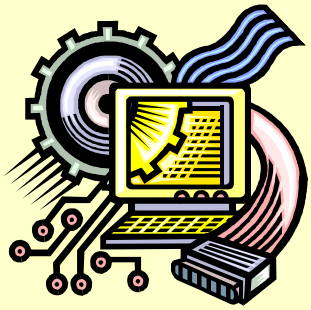
Presented at ACM UIST 2004, Invited Survey, by Saul Greenberg
Note that this includes only a portion of the presentation.
-almost all examples included here were demonstrated by videos.
-a live demonstration of coding and running phidgets was also included.

Finally, images copied from other sources are attributed on the bottom of the relevant slide.

Physical User Interfaces

What they are and how to build them

Saul Greenberg
University of Calgary



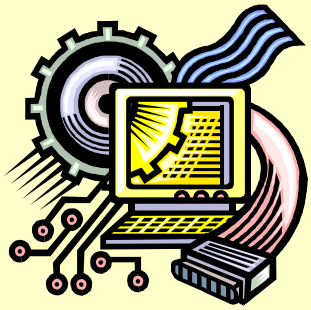
New disciplines and genres of computing

- ubiquitous computing
- pervasive computing
- context-aware computing
- mixed / augmented reality
- attentive user interfaces
- wearable computing
- sensor networks
- information appliances
- tangible user interfaces
- alternative input and output devices
- cooperative buildings
- smart homes
- smart furniture / cloth
- consumer robotics ...

Goals

You will know

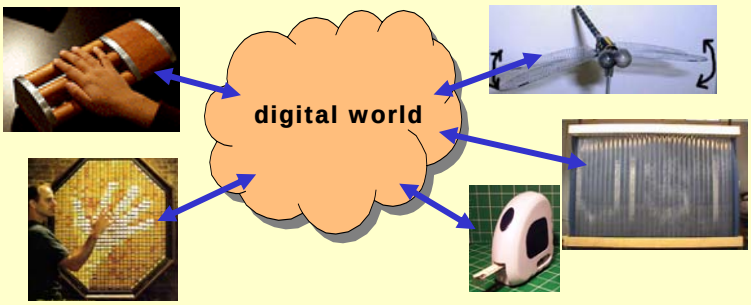
- various genres and opportunities of physical user interfaces
- basic hardware building blocks available to you
- how to get started building your own physical user interfaces



Physical User Interfaces - Scope

Computer-controlled interactive physical devices situated in a real-world setting

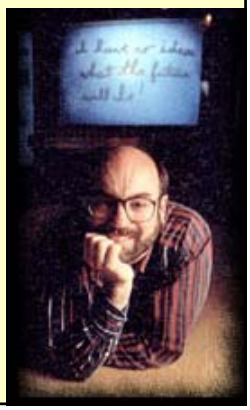
- **appliance-like**: designed for particular context and uses
- **composition**: microcontroller, actuators, sensors, motors…
- **connectivity**: with digital computers and information



Mark Weiser *Xerox Parc*

Ubiquitous Computing - *many computers per person*

"It is invisible, everywhere computing that does not live on a personal device of any sort, but is in the woodwork everywhere. Its highest ideal is to make a computer so embedded, so fitting, so natural, that we use it without even thinking about it."



invisible

- designed to fit
- exploits our everyday participation in the world

Source: Mark Weiser's UbiqCom web site

Hiroshi Ishii *MIT Media Lab*

Tangible User Interfaces

"seamlessly couple the dual worlds of bits and atoms"

- from painted bits to tangible bits
- **input:** grasp and manipulate
- **output:** change physical properties of object

Source: Hiroshi Ishii publications

Outline

Styles of use

- ambient displays
- foreground interaction
- physical controls
- tagging and identity
- attentive user interfaces
- …

How to build them

- building blocks
- hardware / software platforms
- case study: phidgets

Style 1

Ambient displays

Information displayed at the periphery of attention

physical expression:

- light, sound, airflow, movement, pattern changes…

Style 1 - ambient displays

Dangling String

- freely hangs from ceiling in hallway
- connected to ethernet
- 0.1 turn per packet

Natalie Jeremijenko (1995)

Source: Mark Weiser's UbiqCom web site

Style 1 - ambient displays

Dangling String

- freely hangs from ceiling in hallway
- connected to ethernet
- 0.1 turn per packet

- spins madly when busy
- wiggles gently most of the time
- can be seen by those in the hallway
- can be heard, peripherally

- gives body to something virtual
- part of environment, like a breeze

Natalie Jeremijenko (1995)

Source: Mark Weiser's UbiqCom web site

Style 1 - ambient displays

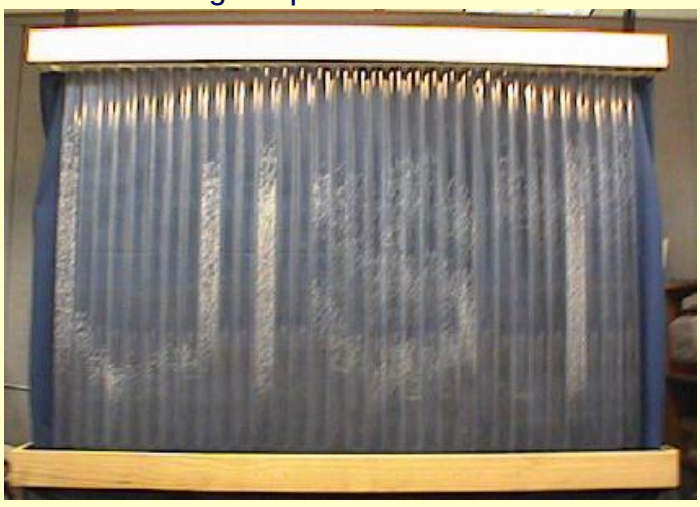
Ambient Room

Source: Tangible Media Group web site, ACM CHI'98

Style 1 - ambient displays

Information Perculator

bubbles of digital patterns



Source: Heiner, Hudson & Tanaka

Style 1 - ambient displays

Information Perculator

bubbles of digital patterns

Source: Heiner, Hudson & Tanaka

Style 2

Foreground interactions

Information displayed at the foreground of attention

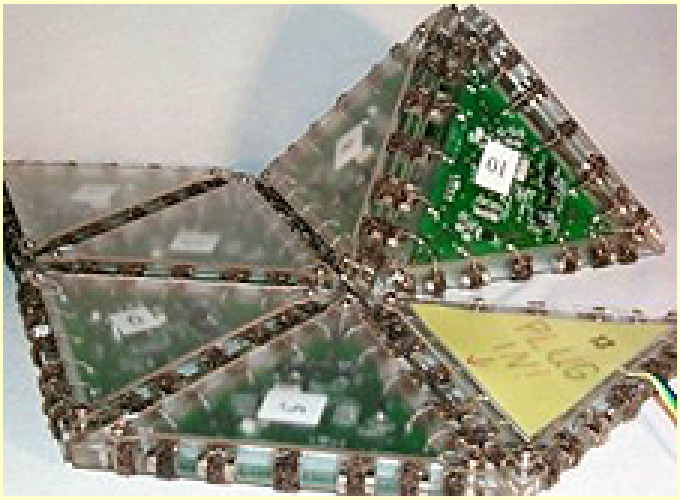
physical expression:

- conscious intentional interactions
- grasping, direct feedback…

Style 2 - foreground interaction

Triangles

Connecting triangles create a digital story

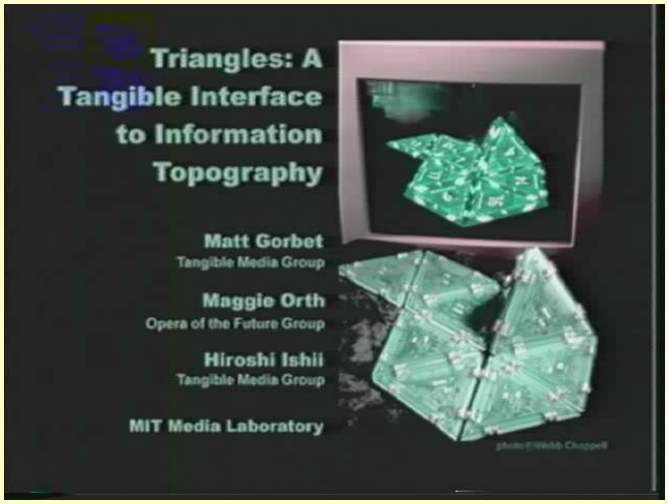


Source: Tangible Media Group web site

Style 2 - foreground interaction

Triangles

Connecting triangles create a digital story

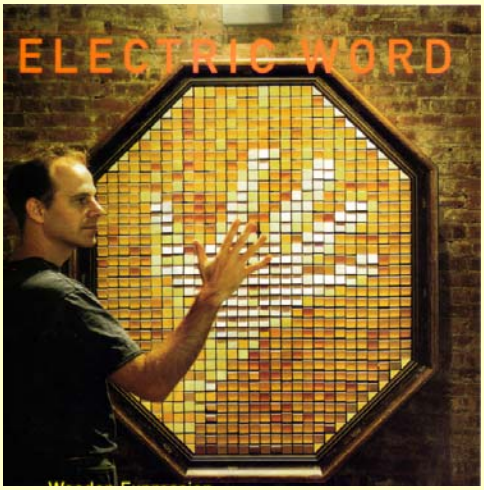


Source: Tangible Media Group web site

Style 2 - foreground interaction

Wooden Mirror

Wood pixels reflect image



Source: Daniel Rozin, NYU

Style 2 - foreground interaction

Wooden Mirror

Wood pixels reflect image

Source: Daniel Rozin, NYU

Style 3

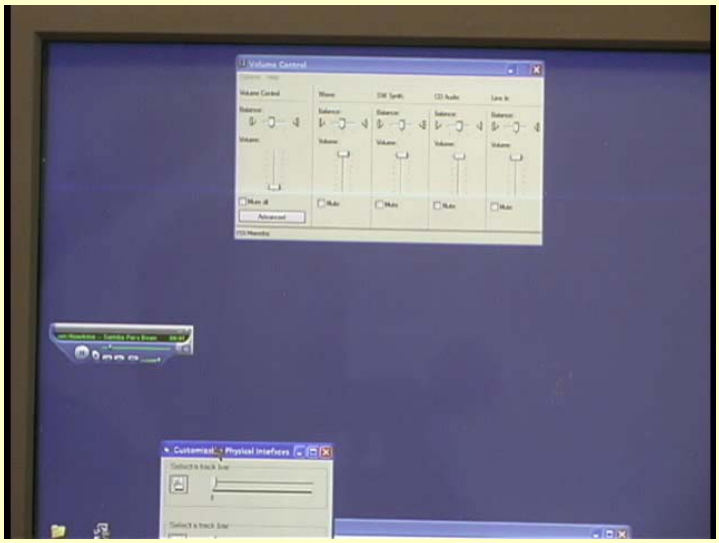
Physical controls to GUIs

richer physical interface

Source: CHI-83

Style 3 - physical controls

Customizable User Interfaces

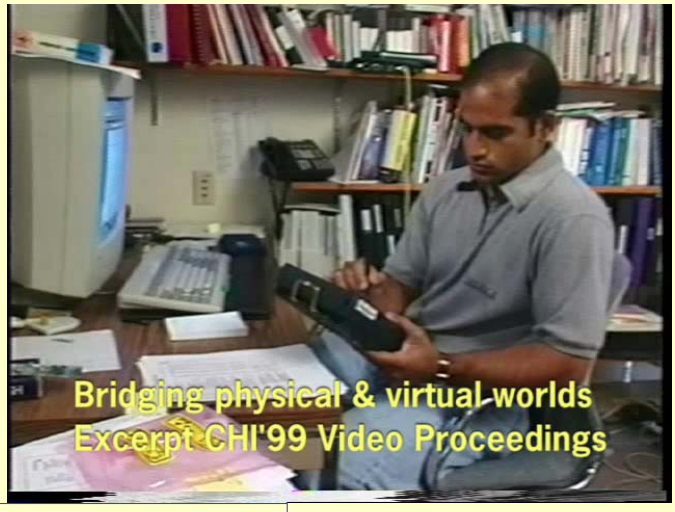


Source: Saul Greenberg, UIST 2002

Style 4

Tagging and Identity

Tags identify and link physical objects to computer information



Source: Xerox PARC, CHI'00 Video Proceedings

Style 5

Attentive User Interfaces

technology that doesn't bug you when you're busy

R. Vertegaal

Source: Roel Vertegaal, Queens U.

Style 6

Geometric Modeling

Model geometry on the screen

Source: Osaka University Human Interface Engineering Lab:www-human.ist.osaka-u.ac.jp/ActiveCube/

Style 6 - geometric modeling

HandScape

digitizes field measurements a visualizes them on a display

Source: Tangible Media Group web site

Style 7

Collaborative interactions

Physical objects connect people

Source: Saul Greenberg, ACM CHI 99 Video Proceedings

Style 8

Aging in place / Health

Physical objects monitor others

keeping an eye out for family members

Source: Georgia Tech. Everyday Computing Lab web site (Rowan and Mynatt)

Style 9

Toys

Source: Nancy Lopez; Saul Greenberg Phidget Project Collection

Style 10

Musical devices

Source: Olive Au; Saul Greenberg Phidget Project Collection

Style 11

Theatre

Source: Kevin Foster; Saul Greenberg Phidget Project Collection

Style 12

Music players

Source: Rob Diaz-Marino; Saul Greenberg Phidget Project Collection

Style n...

Other opportunities

Anywhere you see something physical, ask:

what are the opportunities for repurposing this into a physical user interface?

Outline

Styles of use

- ambient displays
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- physical controls
- tagging and identity
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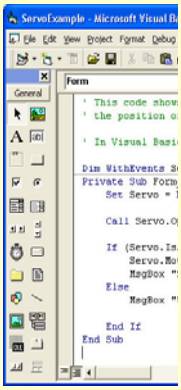
- ...

How to build them

- building blocks
- hardware / software platforms
- case study: phidgets

How to build them



building blocks + **hardware design** + **software** + **design**

Digital inputs - switches

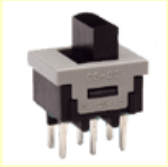
Rocker

Toggle

Push button

Push-Pull

Rotary



Slide

Tactile

Keylock

building blocks

Analog inputs – manual sensors

Force

Mini-joystick

Capacitive

Accelerometer

single-turn

multi-turn

encoder

slider

Potentiometers

building blocks

Analog inputs – manual sensors

Bend

Force

gyroscope

Tilt

building blocks

Analog inputs – environmental sensors

Light

Temperature

Pressure

Motion

Voltage

Weight

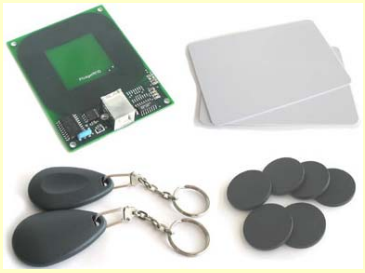
rangefinder

proximity

Distance

building blocks

Custom inputs - identification



RFID tags and antenna

Bar code scanner

Fingerprint reader

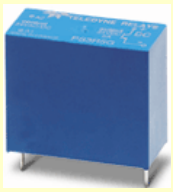
building blocks

Digital outputs – low power

lamps

LEDs

Lights



Relays

Solenoids

building blocks

Analog outputs: Motors

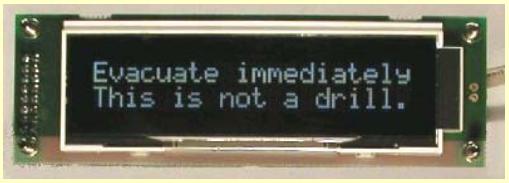
Position: 0-180º
Servo

Rotate by steps: +/- xº
Stepper

Speed
DC Motor

building blocks

Character and image output: Displays



Text LCD

Graphics (not yet)

Numeric-alpha

building blocks

Others...

Outputs

- tactons (vibration)
- scent
- heat
- sound

Inputs

- sound activated switches
- wireless switches
- PH sensor
- humidity sensor
- thermopile (temperature at a distance)
- cameras (images / motion / activation) ...

hardware

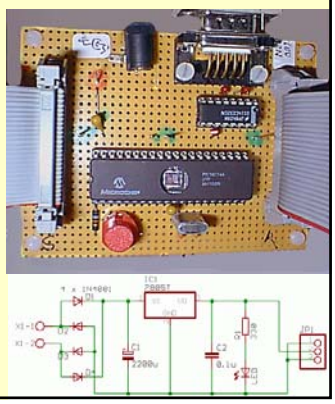
PIC Micro-controller

Single programmable chip computer with:

- CPU, RAM, ROM, I/O, serial/parallel ports, A/D and D/A converters

Need to know:

- basic circuit design (maybe)
- basic electronics
  - resistor, capacitor, diodes, transistors…
- micro-controller details
- low level programming
- networking …



Flexible, but

- high learning curve
- excessive time in low level details
- serial

Products: microchip.com

hardware

Basic Stamp

Pre-built boards

- Pic microcontroler
- pre-wired circuits and connectors
- boards designed for different uses

Need to know

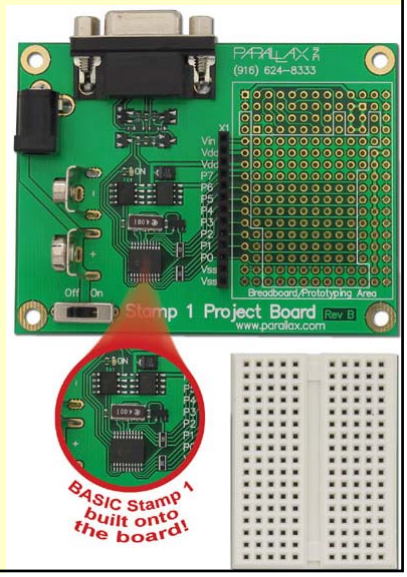
- electronic components + circuitry
- PBasic language: stamp-specific instruction set

Still flexible, but

- learning curve still there
- time in low level details

Tradeoff

- learning *vs.* performance



Products: parallax.com

hardware

Motes

Wireless sensor boards

- Smart Dust Project (Berkeley)
- battery-powered processor/radio board with tinyOS
- stackable daughter boards for sensing
- talks to
  - other motes (programming board: USB to computer)
  - stargate gateway: complete palm-sized linux system

Need to know

- TinyOS libraries / NesC language
- can create own custom daughter boards, but…

Potentially good design flexibility, but

- high software learning curve
- very hard to program

see also SmartIts (Europe)

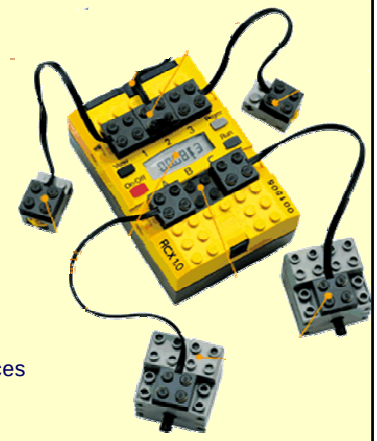
Products: xbow.com

hardware

Lego Mindstorms

Programmable brick

- proprietary RCX microcontroller with infrared communication
- reasonable range of input/output devices
- Lego building blocks
- robotics (downloadable code)
- children's programming language *but*
  - well-defined SDK
  - 3rd party access from standard languages



Need to know

- SDK / language

Low flexibility

- limited input/output (3+3), limited i/o devices
- expensive for basic set, plus add-ons

Products: mindstorms.lego.com

hardware

Off the shelf devices

Fixed function and form

- X10 smart home devices
- hacked products

Need to know

- protocol

Low design potential

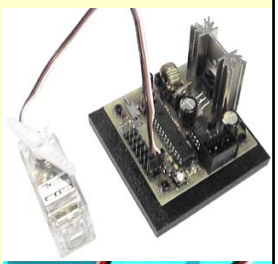
- fixed form factor
- repurposed functionality

hardware

Phidgets *and* Making Things

Hardware as software components

- dedicated devices
- some plug and play electronics
- under direct computer control
- well-defined component-based software
  - interface via APIs, objects, and/or widgets



Need to know

- high level programming language
- software API documentation

Design flexibility *vs.* electronic flexibility

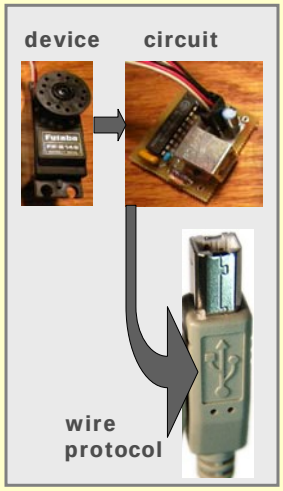
- very low learning curve
- design by combining and varying
- time in conceptual design, not electronics

Products: phidgets.com, makingthings.com

case study

Phidget architecture

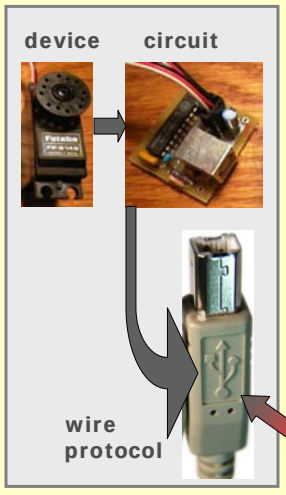
Hardware



case study

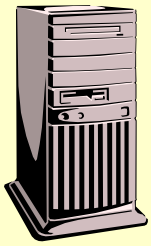
Phidget architecture

Hardware



Software

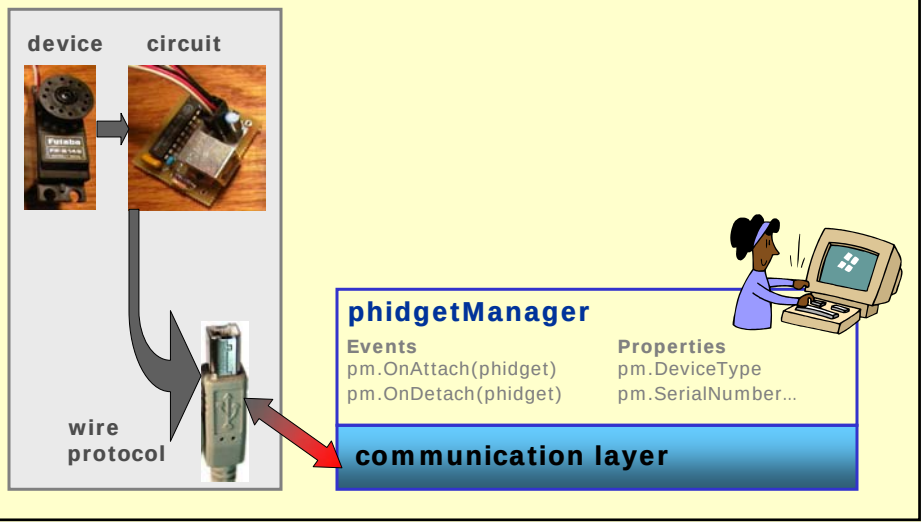
wire protocol



communication layer

case study

Phidget architecture



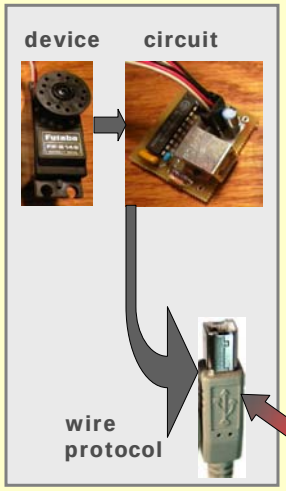
case study

Phidget architecture

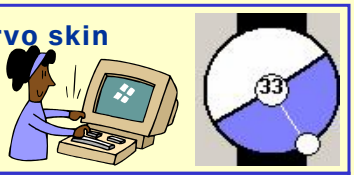
case study

Phidget architecture

Hardware



Software



phidgetServo

Events	Properties
servo.OnPositionChanged	servo.MotorPosition=90

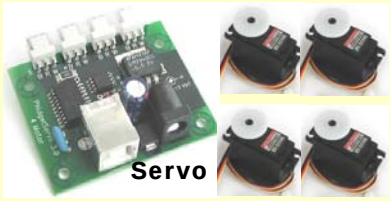
phidgetManager

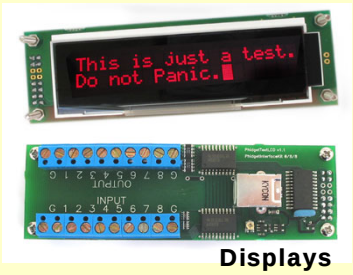
Events	Properties
pm.OnAttach(phidget)	pm.DeviceType
pm.OnDetach(phidget)	pm.SerialNumber...

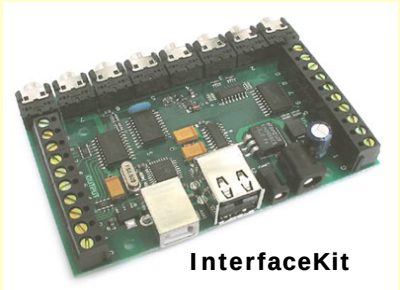
communication layer

case study

Phidget demonstration







case study

Design

One last video…

Physical User Interfaces

What they are and how to build them

You should now know

- various genres and opportunities of physical user interfaces
- basic hardware building blocks available to you
- how to get started building your own physical user interfaces

You too can rapidly prototype physical user interfaces