CPE200, 253FPAT
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What Do We Do?

- : Compilers, Hardware Architectures, and Operating Systems

: Aggregate Function Networks (AFNs)...

: in 1st Linux PC Cluster Supercomputer

- Make the components of a computing system work better together, improving performance & gaining new abilities
You are what you eat...

- I am a computer engineer / systems guy
- Background in CS, EE, ME, Math, & Econ
- From 1983, parallel processing researcher
- In 1970s, photo editor of various school pubs and a published professional photographer
- From birth, trained to know how everything in Dad’s manufacturing company worked
Supercomputers

Computers that can solve big problems and can scale to solve bigger problems.

- Mostly about parallel processing
- Need not be huge, expensive, etc.
- We make them cheap
- We also make them able to do new things
(Old) Cheap Supercomputers
Current Supercomputing Research

• I’m one of the folks who started the cluster supercomputing revolution...

• Several years ago, I realized:
  – My lab has 168kW power, 30 tons cooling
  – My lab heats half the Marksbury building
  – My lab could not power 1 high-end rack!
  – Big systems have thousands of racks

• It’s really all about power / computation
int a, b, c;
c = a + b;

- 32-bit carry lookahead adder...

roughly 650 single-gate operations!
int:4 a, b;
c = a + b;

- Optimized, 17 single-gate operations:
```c
int:4 a, b;
b = 1; c = a + b;
```

- Optimized, **7** single-gate operations:
int:8 a, b, c;
a = (c * c) ^ 70;
a = ((a >> 1) & 1);
a = b + (c * b) + a;
a = a + ~(b * (c + 1));
int:8 a, b, c;
a = (c * c) ^ 70;
a = ((a >> 1) & 1);
a = b + (c * b) + a;
a = a + ~(b * (c + 1));

• About 206,669 gates unoptimized
• Optimized, it’s just a = 0;
Quantum Computers?
Quantum Computing

Parallel processing \textit{without} parallel hardware.

\begin{itemize}
  \item \textbf{Qubits} instead of bits
    \begin{itemize}
      \item Each qubit can be 0, 1, or \textit{superposed}
      \item A “gate” operates on superposed values
      \item \textit{Entangled} qubits maintain values together
      \item Measuring a qubit’s value picks 0 or 1
    \end{itemize}
  \item Quantum computers are \textbf{not} the only way to do that: Parallel Bit Pattern computing
\end{itemize}
An Example: Find $\sqrt{29929}$

- 310 single-gate operations:
An Example: Find $\sqrt{29929}$

- C++ $\text{isqrt}(29929)$ returns 173

```cpp
int isqrt(int val) {
    pint a(val);
    pint b = pint(0).Had(8);
    pint c = (b * b);
    pint d = (c == a);
    pint pos = d.First();
    return(pos);
}
```
An Example: Prime Factoring

// Factor value a
// Primes that fit in 5 bits:
// 2, 3, 5, 7, 11, 13, 17, 19, 23, 29, 31
int a = 11*29;
pint b = 0;
b = b.Had(5, 0); // 1st factor
pint c = 0;
c = c.Had(5, 5); // 2nd factor
pint d = b * c; // multiply 'em
pint e = (d == a); // which gave a?
pint f = e * b;
Print(f);
An Example: factor 319
Our next supercomputer...
Supercomputers
Doing New Things
Computational Photography

Cameras as computing systems; using computation to enhance camera abilities and/or to process the data captured

- New camera / sensor / processing models
- Intelligent computer control of capture
- Detection / manipulation of image properties
“Raw” Repair

- “Raw” means “uncooked” or “unprocessed”
- Can credibly repair corrupted data
  - Fuji X10 “white orbs” blooming ⇒ DeOrbIt
  - Sony ARW compression artifacts ⇒ KARWY
  - Sony ARW PDAF artifacts ⇒ KARWY-SR
Photoplethysmography

- Reprogrammed a $100 camera to detect heartbeats by detecting color change
Covered Safe Entry Scanner

- Detect when a mask is being properly worn
- Also thermal imager & contact tracing
TDCI: Time Domain Continuous Imaging

- TDCI representation: a continuous waveform per pixel, compressed (mostly) in time domain
- TDCI processing enables:
  - High dynamic range (HDR), improved SNR
  - Rendering a virtual exposure for any time interval (start time, shutter speed)
  - Rendering a conventional video at any FPS and shutter angle (temporal weighting)
TDCI Example

- Video is converted to TDCI, then new frames synthesized... with significantly better quality
FourSee TDCI Camera

- Syncs four reprogrammed PowerShots
- 3D-printed structure for alignment, etc.
A Custom 3D-Printed Adapter With M42-Compatible Thread

Lens adapter M42 x 1mm pitch to Sony E

On $180 printer, 0.25mm layers!
Some of our latest work...

- Reprogrammed a <$100 camera to measure heartbeat by detecting color change.
Design For Manufacturability (DFM)

Design product so that it is easy to manufacture.

- E.g., Lego doesn’t easily do curves... and most 3D printers don’t do unsupported spans
- How is this computer engineering?
  - A design is a parametric program (parameterized by machine characteristics)
  - Compiler technology optimizes for DFM
3D-Printed Spanless Hinges
A Fancier DFM Example

- In 2016, researchers at the Hasso Plattner Institute made “metamaterial pliers”: a single part with stiffness, spring, & bending hinge

- Our metamaterial version has a **spring** and a **spanless hinge** and it works...
Programmable Cameras and IoT

This course will start by introducing the basic principles of photography and the details of how digital cameras work. However, cameras are no longer just about photography; they are sensors in embedded computing systems that can serve a wide range of applications. For example, using CHDK, it is trivial to program a Canon PowerShot camera to serve as a non-contact tape measure. The course will use CHDK cameras to explain how camera internals work and students will get hands-on experience using and programming these cameras. Cameras are also now cheap sensors for use within Internet of Things (IoT) devices. An ESP32-CAM IoT module that costs under $10 includes a 2MP camera and can be programmed for tasks as diverse as wirelessly serving live video via an HTML browser interface to unlocking a door when a person's face is recognized. We will discuss IoT devices in general and use of the ESP32-CAM and its OV2640 camera in particular. Students will implement simple IoT projects using the ESP32-CAM via the Arduino programming environment.

Prerequisites: Familiarity with C/C++ programming. No background with photography is required.
You Can Get Involved

- Talk to me, or Paul Eberhart, etc.
- Most stuff is posted at AGGREGATE.ORG
- Quantum computing Education & Research In Kentucky