An Open-Source Research Kit for the da Vinci® Surgical System

Peter Kazanzides
Research Professor
Dept. of Computer Science
Johns Hopkins University
Outline

• Overview of da Vinci Research Kit
• Control architecture
• Open source mechatronics
• Open source software
• Community
• Interoperability
• Future outlook
da Vinci Research Kit

- Mechanical components from da Vinci “classic” systems
- Donated by Intuitive Surgical to selected university labs
- Consortium to provide “open source” engineering and support
  - Software – JHU (CISST/SAW)
  - Controller electronics – JHU
  - Interface electronics – ISI
  - Controller power/packaging – WPI
- Controllers and software also adapted for use with complete recycled da Vinci “classic” systems
- [http://research.intusurg.com/dvrkwiki/](http://research.intusurg.com/dvrkwiki/)
da Vinci Research Kit

Proprietary mechanical hardware, with documentation

Open source electronics (schematics, PCB layout, and FPGA firmware)

Open source software

da Vinci Research Kit

FPGA, I/O, and Amplifiers

Control PC (Linux)

Interfaces

Motors, encoders, pots, switches

IEEE-1394a (Firewire)

ROS
DVRK Video

da Vinci Research Kit
Intuitive Surgical Inc.
Johns Hopkins University
Worcester Polytechnic Institute

Non-human use research system
Robot Control Architecture: Centralized Computation and Distributed I/O

- Possible with high-performance networks/computers
  - All the benefits of distributed I/O (reduced cabling)
  - Computation on familiar development platform (flexibility)
Serial Network Requirements

- Speed of at least 100 Mbits/sec ✔ ✔
- Low latency (tens of µsec) ✔ ✔
- Ability to daisy-chain ✔ ✔
- Readily available ✔ ✔
- Simple FPGA implementation ✔ ?
- Option for high-flex cabling ❌ ✔

IEEE-1394a (FireWire)
EtherCAT

In 2006, FireWire appeared to be best choice
Today, other good options, such as EtherCAT
Open Source Mechatronics

Open source: http://jhu-cisst.github.io/mechatronics/
- Schematics, PCB layout, firmware (Verilog)
da Vinci Research Kit
Control Performance

- Latency primarily due to overhead on PC
  - ~35 µs per asynchronous transaction
  - Individual read/write to 8 boards: ~530 µs
  - Taking advantage of broadcast and peer-to-peer transfers reduces I/O to ~116 µs
Hardware Revisited

• In 2006, FireWire (IEEE-1394) seemed to be a good choice, but less common today than Ethernet
  – Most desktops and laptops contain Ethernet port
  – Linux has good low-level support for FireWire (libraw1394); other platforms do not
  – Development environments, such as Simulink Real-Time (formerly Matlab xPC) and Labview CompactRIO, support Ethernet, but not FireWire
  – Real-time driver for Ethernet available (RTnet); RT-Firewire no longer supported
  – EtherCAT uses standard Ethernet hardware on master, with custom slave hardware to enable daisy-chaining
Ethernet Alternatives

EtherCAT

FPGA-ecat

FPGA-ecat

FPGA-ecat

Ethernet

Bridge Board

FireWire
Ethernet-FireWire Bridge Performance

Measured performance on 8-node system (DVRK)

Analytical performance comparison
Ethernet-FireWire Design
da Vinci Teleoperation (with ROS)
Simulation/Visualization

- ROS/rviz
- Gazebo Model
  Dynamic Simulation
- Matlab Models
  PSM & MTM
User Community

- UBC
- CSTAR
- SUNY Buffalo
- WPI
- Stanford
- Vanderbilt
- CMU
- JHU
- Johns Hopkins University
- Worcester Polytechnic Institute
- Stanford University
- The University of British Columbia
- Vanderbilt University
- University of California Berkeley
- Carnegie Mellon University
- The Hospital for Sick Children
- SUNY Buffalo
- University of Western Ontario
- Intuitive Surgical Inc
- Scuola Superiore Sant’Anna
- Seoul National University
- Imperial College
- Óbuda University

Base map

Google Maps

Copyright © CISST ERC, 2015

NSF Engineering Research Center for Computer Integrated Surgical Systems and Technology
First DVRK User Group Meeting

Johns Hopkins University, March 20-21, 2014
Interoperability

da Vinci master teleoperating
Raven II via ROS
Community Research: Learning by Observation

Autonomous Robot Surgery
Performing Surgical Subtasks without Human Intervention
UC Berkeley, October 2014


Berkeley
University of California
Summary

• Open source research platform based on first-generation da Vinci system:
  – Open source electronics
  – Open source software, with ROS interfaces

• Growing user community:
  – 20 sites up and running (internationally)
  – several more in process

• Links:
  – http://research.intusurg.com/dvrkwiki/
  – http://github.com/jhu-cisst (and jhu-saw)
  – http://github.com/jhu-dvrk
Acknowledgments

- **Partners:** Russell Taylor (JHU), Simon DiMaio (ISI), Greg Fischer (WPI)
- **Software:** Anton Deguet, Zihan Chen, Simon Leonard, Balazs Vagvolgyi, Jonathan Bohren, Kwang Young (Eddie) Lee, Ankur Kapoor, Tian Xia
- **Firmware:** Zihan Chen, Paul Thienphrapa, Long Qian
- **Hardware and Testing:** Lawton Verner, Ravi Gaddipati, Gang Li, Nirav Patel, Zhixian Zhang, Alex Camillo
- **Intuitive Surgical:** Simon DiMaio, Arpit Mittal, Kollin Tierling, Dale Bergman
- **Support:** NSF EEC 9731748, EEC 0646678, MRI 0722943, NRI 1208540, NRI 1327657, NASA NNX10AD17A
Questions?

da Vinci Patient Side Manipulators (PSMs)
da Vinci Master Tool Manipulators (MTMs)
IEEE-1394 controllers (4 enclosures with 8 nodes)
Stereo Viewer
Control PC
Footpedal Tray