Edward A. Lee
Robert S. Pepper Distinguished Professor

Ninth Biennial Ptolemy Miniconference

February 16, 2011
Berkeley, CA, USA
Staff:
- Christopher Brooks
- Edward A. Lee (PI)
- Stavros Tripakis
- Mary P. Stewart

Postdocs:
- Patricia Derler
- Slobodan Matic
- Eleftherios Matsikoudis
- Jan Reineke

Grad Students:
- Ilge Akkaya
- Dai Bui
- Shanna-Shaye Forbes
- Ben Lickly
- Isaac Liu
- Chris Shaver
- Jia Zou
- Mike Zimmer

Visiting Scholars:
- Hugo Andrade
- Janette Cardoso
- John Eidson

Photo by Chamberlain Fong
The 1\textsuperscript{st} Biennial Ptolemy Miniconference: 1995

Ptolemy Project

System-Level Design of Signal Processing Systems

Ptolemy Research

- Design complexity management.
- Visual, algorithm-level system design.
- Formal methods for dataflow systems.
- Programming language semantics.
- Software and hardware synthesis.
- Parallel architectures, partitioning, and scheduling.

This highly multidisciplinary project addresses system-level design and implementation of signal processing systems.

UNIVERSITY OF CALIFORNIA AT BERKELEY
The 1st Biennial Ptolemy Miniconference: 1995

Implementation of Signal Processing Systems

**Hardware/Software Synthesis**
- Design of heterogeneous embedded systems.
- Real-time systems.
- Synthesis of software from dataflow graphs.
- System-level hardware design.
- Cosimulation of hardware and software.
- Codesign of hardware and software.

The design philosophy in Ptolemy is heterogeneous, allowing for effective use of specialized design tools within a general system-level design environment.
The 1st Biennial Ptolemy Miniconference: 1995
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Where to From Here?

- Real-time scalable computing.
- Scalable embedded systems design.
- Design migration from abstract to concrete.
- Formal methods based on partial orders.
- Hybrid systems: combining FSM with dataflow.
- Modeling and analysis of random systems.
- Design of nondeterminate systems.
- Complexity management.
- Design visualization and documentation.
- Partial evaluation and incremental compilation.
- Models for back-end signal interpretation.
- Heterogeneous scheduling.

UNIVERSITY OF CALIFORNIA AT BERKELEY
The 2nd Biennial Ptolemy Miniconference: 1997

Visual Design

- Formal properties.
- Scalability.
- Scheduling.
- Partitioning.
High-Performance Scalable Computing (HPSC) modeling by Sanders, a Lockheed-Martin Company.
Applications of Ptolemy in Securities Trading

or,
Playing the Markets with Ptolemy

Tom Lane
Structured Software Systems, Inc.
The 2nd Biennial Ptolemy Miniconference: 1997

Overview

Chatoyant is a computer aided design tool for the design of Free Space Optoelectronic Information processing (FSOI) Systems. Simulation - Analysis - Synthesis - Interface

Enable the modeling of FSOI systems without costly prototyping

Chatoyant Stars in Ptolemy

<table>
<thead>
<tr>
<th>Modulators</th>
<th>Detectors</th>
<th>Lenses</th>
<th>Lenslets</th>
</tr>
</thead>
<tbody>
<tr>
<td>Detector Size</td>
<td>Focal Length</td>
<td>Diameter</td>
<td>Focal Length</td>
</tr>
<tr>
<td>Detector Spacing</td>
<td>Diameter</td>
<td>Distance</td>
<td>Diameter</td>
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<tr>
<td>Distance</td>
<td>Distance</td>
<td>Distance</td>
<td></td>
</tr>
<tr>
<td>x, y offsets</td>
<td>x, y offsets</td>
<td>x, y offsets</td>
<td></td>
</tr>
<tr>
<td>Radius of Integration</td>
<td>Spacing</td>
<td></td>
<td></td>
</tr>
<tr>
<td>R, C, A</td>
<td>Number</td>
<td></td>
<td></td>
</tr>
</tbody>
</table>
The 2nd Biennial Ptolemy Miniconference: 1997
The switch to Ptolemy II

### Ptolemy Classic vs Ptolemy II

<table>
<thead>
<tr>
<th>Classic</th>
<th>Ptolemy II</th>
</tr>
</thead>
<tbody>
<tr>
<td>C++</td>
<td>Java</td>
</tr>
<tr>
<td>Mature platform</td>
<td>Experimental</td>
</tr>
<tr>
<td>Does code generation</td>
<td>All Java (now)</td>
</tr>
<tr>
<td>Monolithic tool</td>
<td>Modular packages</td>
</tr>
<tr>
<td>Standalone</td>
<td>Networked</td>
</tr>
<tr>
<td>Sequential</td>
<td>Multi-threaded</td>
</tr>
<tr>
<td>GUI-centric</td>
<td>Applet-centric</td>
</tr>
<tr>
<td>Ad-hoc development</td>
<td>Good software practice</td>
</tr>
<tr>
<td>Dynamically linked</td>
<td>Reflective</td>
</tr>
<tr>
<td>Astronomical lexicon</td>
<td>Boring lexicon</td>
</tr>
</tbody>
</table>

### The Ptolemy Project

Heterogeneous Modeling and Design

- Principal Investigator
  - Edward A. Lee
- Staff
  - Jennifer Bosler
  - Christopher Hylands
  - Mary P. Stewart
- Postdocs/Researchers
  - Bart Kienhuis
  - James Lundblad
  - John Reekie
- Students
  - John Davis, II
  - Ron Galicia
  - Mudit Goel
  - Bilung Lee
  - Michael Leung
  - Jie Liu
  - Xiaojun Liu
  - Lukito Muljadi
  - Steve Neuendorffer
  - Nail Smyth
  - Jeff Tsay
  - William Wu
  - Yuhong Xiong

- Choosing the best modeling technique can have a far bigger impact than using a faster modeling tool.
- Mixing modeling techniques permits multi-domain modeling using the best available modeling techniques.
- Threads, objects, and UI infrastructure helps with both.
- Network integration of Java promotes sharing of modeling methods.
- Java performance and infrastructure is rapidly improving.
3rd Biennial PtConf 1999

Algorithm Analysis and Mapping Environment for Adaptive Computing Systems

Eric Pauer, Cory Myers, Ken Smith, and Paul Fiore

ACS Domain - CGFPGA Target

Winograd dataflow (ACS domain)

VHDL design (generated)

CGFPGA target yields: VHDL design and schedule

The results are sent to synthesis and place/route, yielding complete FPGA implementation!

Hardware-in-the-loop

SDF Galaxy

SDF Wildforce star executes complete FPGA design in hardware on Annapolis Wildforce FPGA board
3rd Biennial PtConf 1999

Cosimulating Synchronous DSP Designs with Analog RF Circuits
José Luis Pino and Khalil Kalbasi

HP Ptolemy

Bit/True Synthesizable Models
Behavioral RF/Analog Models
DSP Models
System Level Intellectual Property
Digital Filter Tool
SPICE and Circuit-Envelope Cosimulation

Example: 16 QAM Tx/Rx

(DSP), Synthesized I,Q Data Generator.
RFIC I,Q Modulator
Demodulator

HP Ptolemy Data Flow

Test Instruments
Rapid Prototyping of RADAR Signal Processing Systems using Ptolemy Classic

Ptolemy MiniConference UCB
Denis Aulagnier, Patrick Meyer, Hans Schurer, Xavier Warzee, THALES

CONCLUSIONS (1)

- Main functional requirements are met by the final design (12 of the 19 requirements)
- Throughput and latency requirements are almost met; expected to be met in case of full speed G4 daughter cards and/or VSIPF functions redesign
- Review of graphical Ptolemy designs seems faster and more efficient than code reviews
  - Disadvantage is parameter handling and scope.
  - Design is highly multi-rate, but this is difficult to see
  - Some functionality is inside stars (hidden)
- Total design, validate & test time for bare beamformer was 354.5 hours, while normal development takes 481 hours: Approximately 36% faster (improvement ~1.36)
Director:
- Edward A. Lee

Staff:
- Christopher Hylands
- Susan Gardner (Chess)
- Nuala Mansard
- Mary P. Stewart
- Neil E. Turner (Chess)
- Lea Turpin (Chess)

Postdocs, Etc.:
- Joern Janneck, Postdoc
- Rowland R. Johnson, Visiting Scholar
- Kees Vissers, Visiting Industrial Fellow
- Daniel Lázaro Cuadrado, Visiting Scholar
Relating the problem level with the implementation level
Foundations

Our contributions:

• Behavioral Types
• Domain Polymorphism
• Responsible Frameworks
• Hybrid Systems Semantics
• Dataflow Semantics
• Tagged Signal Model
• Starcharts and Modal Model Semantics
• Discrete-Event Semantics
• Continuous-Time Semantics

Giving structure to the notion of “models of computation”
HyVisual – Hybrid System Modeling Tool
Based on Ptolemy II, Released Jan. 2003

HyVisual is a targeted tool, designed for hybrid system modeling.
6th 2005

KEPLER: Overview and Project Status

Bertram Ludäscher
ludaesch@ucdavis.edu

Some KEPLER Actors (out of 160+ ... and counting...)

KEPLER/CSP: Contributors, Sponsors, Projects

Ilkay Altintas SDM, MI ADR, Resurgence, EOL, ...
Kim Baldrige Resurgence, EOL, ...
Chad Barkley SEEK
Shawn Bowers SEEK
Terence Critchlow SDM
Tobin Frick ROAIDnet
Jeffrey Grethe BiRN
Christopher H. Brooks Ptolemy II
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Matt Jones SEEK
Werner Krebs, EOL
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Steve Neuenzettel Ptolemy II
Jing Tao SEEK
Mladen Vouk SDM
Xiaowen Xin SDM
Yang Zhao Ptolemy II
Bing Zhu SEEK
...

www.kepler-project.org

Collab. tools: IRC, cvs, skype, Wiki: hotTopics, FAQs, ...

Ptolemy Project, Berkeley 22
Growth of the Cal actor language

6th 2005

Jörm W. Janneck
Xilinx Research Labs

Programming with actors

driver application
MPEG-4 decoder

meterics
- 60 atomic actors
- 22 atomic actor classes
- 3307 LOC (Cal)
- LOC per actor class between 7 and 2054

actor constructs
- variable token rates
- static/cyclostatic rates
- data-dependent choice
- test for absence of tokens
- non-prefix-monotonic actors

code generation
2D-IDCT, version 2
- interleave row and column streams
- pipelined 1D-IDCT
- result:
  - 6 multipliers with 46% utilization
  - more operator re-use costly in terms of operand routing
  - >100 Mhz clock
7th 2007

The Kepler Project
Overview, Status, and Future Directions

Matthew B. Jones
on behalf of the Kepler Project team

National Center for Ecological Analysis and Synthesis
University of California, Santa Barbara

REAP breakdown

System-Engineer's View
- manipulate data grid remotely

Scientist's View
- nowcast, forecast & simulation

Outside User's View
- public interfaces

Figure from Bowers and McPhillips
8th 2009

Cyber-Physical Systems (CPS)
Where it is going

CPS: Orchestrating networked computational resources with physical systems.

Ptolemy Project, Berkeley 25
PTIDES: Programming Temporally Integrated Distributed Embedded Systems

Distributed execution under DE semantics, with "model time" and "real time" bound at sensors and actuators.
Parallel Virtual Machines in Kepler

Daniel Zinn
Xuan Li
Bertram Ludaescher

UC Davis
Let the show begin!