Camera Chaos

Which interface is best for me?

There is no single solution

- Its like asking , ‘which car should I get?’
- We are offering this seminar to be informative and help you make the best decision

What to consider

- Application specifics
  - Environment
    - Industrial, Scientific, Military, etc.
  - Useage
    - New Product or continuation
  - Lifetime
    - Short or Long
  - SW Development Environment

Data Rates

- Theoretical vs. actual
  - Make sure that you analyze the actual data rate you are going to get
  - E.g. The PCI bus has a theoretical capacity of 132 MB/s, 33 Mhz * 4 bytes wide
  - Actual data throughput on PCI busses: ~100MB/s
  - You can always measure value by taking data to be transferred and time how long it takes, then divide amount of data by time

Data Rates II

- Rule of thumb
  - 75% of Peak Data rate, or Advertised Theoretical Data rate is what you should expect to get
- Always leave overhead in demanding applications!

Bandwidth

- How much coming out of camera?
- This alone might dictate what you are going to use!
  - Camera Link base mode 255 MB/s actual
  - USB 2.0 60 MB/s theoretical
  - 1394 B 100 MB/s theoretical
  - GiGE 125 MB/s theoretical

Bandwidth II

- Now what are you going to do with it?
- CPU usage
  - USB heavy
  - GigE currently heavy, TOE will reduce
  - 1394 light
  - Camera Link None!
- Does this matter?

Bandwidth III

- Does this matter?
  - Displaying video No
  - Doing real time processing of data Yes
- Can you afford to miss data?
- Do you need determinism?

Bandwith IV

- Data Transfer Mechanisms
- Isochronous (time slots)
- Async (non guaranteed)
- Collision Detect Retry

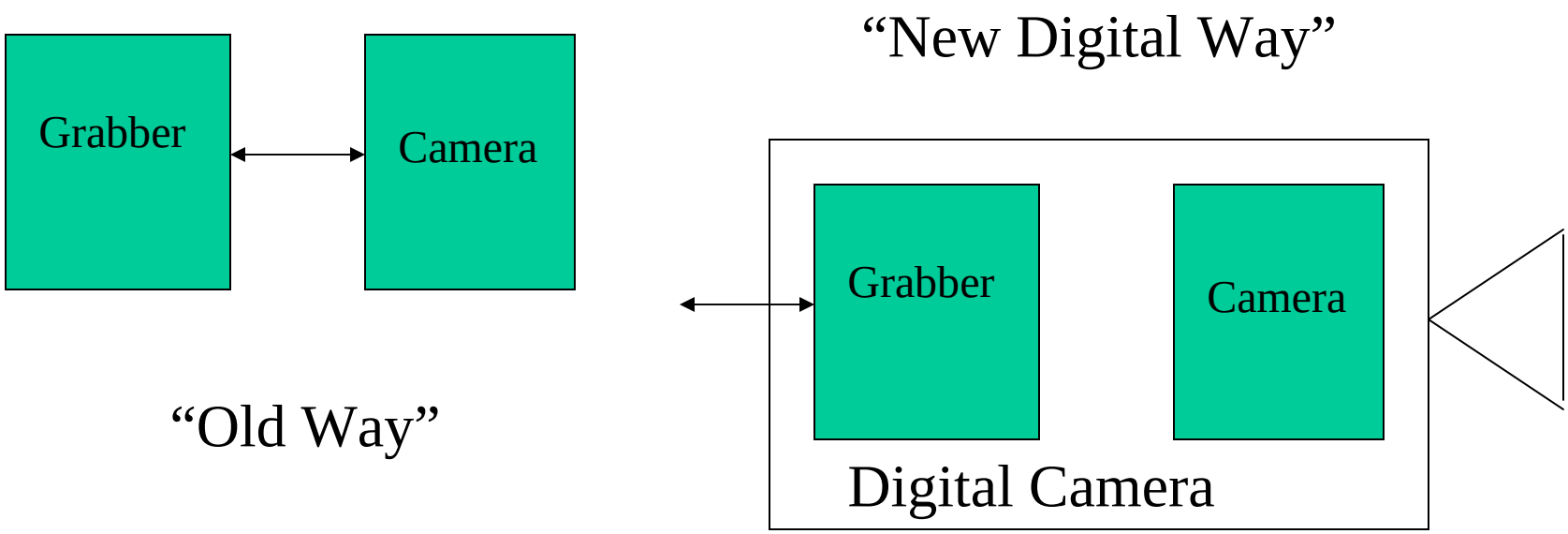
Analog or Digital

- Most of the cameras out there are still Analog!
- Does it really make a difference if you digitize at the grabber or in the camera
  - Bits are Bits!

Getting Rid of the Framegrabber: A Big Myth

- Looking to go digital , so you think there is no grabber; think again.
- Something has to digitize, format, and transfer data to the computer (used to be called a framegrabber).
  - That functionality is still there, it’s just all inside the camera

Digital Cameras



New Digital Cameras are not just Cameras

- In the past, the camera company worked on getting a good picture out of the sensor
- The framegrabber company worked on digitization , getting a picture, and giving you a SW development environment
- With USB, GigE, 1394, that is all combined

Choosing your Vendor

- Many are ‘expert’ in single technology, which is a good thing
  - Especially true for smaller companies
- Are you looking for HW, Sensor Technology, SW, etc.

USB 2.0

- Greatest potential since most ubiquitous!
- Found in every new PC for the past several years, and will continue

USB 2.0 Bandwith

- 480 Mb/s = 60 MB/s theoretical
- Both isochronous and asynchronous
- RS170 video , 640x480x30fpsx8 bits/pixel = ~8MB/s
- NTSC , YUV format, 2 bytes/pixel = 16 MB/s
- RGB 3 bytes/pixel = 25 MB/s
- USB 2.0 can handle them all!

USB 2.0 limitations

- Chain devices, slowest device pulls down everybody else
  - If you put a USB 1.1 device on the chain, all 2.0 devices only go at 1.1 speeds
  - Lots of 1.1 devices (mice, keyboards, modems, etc.)
- Heavy CPU intervention to transfer data

USB features

- Can power devices, but limited to 5V and 500ma
- Can power CMOS sensors/cameras
- CCD sensors need 12V and more amps than supplied by USB so currently not able to power CCD sensors

USB Bottom Line

- 1. Data rates are under 45MB/s
- 2. CMOS sensor (5V power only) does not limit picture
- 3. Data processing rate is not too high. CPU load can be medium during data transfer.
- 4. low cost is of high consideration.
- 5. Non locking cable is OK.
- 6. Cable length is shorter than 5 meters
- 7. Lack of SW standard is OK.
- 8. Missed frames is OK.

IEEE 1394 / Firewire

- Developed by Apple Computer Inc.
- Also known as iLink ™ Sony
- Put into IEEE
- Within 1394 spec, is a video standard, know as ‘DCAM’ or IIDC 1.03
- Has format ‘A’ and now ‘B’

DCAM Standard

- Defines various modes of video, 640x480x30 fps x mono, color (YUV), color (RGB), etc. Many modes and many formats
- Mode for custom format as well
- Camera gets identified when plugged in, camera’s modes are identified

DCAM Standards II

- Camera’s registers are defined .
- This means SW written for one DCAM camera will work with any DCAM camera!
- This standard is unique to firewire, it is the only protocol that currently has this capability!

Advantage of DCAM

- Lets the user be truly HW independent
- No other standard has this ability

1394a

- 400 Mb/s capacity
- Both Isochronous and Asynchronous
- Isoch is used for data transfer and is 75% of time
- Asynch is used for handshaking and control. If not used for this, data transfer can be added in as well

1394a II

- So with Isoch transfers, 1394a guarantees a minimum of 32 MB/s of data transfer per OHCI port
- Many 1394 interfaces have 3 connectors per OHCI port, these all share the 32 MB/s, so be careful
- 1394 and Camera Link are the only standards that guarantee data transfer rates

1394a III

- Firewire can power devices (up to 30 V) so CCD sensors can be used
- Cable length is 4.5m, but longer cables can be used; 1394 will autonegotiate lower speeds if needed.
- Hubs/repeaters are also available

Future of 1394

- 1394 b is defined, and products are just coming into play. 800 Mb/s.
- Lack of standard PHYs, currently manufacturers are creating their own PHYs, could cause interoperability issues

1394 bottom line

- 1. You want an standard that allows for interchangeability of devices without losing
- software investment
- 2. You want guaranteed data transfer rates
- 3. Data transfer rates are below 33 Mbytes/S for 1394a or 66 MB/s for 1394b
- 4. Cable length is relatively short <20m
- 5. Deterministic processing application
- 6. DMA of data

Gigabit Ethernet (GigE)

- Newest and most promising!
- New computers will have Gigabit Ethernet connections
- Uses standard Enet connectors, wiring and hubs

Ethernet

- Been around a long time now, established protocols, 7 layer protocol datagram for SW/HW
- Currently, Fast Enet, 100 Mb/s = 10 MB/s maximum. In practice, about 25% efficient, way too slow for uncompressed video

GigE

- With GigE, now 1000 Mb/s = 125 MB/s, plenty of capacity for lots of video!
- Cable length of 100 meters, and with switches, unlimited, but clearly loss of bandwith
- Data moved via standard protocols

Protocols

- Ethernet works on collision detect, retry mechanism. If packets collide, they are resent.
- Makes for very simple, easy to implement, but potentially very inefficient, and of course, non deterministic
- These issues lessen if you have direct connect between camera and enet card

Enet Protocols

- TCP is standard mechanism for moving data on ethernet, but ineffecient
- TCP guarantees data will be what you expect to be on the receive side, called quality of service QOS. What you send is what is received

GigE Protocols

- Data is sent on UDP layer 4
- Data goes much faster , but not QOS
- Vendors must write QOS to make sure data sent is data received

Data Transfer

- TCP on GigE can use up 40% of the CPU to decode tcp packets
- TOE , tcp offload engines are coming to free the cpu from this task
- Currently why UDP is used

GigE Standards

- AIA has sponsored a standard with many camera and framegrabber companies
- Lots of work done, hope to have full standard ratified by end of 2005
- No power on enet, separate supply is needed to power camera

GigE Bottom Line

- GigE Bottom Line
- 1. Best choice when you need long cable lengths
- 2. You want routable (IP) data
- 3. Data rates are under 80 MB/s
- 4. High(er) CPU utilization is acceptable
- 5. Non Determistic processing, non hard real time is OK
- 6. Most ‘standard’ of the standards regarding HW interface useage
- 7. Don’t need ‘standard’ imaging protocol

Camera Link

- Extension of LVDS protocol
- Simplified data transmission and connectors for digital cameras
- Very high speed
- Purely deterministic

Camera Link Specs

- Base mode: 24 bits of data at up to 88 Mhz, 250 MB/s
- Full mode is 64 bits at 85 Mhz. 650 MB/s
- Point to Point, determinstic
- Requires framegrabber and camera
- 10m limit on cable

Camera Link Specs

- It is the only way to get high speed data
  - Current Kodak KAI sensors produce data at 66 Mhz, and can be digitized at 2 bytes. This is 132 MB/s. NO OTHER DATA TRANSFER MECHANISM CAN DO THIS.
  - Multi tap cameras, 8 taps, etc. Need camera link again for this!

Camera Link built for Imaging

- Serial protocol built in
- DMA mechanisms built into grabber
- Higher cost because it was not intended as general purpose interface like usb and firewire and gige, not for the masses, made for imaging, not another mass market standard adopted for imaging!

Camera Link Bottom Line

1. Need deterministic processing
- 2. Cable length shorter than 10m
- 3. High data rate applications
- 4. Transfers don’t bog down CPU
- 5. Want to offload CPU with attached processing
- 6. Rugged industrial connector
- 7. Multiple data streams

- **Short Term Long Term Comments**
- **Analog** Level Decline Decline when used with grabbers
- **USB 2.0** Growth Growth Strong in low cost applications
- **Firewire** Growth Level
- **GigE** Growth Growth
- **Camera Link** Growth Level Strong in very high end

Digital Cameras – Cost savings or not?

- Does
  - $separate camera + $ separate grabber <
  - $Combined grabber + camera?
  - Currently, in some cases it is more expensive, in some cases, less, but no clear advantage in cost
  - In future, USB, GigE, 1394 interfaces should prove to be less costly

Cabling

- Very hard to beat Analog BNC, closest is CAT 5E
- Distance is issue with high data rates