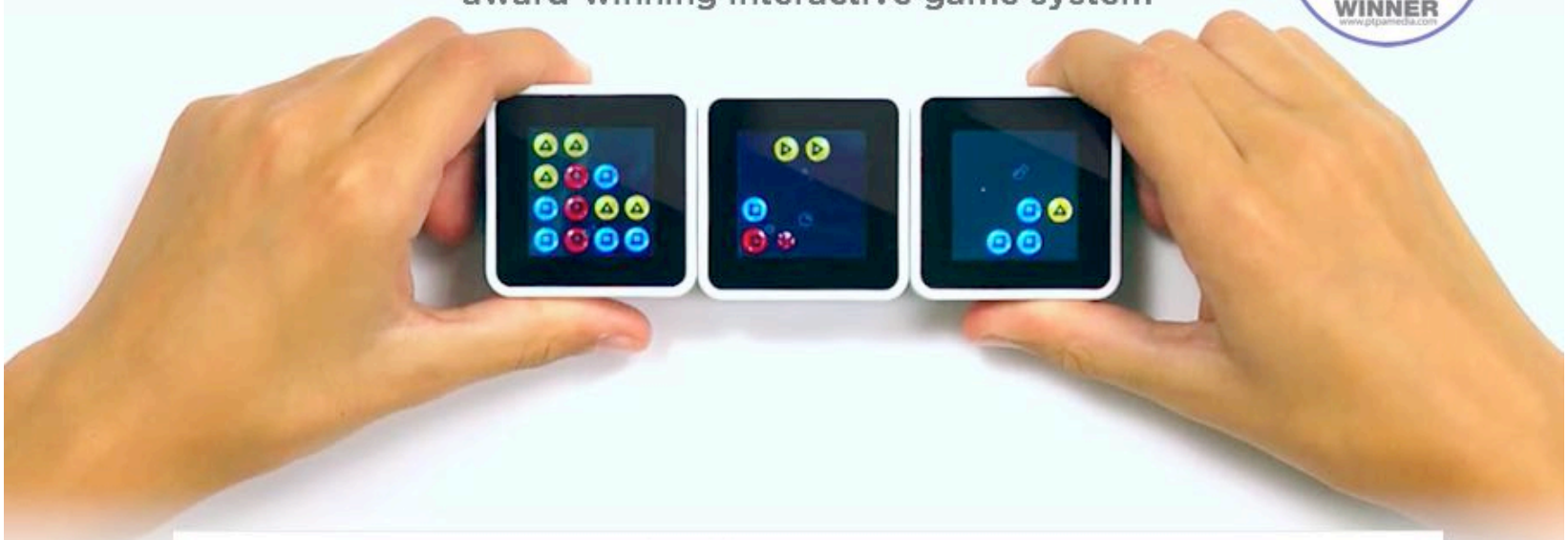
sifteo

Sifteo Cubes | Intelligent Play | Games | About Us | Press | Shop

# Sifteo Cubes

award-winning interactive game system

parent tested parent approved WINNER



thought possible." — San Francisco Chronicle — "a clever new way for childre


projet "fat and furious" Master ENJMIN 2013

sifteo ♥ 3D Robotics

# So long, thank you, we're still here

We'll cut to the chase: Sifteo has been acquired by 3D Robotics! We're really excited about it; we will continue to support Sifteo Cubes and Sifteo users; and we are so grateful to our customers and supporters around the world. *Thank you.*

*handbuilt prototypes from our MIT days*

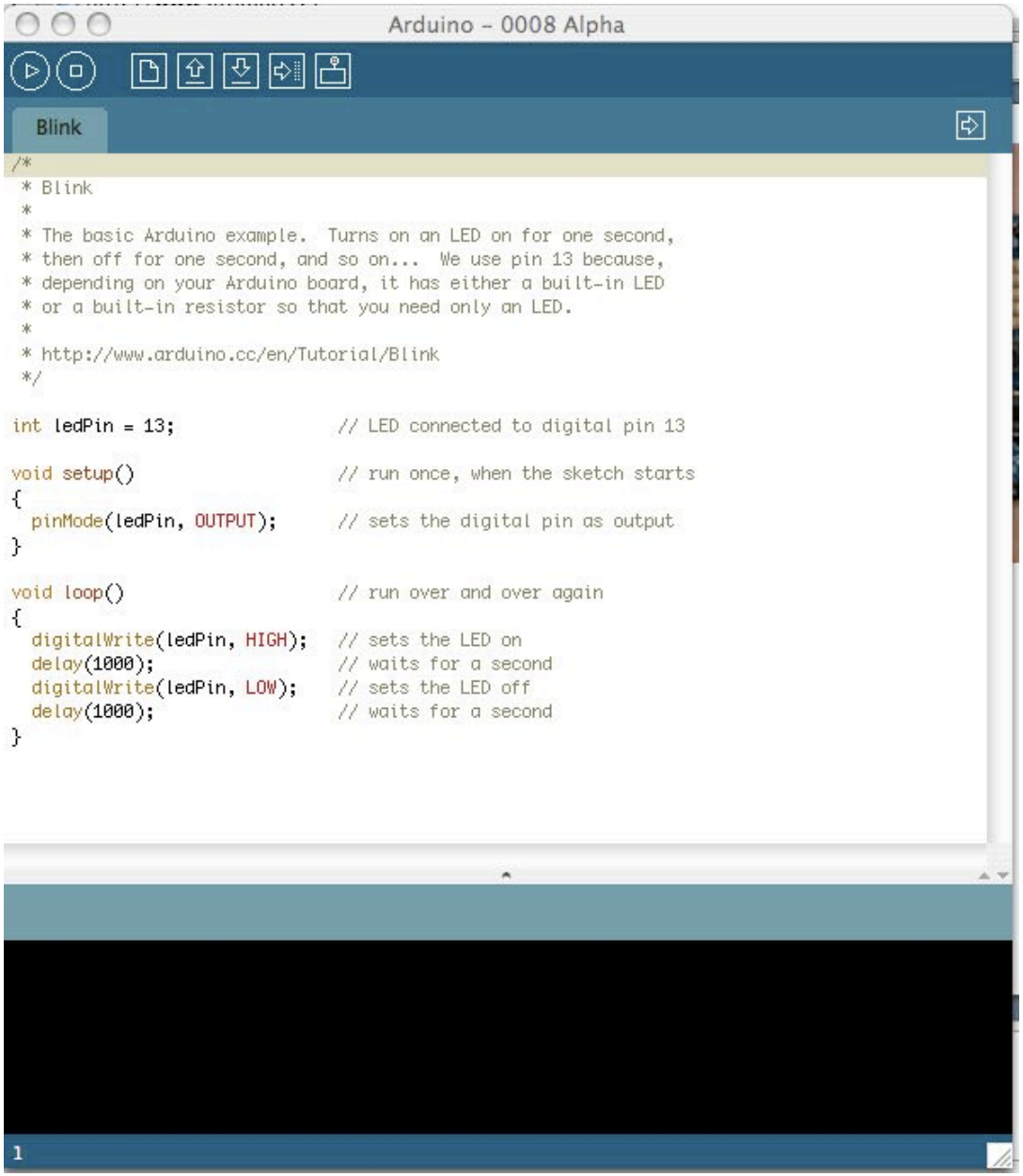
When we (Dave and Jeevan) started Sifteo in 2009, we knew we could deliver magical versions of everyday objects - that we could use the latest in computing and sensors to create new interactions that were more natural, more human, and just better than what currently existed.

### zooids

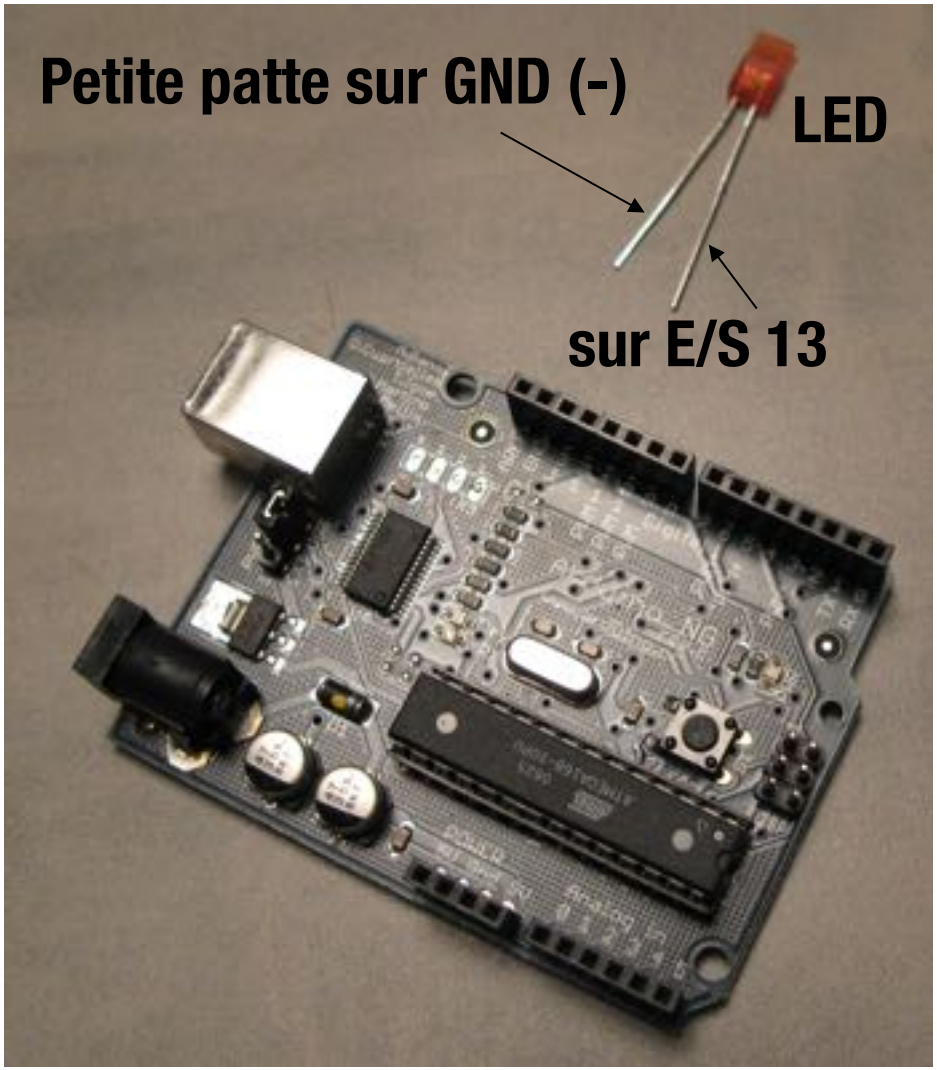
# La carte ARDUINO

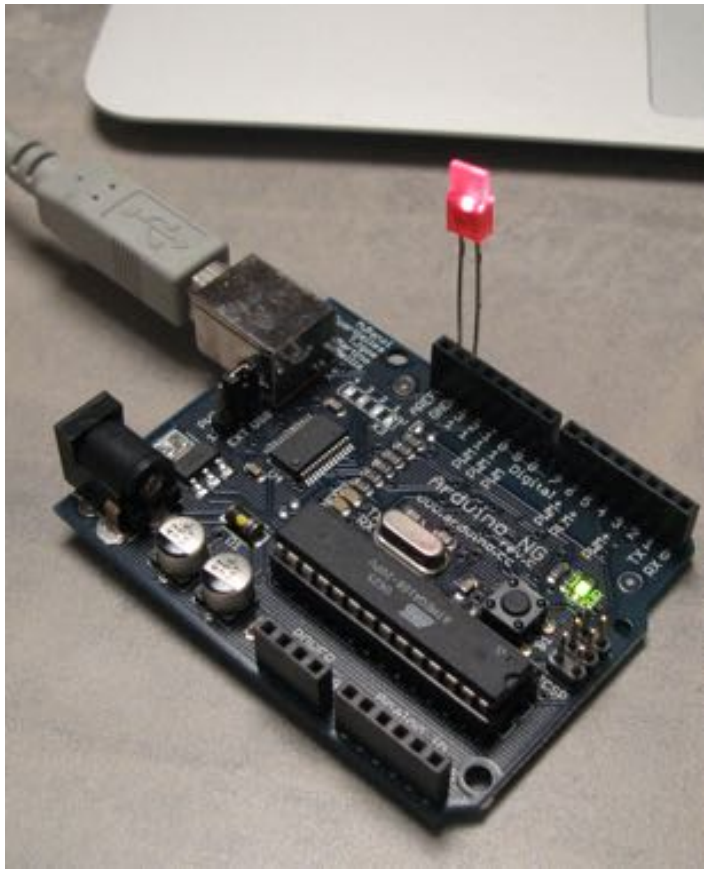

(Science et vie junior - février 2012)

# « blink » : le Hello world de l'Arduino



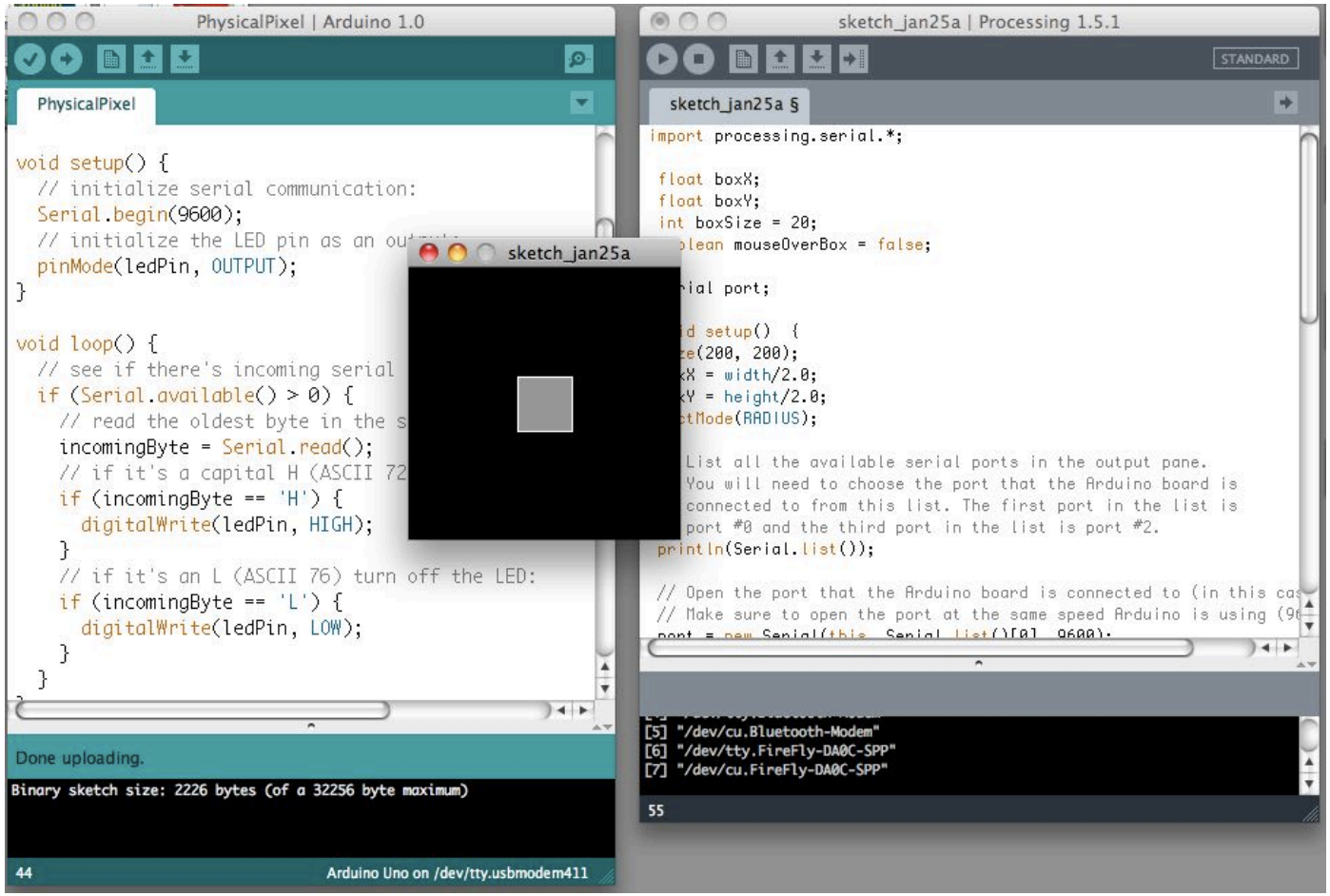
# Blink : le montage



Fiat lux …

# Dialogue avec une application processing (liaison série) : La demo "physical pixel" de exemples->communication




=> à suivre cours de J. Dupire