Methodologies for Rapid Prototyping of Tools for Visualizing Performance of Parallel Systems

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OUTLINE:

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II. Overview of PARADISE

III. User View

IV. Meta-Tool Designer View

V. Toolkit View

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INTRODUCTION

Selected Questions:

- What performance data would you like to see from a 1K-10K PE MIMD system?
- What performance data would you like to see from a large SIMD system?
- What is the relative importance of system performance data versus application data?
- Do we need time-dependent data or are averages sufficient?
- How do we compare application performance across multiple architectures?
- Can we get more detailed, portable data than just execution times?
- What kind of performance tools do we need?

Answers:

- Don't know. Maybe this, but what about that? Not sure.

$\rightarrow$ Too early to tell yet?

MOTIVATION

- Complexities of Parallel Software Development
- Standard Sequential Methods Inadequate
- Visualization Techniques: "Program Visualization"

PROBLEMS

- Visualization is Special Purpose in Nature - Custom Tools
- Expensive Development of Visualization Tools
- Requires Working Knowledge of Graphics System
- What to Visualize?

  $\Rightarrow$ Every User Has Unique View and Intuition

  $\Rightarrow$ Is the Effort Actually Worth the Benefit?

APPROACHES

- User View

    $\rightarrow$ What Does the User Want?

- Meta-Tool Designer View

    $\rightarrow$ What Can a Meta-Tool Designer Provide?

- Toolkit View

    $\rightarrow$ Are We Making It All Too Complicated?

$\Rightarrow$ Why Do Users Do It The Hard Way?

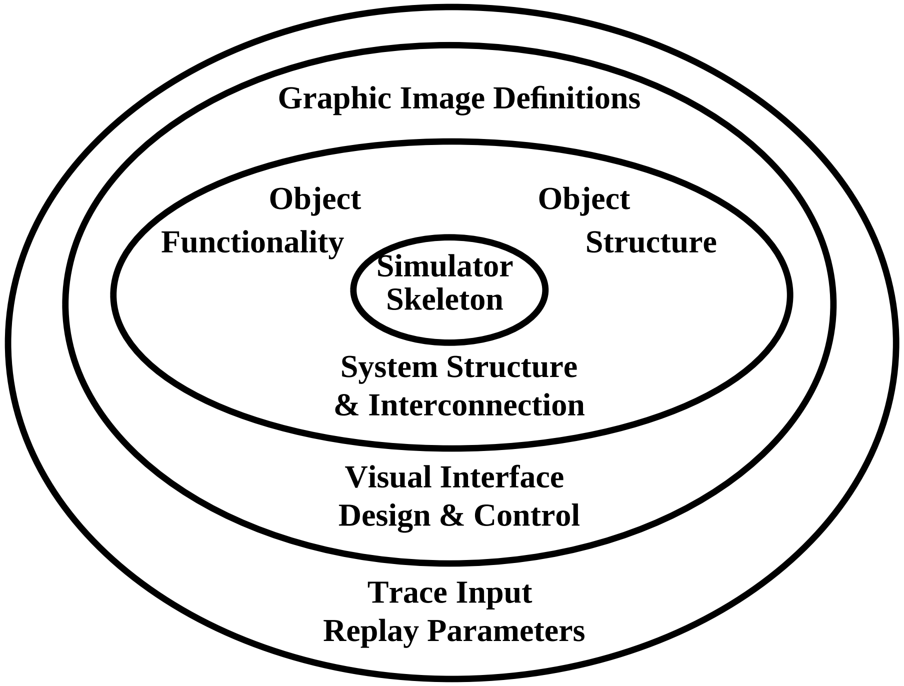
PARADISE

PARallel Animated DebuggIng and Simulation Environment

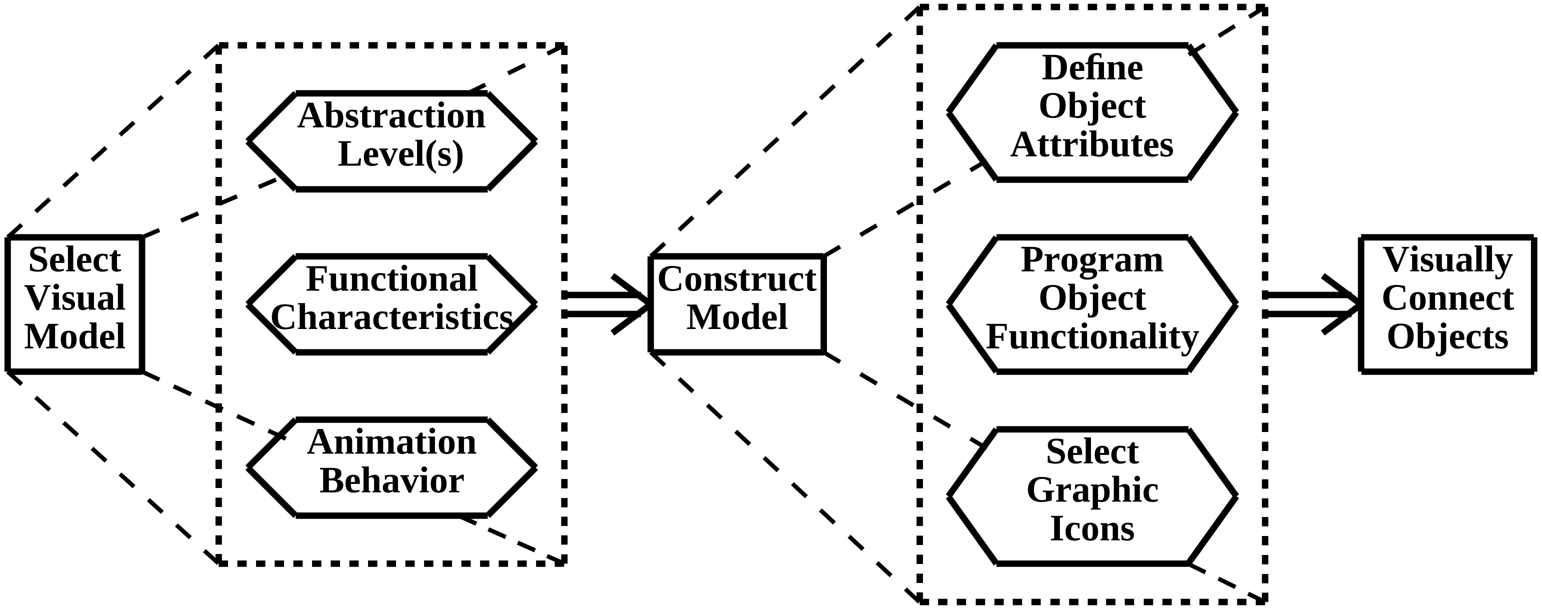
- Meta-Tool for Constructing Visual Analysis Tools
- Custom Visual Models
  - $\longrightarrow$ Object-Oriented, Modular
  - $\longrightarrow$ Animated Simulations
- Interactive Visual Interface
  - $\longrightarrow$ Model Construction
  - $\longrightarrow$ Simulation Control
  - $\longrightarrow$ Manipulate Objects in Model Visually

PARADISE INTERFACE

PARADISE LAYERED STRUCTURE



SCENARIO OF USE:



- User Constructs Visual Model
- PARADISE Animates Overall System Behavior
  - → Individual Object State
  - → Interaction Among Objects
  - → Global System Dynamics

USER VIEW

- Custom Views / Configurability

    → Individual User Preferences & Perspectives

    → "Law of Unlimited Options"
    Users will continue to request new options throughout development and usage of tools. The number of options expands without bound and the tool is never completed.

    → User Never Completely Pleased Unless They Can Customize

⇒ PARADISE Provides Design of Arbitrary Objects

  → User Chooses Object Images and Functionality

  → Model Caters to Individual User Intuition

⇒ Pablo/Hyperview & Triplex Configurability Via Filters

  → User Creates Configurable Processing Modules

  → Arbitrarily Arrange Filters to Produce Views

⇒ Tango, Voyeur, BALSA, Q+ - Arbitrary Animations

USER VIEW

- Flexibility and Expressive Power of Interface

    $\rightarrow$ Want Power to Construct Highly Custom Analyses

    $\rightarrow$ Want Simple and Automatic Alternatives As Well

    $\Rightarrow$ e.g. C Language - Low & High Level Capabilities

$\Rightarrow$ PARADISE Supports Abstract Visual Interface

$\rightarrow$ Animations as Complex as Desired (Advantage?)

$\rightarrow$ Automated Simulations

$\rightarrow$ Visual Model Specification Not Automatic

$\rightarrow$ Needs More Fundamental Graphics Capabilities

$\Rightarrow$ ParaGraph & TOPSYS Highly Automatic

$\rightarrow$ Less Flexible?

USER VIEW (cont.)

- Fast and Efficient Use

  $\rightarrow$ General Functionality as Automatic as Possible

  $\rightarrow$ Concise Specification of User Preferences

  $\rightarrow$ Natural Interface for Intuitive Interaction

  $\rightarrow$ Accumulation of User Configurations and Style

  $\Rightarrow$ One-Time Setup for Years of Analyses

  $\Rightarrow$ What Information?

$\Rightarrow$ PARADISE Visual Model Construction and Simulation Control

$\rightarrow$ Reusability of Specification Through Libraries

$\rightarrow$ Still Some Textual Specification

$\Rightarrow$ ParaGraph & TOPSYS - Automatic Views From Visual Menus

$\Rightarrow$ Pablo/Hyperview Visual Filter Configuration & Defaults Manager

USER VIEW (cont.)

- Multiple Granularity Control
  - $\rightarrow$ Visualization Speed Control
    - $\Rightarrow$ Adjustable Speed for Focusing
    - $\Rightarrow$ Flash Quickly Through Uninteresting Portions
    - $\Rightarrow$ Slow Down for Close Examination of Important Details
  - $\Rightarrow$ PARADISE, SHMAP, Others - Support Variable Speed Controls
  - $\Rightarrow$ Many Tools Support Start/Stop & Single Step
  - $\Rightarrow$ Real Time vs. Post Mortem?
    - $\rightarrow$ Control Speed in Real Time?
    - $\rightarrow$ Post Mortem Flexible, But Cumbersome Data Collection & Storage

USER VIEW (cont.)

- Multiple Granularity Control (cont.)
  - $\rightarrow$ Visualization Direction Control
    - $\Rightarrow$ Forward and Reverse Playback
    - $\Rightarrow$ Causality Problem - When to Stop?
    - $\Rightarrow$ Inherent Human Inaccuracy - Oops, Rewind !!
  - $\Rightarrow$ Difficult With PARADISE $\rightarrow$ Reverse Functionality? (Histories)
  - $\Rightarrow$ Easy With Timeline Displays
  - $\Rightarrow$ Not Easy for Most Displays
    - $\rightarrow$ No Inverse for Display Functions
    - $\rightarrow$ Undrawing Graphics?

USER VIEW (cont.)

- Multiple Granularity Control (cont.)
  - → Abstraction Level & Display Size
    - ⇒ Skip Low Level Details During General Viewing
    - ⇒ Avoid Unnecessary Sensory Overload
    - ⇒ Examine Low Level Details of Interest
  - → Analogies
    - ⇒ Human Grasping - Quick Move, Then Slow Grasp
    - ⇒ Learning - High-Level Overview, Then Low-Level Details
    - ⇒ Far Side Cartoons - Punch Line is in the Detail
  - ⇒ PARADISE Paradigm Supports Abstraction Capabilities
    - → Model Hierarchy
    - → Abstraction Zooming

USER VIEW (cont.)

- Animations and Views
  - $\rightarrow$ What Level of Abstraction or Detail?
  - $\rightarrow$ Scalability?
    - $\Rightarrow$ Some Analyses On Small Scale Elude To Large Scale
    - $\Rightarrow$ Many Large Scale Analyses Require Large Scale Details
    - $\Rightarrow$ Triplex "Binning" of Equivalence Classes
  - $\rightarrow$ How to Specify Visual Details - Choices / Alternatives
    - $\Rightarrow$ Fixed vs. Dynamic Images
    - $\Rightarrow$ Movable Images
    - $\Rightarrow$ Discrete vs. Continuous
  - $\Rightarrow$ PARADISE - Dynamic Images (Discrete), Immobile
  - $\Rightarrow$ TOPSYS (VISTOP) - Fixed Images, Mobile
  - $\Rightarrow$ Tango - Continuous Animation

USER VIEW (cont.)

- Extra Assistance in Analysis
  - $\rightarrow$ Show Information To Guide User
    - $\Rightarrow$ User Doesn’t Always Know Where to Start
  - $\rightarrow$ Display Information in Views Which Stimulate User
    - $\Rightarrow$ Emphasize Similarities and Contrasts
    - $\Rightarrow$ Inherently Provided By "Good" Visualization

$\Rightarrow$ Unanswered Issue

- $\rightarrow$ Custom vs. General
  - $\Rightarrow$ What is the Best Visual Display?
  - $\Rightarrow$ Is There a Best At All?
- $\rightarrow$ How Much of the Burden is on User Intuition?
- $\rightarrow$ Can General Visualization Spark User Ideas?

META-TOOL DESIGNER VIEW

- Mask Unnecessary Detail From User
  - → Hide Internal Graphics & Simulation Details
  - → Utilize Abstractions in User Interface - Visual Semantics
    - ⇒ Control of Simulation - "Visual Programming" of Analysis Control
    - ⇒ Specification of Visualization - Abstract Visual Language
      - Solves Visual Programming Problem?
      - More Difficult Than Natural Language - Universal Language
      - Possible Within Limited Context of Visualization?

⇒ PARADISE Hides Internal Simulation and Graphics Details

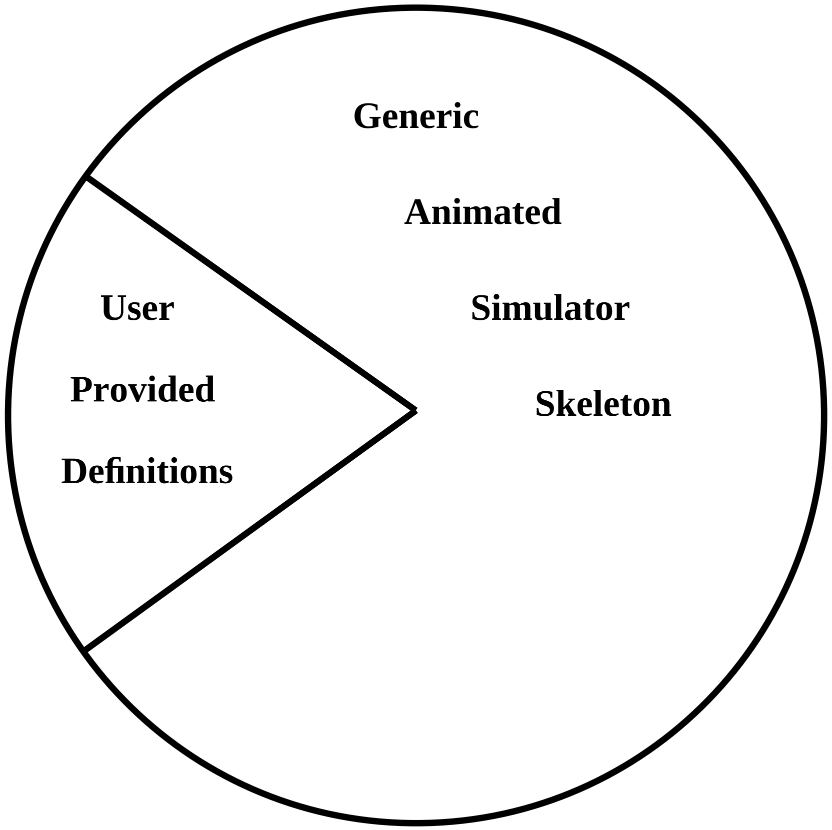
- → Plug-In Simulator Concept (See Figure)
- → Specification of Model Functionality → Cumbersome
- → Need Better, More Abstract, Visual Semantics

⇒ Tango Uses Abstract Visual Manipulations

- → Highly Integrated With Source Program - Need Separation of Concerns

Plug-In Simulator Concept

User generates a module of fundamental system definitions of event types and objects, including structure and functionality, and then "plugs in" these definitions, into a generic animated simulator structure, to produce a customized animated simulation environment.



→ Complete Customized Animated Simulator

META-TOOL DESIGNER VIEW (cont.)

- Provide Customizability in Views and Options
  - $\rightarrow$ Generalize and Formally Classify Fundamental Parameters
    - $\Rightarrow$ What Are These Parameters?
    - $\Rightarrow$ What Operations On These Parameters?
  - $\rightarrow$ Construct Means for Specifying Parameters of Classes
    - $\Rightarrow$ Abstract, Probably Visually-Oriented, Language
  - $\rightarrow$ Design Environment Without Static Semantics
    - $\Rightarrow$ Minimal Predefined Parameters and Configurations
    - $\Rightarrow$ Generic Skeleton - Details To Be Filled In By User
  - $\Rightarrow$ PARADISE, Tango, Pablo/Hyperview, Triplex
    - $\rightarrow$ Various Levels of Customizability
    - $\rightarrow$ Assortment of Visual "Languages" or Interfaces

META-TOOL DESIGNER VIEW (cont.)

- Provide Flexibility for User Specification Interaction
  - $\rightarrow$ Allow Dynamic, Interactive Specification
    - $\Rightarrow$ Interpretation for Dynamic Characteristics & Parameters
    - $\Rightarrow$ Dynamic Compilation for Static Characteristics & Parameters
    - $\Rightarrow$ Interactive Modification of Specification

$\Rightarrow$ PARADISE, Pablo/Hyperview, Triplex, ParaGraph

- $\rightarrow$ Various Levels of Dynamic Specification

META-TOOL DESIGNER VIEW (cont.)

- Provide Fast and Efficient Interface
  - → Minimize User Overhead
    - ⇒ Minimal Number of Steps for Operations
    - ⇒ Reduce Keystrokes, Mouse Clicks, etc.
  - → Automatic Capabilities
    - ⇒ Intrinsic Functions For Standard (Generic) Analysis Functions
  - → Specification Reuse
    - ⇒ Simple Storage and Retrieval Interface
    - ⇒ Libraries for Application Sets
    - ⇒ Replication Schemes / Specification "Macros"
  - → Default User Preferences
    - ⇒ Categorize Candidate Parameters
    - ⇒ Organize Information Using Database
    - ⇒ Concise Yet Simple Interface

META-TOOL DESIGNER VIEW (cont.)

- Providing Animations and Views
  - $\rightarrow$ How to Drive An Animation - State Machines?
    - $\Rightarrow$ Moore Approach - Large Collections of States Control Output
    - $\Rightarrow$ Mealy Approach - Fewer, More Complicated States
  - $\rightarrow$ Specify Animations?
    - $\Rightarrow$ Sequences of Discrete Images
    - $\Rightarrow$ Initial States & Functions for Continuous Modulation
    - $\Rightarrow$ Expressions for Relating Performance Data to Animation

TOOLKIT ALTERNATIVE

- Provide Limited Set of General Tools
- User "Makes Tools Work" for Desired Analysis

  $\Rightarrow$ e.g. Unix Hacker, "Hammer Fixes Anything" Approach.

- Larger the Tool Kit, Better the Solution
- Adding New Tools to Kit - Cost / Performance Issue

Drawback:

- Even When "Good" Solution Exists, High Overhead to Create

  $\rightarrow$ User Experience With Tool Kit Reduces Overhead

  $\rightarrow$ Feasible Alternative - To What Extent?

$\Rightarrow$ TOPSYS, ParaGraph, IPS-2, Faust

  $\rightarrow$ Lean Towards Tool Kit Perspective

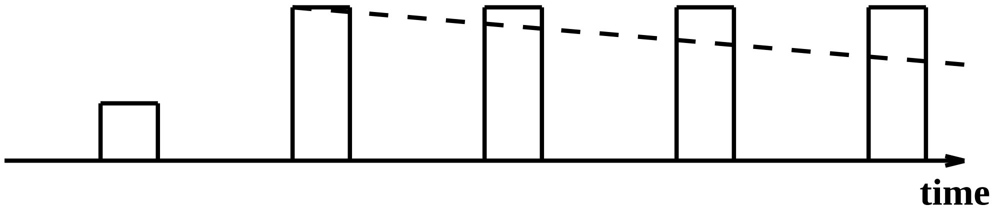
EFFECTS OF EXPERIENCE AND LEARNING

Time for First Analysis = Learn_Time + Design_Time(Analysis.1)

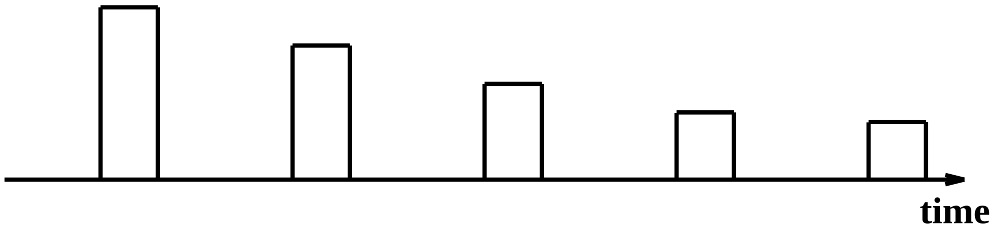
Time for Subsequent Analyses = Design_Time(Analysis.N) - f(Experience)

$\rightarrow$ Pay the "Dues" of Learning, Benefit From Experience

- Tool Kit Approach



- Meta-Tool Approach



Directions for Future Work

Δ Consideration of True User Needs and Perspectives

Δ Development of Abstract, Natural, Visual Specification Language

→ Construction of Specifications for Analysis

→ Visual Programming in General

→ Manipulation of Graphics in Animation

Δ Range of Capability → Simple Power

Δ More Flexible User Preference Integration

Δ Visualization Control Issues - Focusing & Scalability