Big data, small brain

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Company history

75+ years of experience

50’s and 60’s
Barco one of the first manufacturers to use printed circuits for its television sets

70’s and 80’s
Diversification and international expansion with video projection systems

90’s
Barco moves into professional markets (projection, medical imaging, 3D and LED)

21st century
Become a global leader in networked visualization
About Barco
You will find us where images are critical to professionals

NYSE Euronext
International company
Headquartered in Belgium
listed (BAR) on
NYSE Euronext Brussels

90
Presence in
90 countries

3,900
Employees

1.500
Billion 
$ sales in 2012
Technology

- **43,000** Lumens for world’s brightest cinema projector
- **10 million** Pixels of grayscale perfection
- **unlimited** Number of sources with Barco’s networked control rooms concept
- **10x** More silent than competition in its class
- **10 million:1** Contrast ratio in Barco’s simulation projectors
- **71°C** Withstanding extreme temperatures
Healthcare

“Supporting healthcare professionals a billion times a year”
Digital Cinema

“Enchanting 10 million moviegoers every day”
Control Rooms

“Helping over 2.5 billion commuters get home safely every day”
Media & Entertainment

“Setting the scene for over 2,500 gigs and shows every year”
Simulation & Virtual Reality

“Broadening the horizons of 250 research centers”
Defense & Aerospace

“Flying aboard 100 types of aircraft every day”
Our best screens so far...
Always more pixels...

Full HD TV
~2 million
NHK’s Super Hi-Vision

Image format of Super Hi-Vision

- Visual acuity = 1.0×20/20
- Standard viewing distance

Super Hi-Vision

- 7680 pixels
- 3.0 × Picture Height
- 1.5 × Picture Height

HDTV

- 1920 pixels
- 1080 pixels
- 30deg
- 55deg

Digital Cinema

- 4096 pixels

Audio system configuration

- 22.2-channel Audio system
- Loudspeaker array

Screen size: 600 inches
Maximum capacity: 400 people

Acoustic system: 22.2 multi-channel

Super Hi-Vision Theater at the World Expo
Enough pixels already?

8K Super Hi-Vision
~32 mln pixels

4K Digital Cinema
or Ultra-HDTV
~8 mln pixels
The Ultimate Display

- How many pixels is really enough?

- 20/20 vision corresponds with 1 arc-min separation between lines
  - Pixels should be smaller than 0.5 arc-min
  - On a sphere we can fit ~600 million of these pixels

- But to have perfect depth perception we would need to correctly position each pixel in the z-plane
  - A young person can accommodate approx 10 diopters
  - Eye focus resolution (depth of field) is approx. 0.3 diopters
  - We would need 30 parallel screens

- A grand total of 600 x 30 = 18 Gpixels
The Ultimate Sound System

- Humans have only two ears but left-right time delays as well as spectral coloring allow us to identify sound direction, even from above and behind.
- The spatial audio resolution for humans is about 7 degrees horizontally and 15 degrees vertically.
- We would need approx. 400 speakers to fill a sphere.
When we become conscious of a flavor, we experience a mix of emotions, linked with past emotional memories evoked by that specific flavor, because enjoying an aliment depends not only on the aliment itself, but also on individual aspects, such as emotion and memory.

The *final hedonic judgment* is the result of the chemical composition of the coffee cup interpreted by the filtering activity of the central nervous system where the signal is compared with the memorized experience. The hedonic value is the fundamental attribute to process taste information in order to decide its rewarding value.

Special thanks to Furio Suggi Liverani, CTO illycaffè
Multi-Media
Taste – Smell – Touch – Hearing – Sight
Taste perception

- 10,000 taste buds with 100 taste receptor cells each
  - The receptor cells detect the presence of chemicals
- There are only 5 different types of taste
  - Salty: control salt intake
  - Sour: maintain acid balance
  - Bitter: avoid poisons
  - Sweet: detect calorie-rich food
  - Umami: detect protein-rich food

- Bitter, sweet and umami have been linked to specific protein receptors and to specific genes
- Salty and sour appear to use a different type of channels

- There are many different receptors for different kinds of ‘bitter’ but they seem to share just one signaling channel to the brain
  - Detect many kinds of potential poisons
- There appears to be just one receptor for sweet
  - Detect digestible sugars
Taste bit-rate

- 5 independent taste channels
- Assume there is limited spatial resolution
  - Tip, left, right, back etc.
- Estimate 10 taste sensations per second
- Distinguish between
  - barely salty
  - slightly salty
  - a bit salty
  - salty
  - very salty
  - extremely salty
  - inedible
- In total $5 \times 3 \times 10 \times 4 \approx 600 \text{ bit/s}$
Smell perception

- Humans can distinguish many tens of thousands of different smells
  - The odorants interact chemically with smell receptors
  - There are ~12 millions of ‘olfactory’ sensory neurons in the nose but they do not map directly onto individual smells

- Buck & Axel, Nobel prize 2004
  - There are 347 distinct receptors
  - Each receptor can recognize multiple odorants
  - A single odorant is typically recognized by multiple receptors
Smell bit-rate

- 347 independent smell signals
  - Not-quite binary

- Assume there is no spatial resolution
  - Not even left/right nostril

- We smell when we breathe in
  - Assume a maximum smell-rate of 10/sec

- Distinguish between:
  - What is it that I smell?
  - Whooff, what a stink!
  - More discriminatory than taste

- In total 347x10x8 ≈ 28 Kbit/s
Touch perception

- The ‘somato-sensory’ system comprises
  - Touch
  - Temperature
  - Body position
  - Pain

- Receptors cover skin, muscles, bones and organs
  - React to movement, pressure, temperature or chemical stimulus
  - Can be slow (position: DC) or fast (touch: 250Hz)

- The distribution of sensors is very un-even
  - We can resolve two pressure points:
  - 2 mm apart in our fingertips
  - 40 mm apart on our lower leg
Touch bit-rate

- First estimate only ‘pure touch’
- Approximately 5,000 sensors
  - The human body is covered by ~ 2 m² of skin
  - Assuming an average spatial resolution of 20 mm
- A sampling rate of 250 Hz
- A dynamic range of 10 decades?
  - Mosquito landing
  - Getting hit by Mike Tyson
  - Pain takes over...
  - Let stick to 8 bits
- (ignoring temperature, position and pain sensation)
- Total is 5000x250x8 ≈ 10 Mbit/s
Sound perception and bit-rate

- Sound is detected by approx 15,000 hairs in the cochlea

- From many studies we (think we) know
  - Frequency range 20Hz - 20kHz
  - Dynamic range 140 dB

- Total is $2 \times 48000 \times 24 \approx 2.3 \text{ Mbit/s}$

- BTW iTunes gives you 256 Kbit/sec...
The retina contains about 5 million ‘cones’ and 100 million ‘rods’
- The cones are color sensitive
  - 64% red, 32% green and 2% blue
- The rods are faster and more sensitive
- The highest visual acuity is located in a 20° central region
- The rods suffer from neural undersampling

Humans are very good at detecting differences in color and brightness

The human eye is able to detect single photons
Vision bit-rate

- First the cones:
  - Assume 20/20 vision within a 20° central zone
  - This needs less than 2 million pixels
  - These cones can distinguish color with about 30 bits/pixel
  - The upper range of frequency response is 100 Hz

- Then the rods:
  - Assume 1/10 of the visual acuity of the center over a 160° angle
  - This needs less than 1 million pixels
  - These rods have a dynamic range of about $10^7$ and an upper frequency response of 200 Hz

- The total is $2 \times (2000000 \times 30 \times 100 + 1000000 \times 24 \times 200)$

- $\approx 20$ Gbit/s
The grand total

- 'Direct Input'
  - Taste: 600 bit/s
  - Smell: 28 Kbit/s
  - Touch: 10 Mbit/s
  - Hearing: 2.3 Mbit/s
  - Sight: 20 Gbit/s

- Compared with the 'Ultimate Display'

  - 18 billion pixels x 30 bits x 200 Hz $\approx 108$ tera-bit/sec

- And there is no practical way to broadcast taste & smell yet...
The challenge ahead

- “Towards overwhelmingly realistic face-to-face communications”
  - Prof. Yasuhiro Koike of Keio University, Japan
  - SID keynote speech on polymer photonics

- Challenge for MIT 😊
  - 20 Gbit/sec biological interfaces

- In the meantime, back in the real world:
Reality...
“Barco’s projectors have greatly helped us to make this one of the UK’s most advanced ship bridge simulators”

Peter Woods, Simulator Manager and Lecturer, Lairdside Maritime Center, Liverpool, United Kingdom
Fighter jet simulator

- 360° Field-of-View
- Near eye-limiting resolution
- High contrast combined with high brightness
- Uniform display quality over the full view
  - Warping
  - Blending
  - Color and brightness matching
- Enable fast flight simulation
  - Smearing reduction
  - Low latency
  - Night-vision capable
  - At day/dusk/night-time
- Rear dome concept
- 13 LCOS 10Mpix projectors
Contrast

Zenith Contrast

Setups

System Contrast

Measurements

Simcad simulation
Make-belief...
“Providing the sense of realism needed to accurately predict the look and feel of our products”
Virtual reality cave

- A big cave to allow joint research projects, with a highly interdisciplinary character

- Largest possible footprint to enable users to move freely
  - Bigger than the “standard” 3m x 3m caves!
  - Extra attention for floor projection due to the size

- Very high side walls to avoid the use of a ceiling
  - Ceiling challenges integration of tracking, sound...

- Robust and innovative mechanical structure
  - Safety aspects!
- Walls & floor 5.25m x 5.25m x 3.3m
- 22 projectors (1.6 mm pixels)
Contrast

Contrast wrt diffuse reflection (DC value)

- **corner contrast**
- **center contrast**
- **Power (corner contrast)**
- **Power (center contrast)**

Graph showing the relationship between contrast ratio and diffuse reflection percentage.
Building it, in Germany
The walls were easier...
195m wide display wall for the world’s largest refinery site

Reliance Petroleum, Jamnagar, India
Why so large?

- The large screen is unique in providing:
  - Quick overview
  - Direct visual access to key information in fixed locations
  - Common frame of reference for the crew
  - Provide “big picture” overview of plant status
  - Enhances teamwork among operators
  - Improves situational awareness

and it provides a valuable wow-factor...
The Reliance site integrates control of:

- 8 manufacturing plants in one center:
  - Crude Distillation Units or Vacuum Gas Oil High Temperature Coker
  - Fluid Catalytic Cracking Power Regulation Unit for Clean Fuel Alkylation
  - Hydrogen Manufacturing Units
  - Regulatory Time Frame and Manual Transmission Fluid Plant Utilities
  - Ethyl Benzene & Styrene Monomer
  - Polypropylene Aromatics Plant
  - Polypropylene Integrated Gasification Combined Cycle Captive Power Plant
  - Generic Captive Power Plants

- For each plant, the following subsystems are shown on for the display walls:
  - Tankage Information System (TIS) – by Foxboro
  - Terminal Automation System (TAS) – by Foxboro
  - Distributed Control System (DCS) – by Foxboro
  - Emergency Shutdown (ESD) via the DCS – by Foxboro
  - Programmable Logic Controllers (PLCs) – by Foxboro
  - Fire and Gas (F&G) – by Honeywell
  - Closed Circuit Television (CCTV) – by Honeywell
  - Electrical Load Management System (ELMS) – by Yokogawa
  - Electrical Distribution Management System (EDMS) – by Yokogawa
  - Analysers – by Aspentech
  - Advanced Process Control (APC) – by Aspentech
The "key-hole" effect

- Only a small fraction may be viewed at the same time
- Causes fragmented understanding of the process
- Requires extensive navigation
- Very little data in each display
Start Up

Steady State

Emergency
Where do all those pixels come from?
Three levels of sophistication

- Wall management for large control rooms
  - Scenario driven & procedural
  - Well-trained operators
  - Very large collections of information

- Management of screen real-estate for planned meetings
  - Teams of professionals
  - Focused on specific issues
  - Large online datasets

- Ad-hoc meeting room cooperation
  - ‘Naïve’ users
  - Sharing personal desktops
A simple system configuration
2 display walls and 4 operators

Display Wall

Windows Operating System

LAN

Central Server
Virtual desktop
Operator 1
Operator 2
Operator 3
Remote PC

NGP-124

BARCO
Visibly yours
STEP 1
operator 1 loads perspective on display wall
STEP 2
Operator 2 Wants to interact with remote PC
STEP 3
operator 3 loads an additional perspective on the display wall
STEP 4
operator 1 sends display wall contents to LCD wall
‘Professional’ meetings

Windows desktop
Windows applications
Local sources
Networked sources
‘Professional’ meetings

- Data, not Powerpoint!
  - Work with up-to-date information
  - Make faster and better decisions

- Parallel scenarios
  - Display multiple information sources simultaneously
  - From local and remote sources

- Interactive & real time
  - Interact with any (remote) PC source on the collaboration display
  - Place any source anywhere on the display

- Integrate with 3rd party functionality
  - Video conferencing
  - Lighting management
  - Audio mixing
‘Professional’ meetings
Connect
your button to the computer’s USB port
and start the ClickShare application

Click
to display your laptop’s screen

Share
your presentation
Click from a 2\textsuperscript{nd} person, and you are sharing the screen

Click again and share up to 4 presentations at the same time

Click with up to 25 participants able to share the screen
Looking back, and ahead

- Things were going so well...
  - Vinyl & Compact Cassette → CD audio
  - Black & white television → HDTV
  - VHS & Betamax → BluRay disc

- And then the internet took over...
  - MP3 compression
  - YouTube video
  - Twitter messages

- Access, convenience & simplicity
  - “The medium is the message”

- Have we lost our appetite for high-fidelity?
The wheels of progress...

- **Fidelity**
  - size
  - #pixels
  - gamut
    - contrast
    - 3D

- **Ubiquity**
  - professional
  - personal
  - mobile
    - public

- **Connectivity**
  - codecs
  - secure
  - social
  - usable
The Holy Grail
1977 – Star Wars

Princess Leia’s Holographic Communicator
Thank you

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