Edward A. Lee
Robert S. Pepper Distinguished Professor

Tenth Biennial Ptolemy Miniconference

November 7, 2013
Berkeley, CA, USA
Technical Staff:
- Christopher Brooks
- Marten Lohstroh
- Edward A. Lee (PI)
- Stavros Tripakis
- Mary P. Stewart

Postdocs:
- Patricia Derler
- Eleftherios Matsikoudis
- Armin Wasicek

Grad Students:
- Ilge Akkaya
- Hokeun Kim
- Chris Shaver
- Matt Weber
- Mike Zimmer
- Ben Zhang

Visiting Scholars:
- Hugo Andrade
- Jain Cai
- David Broman
- John Eidson

Undergrads:
- Sam Mansfield

Photo by Chamberlain Fong
The 1st Biennial Ptolemy Miniconference: 1995

Ptolemy Project 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 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
The 1st Biennial Ptolemy Miniconference: 1995

The Ptolemy Project

Shuva Bhattacharyya
Joseph T. Buck
Wan-Teh Chang
Brian L. Evans
Steve X. Gu
Sangjun Hong
Christopher Hylands
Asawaree Kalavade
Alan Kamas
Allen Lao
Bilung Lee
Edward A. Lee
David G. Messerschmitt
Praveen K. Murthy
Thomas M. Parks
Jose Luis Pino
Farhana Shiekh
S. Srinivasan
Juergen Teich
Warren W. Tsai
Patrick J. Warner
Michael C. Williamson

Domains in Ptolemy

PTOLEMY KERNEL

process networks
dynamic dataflow
Boolean dataflow
synchronous dataflow

multidimensional SDF
circuit simulation
discrete-event

design methodology management

Ptolemy Project, Berkeley 6
The 1st Biennial Ptolemy Miniconference: 1995

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.
The 2\textsuperscript{nd} Biennial Ptolemy Miniconference: 1997

Visual Design

- Formal properties.
- Scalability.
- Scheduling.
- Partitioning.

Approximate a Square Wave by a Finite Number of Sinusoids

Square Wave Approximated by Sinusoids
High-Performance Scalable Computing (HPSC) modeling by Sanders, a Lockheed-Martin Company.
The 2nd Biennial Ptolemy Miniconference: 1997

Applications of Ptolemy in Securities Trading

or,

Playing the Markets with Ptolemy

Tom Lane

Structured Software Systems, Inc.
**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>Modulator</th>
<th>Detector</th>
<th>Lens</th>
<th>Lenslet</th>
</tr>
</thead>
<tbody>
<tr>
<td>Area</td>
<td>Detector Size</td>
<td>Focal Length</td>
<td>Focal Length</td>
</tr>
<tr>
<td>Focusing</td>
<td>Detector Spacing</td>
<td>Diameter</td>
<td>Diameter</td>
</tr>
<tr>
<td>Lambda</td>
<td>Distance</td>
<td>Distance</td>
<td>Distance</td>
</tr>
<tr>
<td>Spotsize</td>
<td>x, y offsets</td>
<td>x, y offsets</td>
<td>x, y offsets</td>
</tr>
<tr>
<td>Filename</td>
<td>Radius of Integration</td>
<td>Spacing</td>
<td>Number</td>
</tr>
<tr>
<td>Gauss/Ray</td>
<td>R, C, A</td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

**Modeling Free Space Optoelectronic Systems Using Ptolemy**

Steven P. Levitan
Donald M. Chiarulli
Tim P. Kurzweg
Mark A. Rempel

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Funding: National Science Foundation- MIP-9421777
The 2\textsuperscript{nd} Biennial Ptolemy Miniconference: 1997

Tycho (1)

Tycho (2)

Tycho

Christopher Hylands
Edward A. Lee
H. John Reekie

Contributors:
Kevin Chang
Wan-Teh Chang
Cliff Cordeiro
Wei-Jen Huang
Joel King
Farhana Sheikh
Mario Jorge Silva
3rd Biennial PtConf 1999

The switch to Ptolemy II

Ptolemy Classic vs Ptolemy II

- **C++**
- **Mature platform**
- Does code generation
- **Monolithic tool**
- Standalone
- Sequential
- **GUI-centric**
- Ad-hoc development
- Dynamically linked
- Astronomical lexicon

- **Java**
- Experimental
- All Java (now)
- Modular packages
- Networked
- Multi-threaded
- Applet-centric
- Good software practice
- Reflective
- Boring lexicon

Modeling in Java ?!?!?!?!

- 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.

The Ptolemy Project

Heterogeneous Modeling and Design

Principal Investigator
Edward A. Lee

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Michael Leung
Jie Liu
Xiaojun Liu
Lukito Muliadi
Steve Neunorffer
Neil Smyth
Jeff Tsay
William Wu
Yuhong Xiong
3rd Biennial PtConf 1999

Algorithm Analysis and Mapping Environment for Adaptive Computing Systems

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

Lockheed Martin Company
Nashua, NH 03061

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!

Dataflow/Hardware schedule

Hardware-in-the-loop

SDF Galaxy

SDF Wildforce star executes complete FPGA design in hardware on Annapolis Wildforce FPGA board

Ptolemy Project, Berkeley 14
3rd Biennial PtConf 1999

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

HP Ptolemy

Example: 16 QAM Tx/Rx

(PSP), Synthesized I/Q Data Generator.

Demodulator
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 VSIP 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

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- J. Adam Cataldo
- Chris Chang
- Elaine Cheong
- Sanjeev Kohli
- Xiaojun Liu
- Eleftherios D. Matsikoudis
- Stephen Neuendorffer
- James Xeh
- Yang Zhao
- Haiyang Zheng
- Rachel Zhou
Relating the problem level with the implementation level

Heterogeneous, problem-level description

Heterogeneous, implementation-level description

Modeling

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

KEPLER: Overview and Project Status

Bertram Ludäscher
ludaesch@ucdavis.edu

Associate Professor
Dept. of Computer Science & Genome Center
University of California, Davis

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

KEPLER/CSP: Contributors, Sponsors, Projects

www.kepler-project.org

Collab. tools: IRC, cvs, skype, Wiki, hotTopics, FAQs...
6th 2005

Growth of the Cal actor language

Driver application
MPEG-4 decoder

Metrics
- 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 reuse costly in terms of operand routing
  - >100 Mhz clock

Pipelined 1-D IDCT

Programming with actors

Jörn W. Janneck
Xilinx Research Labs
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

Figure from Bowers and McPhillips
Cyber-Physical Systems (CPS)
Where it is going

CPS: Orchestrating networked computational resources with physical systems.
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
Using MapReduce Actor for Word Count

**Word count workflow in Kepler**

- **Map sub-workflow**
  - MapInputValue
  - String Splitter
  - Iterate Over Array
  - MapOutputList
- **Reduce sub-workflow**
  - ReduceInputList
  - Expression `sum(inputArray)`
  - ReduceOutputValue

**Sub-workflow in IterateOverArray actor**

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- Isaac Liu
- Chris Shaver
- Jia Zou
- Mike Zimmer

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

Distributed Execution Architectures in Kepler
Jianwu Wang, Daniel Crawl, Ilkay Altintas, Chad Berkley, Matthew B. Jones, San Diego Supercomputer Center, UCSD
Semantics of Modal Models in Ptolemy II
Edward A. Lee, Stavros Tripakis

Giving semantics to modal models

Goal:
define $F, P$ functions for the modal model

$F_c, P_c$ functions already defined for the "controller" automaton

$F_1, P_1$ functions already defined for this refinement

$F_2, P_2$ functions already defined for this refinement
Static Analysis using the Ptolemy II Ontologies Package
Charles Shelton, Elizabeth Latronico (Bosch)
Ben Lickly, Edward Lee (UC Berkeley)

Fix the Model Error and Reanalyze

This erroneously connects Acceleration output data to an input expecting Velocity data

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- Janette Cardoso
- John Eidson
Workflow Fault Tolerance for Kepler
Sven Köhler, Timothy McPhillips, Sean Riddle, Daniel Zinn, Bertram Ludäscher
UC Davis

Example: Checkpoint in SDF

Workflow with a mix of stateful and stateless actors. Corresponding schedule of the workflow with a fault during invocation B:2.
10th 2013

Let the show begin!