Model-Driven Design for the Visual Analysis of Heterogeneous Data

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Heterogeneous Data Analysis

Massive amounts of data
Different abstraction levels
Different sources
  Databases, web, streaming data...
Different types of data
  Graphs, images, text, maps, tabular data...

How to turn heterogeneous data into meaningful information in turn into knowledge?

[CoVis 2009]

Data → Information → Knowledge

[Andrianantoandro et al., 2006]
Problem Statement

Users easily get **lost in the information landscape**

Intact mental map is essential

Provision of feature-rich applications is not sufficient

How to **support the user** during the analysis?
Which kind of support is needed?

**Orientation**

You are here!

**Guidance**

Turn-by-turn instructions
Two Levels of Support

**Orientation** that communicates the current position within the information landscape, the analysis steps that led there (*history*), and possible directions for further investigation.

**Guidance** that suggests concrete analysis steps to be taken in order to get from an analysis hypothesis to an analysis result.
Model-Driven Approach

Unified model captures:

**what** can be analyzed (**data set**)

**in which way** (**visual and computational interfaces**)

with **which goal** (**aim of this analysis task**), and

in **which order** (**Workflow**).
Three-Stage Process

Stage 1: Setup Model
- Step 1: Data Description
- Step 2: Interface-Data Assignment
- Step 3: Interface-Operator Assignment

Stage 2: Domain Model
- Step 4: Task-Data Assignment
- Step 5: Task-Operator-Sequence Assignment

Stage 3: Analysis Session Model
- Step 6: Workflow (Task-Sequence)
- Step 7: Workflow Pruning

Data Manager
Visual Analysis Expert
Domain Expert

SUPPORT EACH OTHER

Data Manager
Visual Analysis Expert
Domain Expert

Informed Analyst
Guided Analyst

Marc Streit
Step 1: Data Description

Dataset 1

Dataset 2

Dataset 3

Step 1: Data Description
Step 2: Interface-Data Assignment
Step 3: Interface-Operator Assignment
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Stage 1: Setup Model
Stage 2: Domain Model
Stage 3: Analysis Session Model

Informed Analyst
Guided Analyst
Step 2: Interface-Data Assignment

**Visual Interfaces**
- VI1
- VI2

**Comput. Interfaces**
- CI1
- CI2

**Dataset 1**
- VI1
- VI2

**Dataset 2**
- VI1
- VI2
- CI1

**Dataset 3**
- CI2

**Step 1**
Data Description

**Step 2**
Interface-Data Assignment

**Step 3**
Interface-Operator Assignment

**Step 4**
Task-Data Assignment

**Step 5**
Task-Operator-Sequence Assignment

**Step 6**
Workflow (Task-Sequence)

**Step 7**
Workflow Pruning

**Stage 1: Setup Model**

**Stage 2: Domain Model**

**Stage 3: Analysis Session Model**

Informed Analyst

Guided Analyst
**Step 3: Interface-Operator Assignment**

**Visual Interfaces**
- VI1
- VI2

**Comput. Interfaces**
- CI1
- CI2

**Operators**
- OP1

**Dataset 1**
- VI1
- VI2

**Dataset 2**
- VI1
- VI2
- CI1

**Dataset 3**
- CI2

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**Stage 1: Setup Model**
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**Visual Analysis Expert**

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**Guided Analyst**

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**Informed Analyst**
Stage 1 Completed

Visual Interfaces
- VI1
- VI2

Comput. Interfaces
- CI1
- CI2

Operators
- OP1
- OP2

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  (Task-Sequencer)
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Informed Analyst

Guided Analyst
**Step 4: Task-Data Assignment**

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- OP2

**Dataset 1**
- VI1
- VI2

**Dataset 2**
- VI1
- VI2
- CI1

**Dataset 3**
- CI2

**Tasks**
- Task A
- Task B
- Task C
- Task D

**Guided Analyst**
- Informed Analyst

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"Explore related pathways"
Step 5: Task-Operator Sequence Assignment

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- VI2

Comput. Interfaces
- CI1
- CI2

Operators
- OP1
- OP2

Dataset 1

Dataset 2

Dataset 3

"Explore related pathways"

Step 1: Data Description
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Step 6: Workflow (Task-Sequence)
Step 7: Workflow Pruning

Stage 1: Setup Model
Stage 2: Domain Model
Stage 3: Analysis Session Model

CI1 VI1 VI2
CI1 VI1 CI1 CI2
CI1

Guided Analyst
Informed Analyst

Task A: OP2
Task B: OP2, OP1
Task C: OP1
Task D: OP1

Visual Interfaces
Comput. Interfaces
Operators
Step 6: Workflow

Stage 1: Setup Model
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Interface-Data Assignment
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Workflow (Task-Sequence)

Step 7
Workflow Pruning

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- OP2

Guided Analyst

Informed Analyst
Step 7: Workflow Pruning

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Informed Analyst
Guided Analyst
Model Completed

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Informed Analyst
Guided Analyst

CI1
CI2
VI1
VI2
OP1
OP2
Utilizing the Model for Support

Model itself already provides a map for orientation

Analysis system bases recommended path on model for guidance
Stack’n’flip

Realizes orientation and guidance support
Employs full model

**Navigation view**
- Encodes history
- Presents all possible paths
- Highlights suggested steps

**Data view**
- Contains full interactive visualizations
Implementation Details

Realized within the CALEYDO framework

Model defined in XML

Stored in graph data structure

→ Back-end traverses graph
Implications

Data selection
- Dynamically determine relevant subset of data
- System can anticipate next steps
  - Pre-process, pre-fetch, pre-layout data in idle time

Missing data/interface detection
- Tasks might not be possible

Post analysis optimization
- Log the actually taken analysis path
- Use information for optimizing the workflows / application
Conclusion

Defined support levels

Orientation
Guidance

Presentation of a model-driven design concept

Stack’n’flip system realizing support
Future Work

Now: Analyst ≠ Author
Author feeds information into system
Analyst runs analysis
→ Static

Desired: Analyst = Author
Mesh authoring with system configuration
On-the-fly adaptation of model during analysis
Super Application?

Stack’n’flip demonstrates guidance in a single app scenario for a Super Application that can visualize everything.

Not Feasible! Solution: use existing applications.

Downsides:

- not integrated
- no highlighting, linking, etc.
Guidance Across Applications
How far should guidance go?

Analysts should **not** stop thinking.
Model-Driven Design for the Visual Analysis of Heterogeneous Data

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We are hiring PhD students!