Taxonomy of Effortless Creation of Algorithm Visualizations

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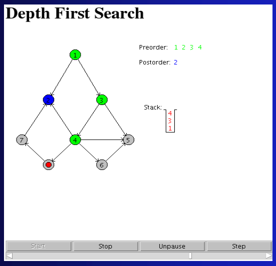
Outline

- What is Algorithm Visualization?
- Motivation & Objectives
- Taxonomy of Effortless Creation of AV
- Example Evaluation of 4 AV systems
- Conclusions

Software Visualization

- Visual = sight (lat.), **but**
- **Visualization** = "the power or process of forming a mental picture or vision of something not actually present to the sight"
- Research area in Software Engineering
- Algorithm Visualization is a subset of SV

Example: JAWAA



Areas of Interest

- Visualization Techniques
  - Pretty-printing, graph models, program visualization, algorithm animation, program auralization, specification styles
- Specialized Domains
  - Visualization of object-oriented programming, functional programming, knowledge based systems, concurrent programs, etc.
- Visualization for Software Engineering
  - Integrated Development Environments (IDE)
- **Visualization for Education & Evaluation**

Motivation

- SV research is technology driven
  - focus on new innovations such as
    - "backward and forward animation" or
    - "multiple views" or
    - "smooth animation"
- Missing connection to CS education research
  - the above are "nice to have", but do they **promote learning**?
- Need for communication channel between
  - SV developers (SV research) and
  - CS educators (CSE research)

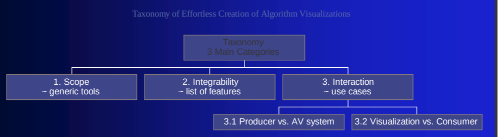
Objectives

1. Methods and tools to **analyse and evaluate** Software Visualizations (SV) (in Educational context)
2. Focus on the “burden of creating new visualizations”, i.e., the **time and effort** required to design, integrate and maintain the visualizations
3. **Taxonomy**: effortlessness in AV systems

Related work

- First evaluation of SV systems (2002) based on taxonomy of Price et al. (1993)
  - technical analysis, no link to CS education
- Questionnaire for CS educators (2004)
  - 22 answers (mostly from SV developers)
- Several other taxonomies and evaluations
  - e.g., Engagement taxonomy, Naps et al. (2003)
- The following taxonomy is a synthesis

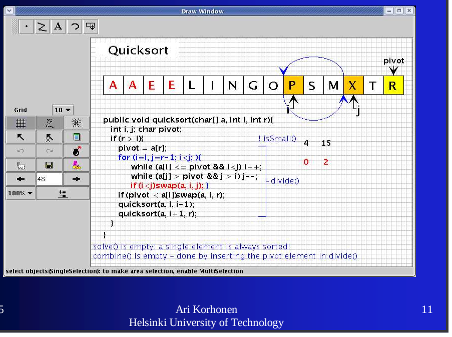
Taxonomy


Taxonomy of Effortless Creation of Algorithm Visualizations
Taxonomy
3 Main Categories
1. Scope
~ generic tools
2. Integrability
~ list of features
3. Interaction
~ use cases
3.1 Producer vs. AV system
3.2 Visualization vs. Consumer

Category 1: Scope

- The range or area the tool deals with
- **Generic tools** like Animal or JAWAA
  - one can produce (almost) any kind content
- vs. **non-generic** tools like MatrixPro and Jeliot 3
  - content (almost always) related to CS education
- More fine-grained classification in the paper

Example: Animal



```
public void quicksort(char[] a, int l, int r){
   int i, j; char pivot;
   if (r > l){
      pivot = a[r];
      for (i=l, j=r-1; i<j; ){
           while (a[i] <= pivot && i<j) i++;
           while (a[j] > pivot && j > i) j--;
           if (i<j)swap(a, i, j); }
      if (pivot < a[i])swap(a, i, r);
      quicksort(a, l, i-1);
      quicksort(a, i+1, r);
   }
}
```

solve() is empty: a single element is always sorted!
combine() is empty – done by inserting the pivot element in divide()

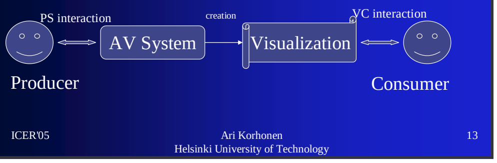
select objects(SingleSelection): to make area selection, enable MultiSelection

Category 2: Integrability

- Basically: a number of “features” that are “nice to have” in all SV systems including
  - easy installation and customization
  - platform independency
  - internationalization
  - documentation and tutorials
  - interactive prediction support
  - course management support
  - integration into a hypertext, etc.
- Bottom line: these are essential, but not sufficient

Category 3: Interaction

- Two kinds of interaction
  - Producer vs. System (PS)
    - resulting new visualization
  - Visualization vs. Consumer (VC)
    - use of the outcome



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Producer-System Interaction

- Producer can be, e.g,
  - teacher creating a new lecture demonstration
  - learner submitting a visualization to be graded
- Evaluation based on
  - number of use cases covered in terms of
    - no prior preparation at all
    - requires programming
    - requires programmin and annotation/instrumentation
  - time-on-task

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Use Cases (Based on Survey 2004)

- Lecture
  - single lecture example (14)
  - answering student's questions (14)
  - preparing questions for a lecture (14)
- Teaching material production
  - on-line illustrations (12)
  - static (e.g., lecturer's notes) illustrations (12)
- Examination/summative evaluation (12)
- Practice session material
  - exercises (12)
  - demonstrations for tutor/close labs (9)
  - demonstrations for students/closed labs (7)
  - demonstrations for students/open labs (6)

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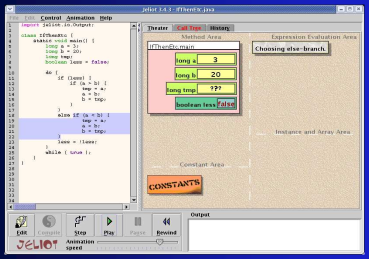
Example: Jeliot 3



```
import jeliot.io.Output;

class IfThenEtc {
    static void main() {
        long a = 3;
        long b = 20;
        long tmp;
        boolean less = false;

        do {
            if (less) {
                if (a > b) {
                    tmp = a;
                    a = b;
                    b = tmp;
                }
            }
            else if (a < b) {
                    tmp = a;
                    a = b;
                    b = tmp;
            }
            less = !less;
        }
        while ( true );
    }
}
```

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Producer-System Interaction

- Producer can be, e.g,
  - teacher creating a new lecture demonstration
  - learner submitting a visualization to be graded
- Evaluation based on
  - number of use cases covered
  - **time-on-task**
- Especially **on-the-fly** use like in MatrixPro
  - vs. prior preparation

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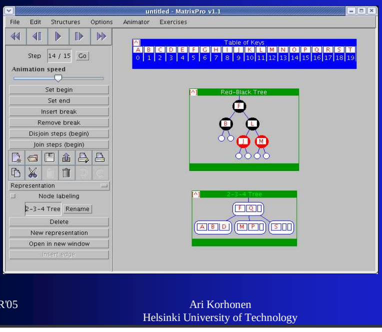
Example: MatrixPro



Step 14 / 15

2-3-4 Tree

Table of Keys

A	B	C	D	E	F	G	H	I	J	K	L	M	N	O	P	Q	R	S	T
0	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	19

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Visualization-Consumer Interaction

- Also consumer can be teacher or learner
- Trivial case: consumer = producer
- In evaluation, consumer = learner
- Engagement taxonomy
  - viewing
  - responding
  - changing
  - constructing
  - representing

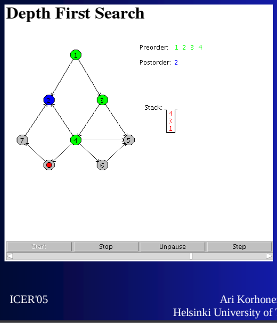
Example Evaluation of 4 Systems

- Systems visualizing concepts in Algorithms and Data Structures course
  - Animal
  - JAWAA 2
  - Jeliot 3
  - MatrixPro
- Disclaimer: some other systems could have been evaluated instead or as well (actually, we did!). However, these are enough to demonstrate the taxonomy in context of algorithms and data structures.

Evaluation

- Based on
  - journal and conference articles as well as subjective experiments (4 authors) with the systems
  - the latest available version
  - the most obvious way to use the system (i.e., how it is intended to be used by the developer)
  - majority of the use cases (i.e., there can be a small number of use cases in which the evaluation could end up to be different)

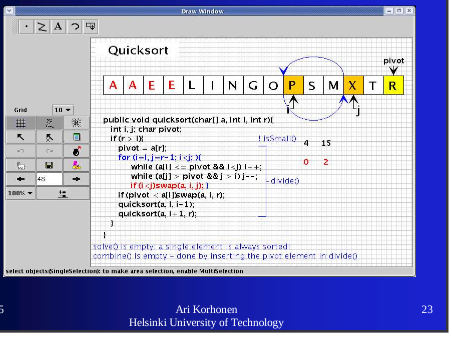
Example: JAWAA



JAWAA animation based on instrumenting code (interesting events)

Separate editor available

Example: Animal



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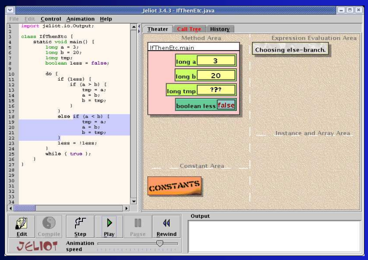
Example: Jeliot 3



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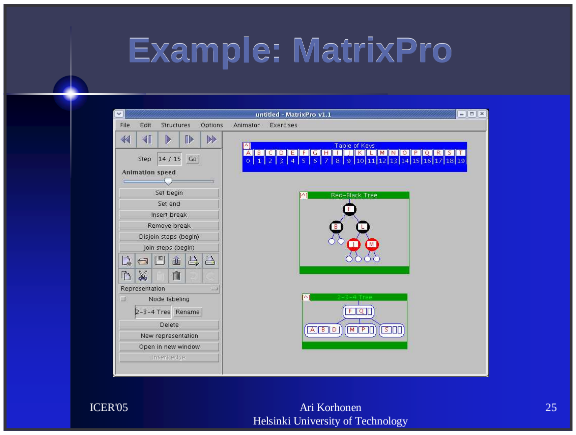
                    a = b;
                    b = tmp;
                }
            }
            else if (a < b) {
                    tmp = a;
                    a = b;
                    b = tmp;
            }
            less = !less;
        }
        while ( true );
    }
}
```

IfThenEtc.main
long a 3
long b 20
long tmp ???
boolean less false

Choosing else-branch.



Example: MatrixPro

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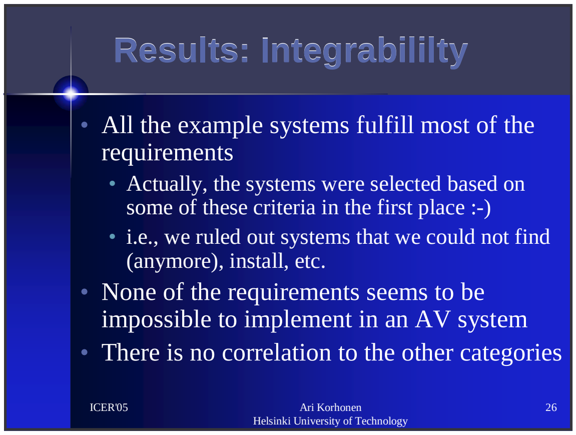

Results: Integrabililty

- All the example systems fulfill most of the requirements
  - Actually, the systems were selected based on some of these criteria in the first place :-)
  - i.e., we ruled out systems that we could not find (anymore), install, etc.
- None of the requirements seems to be impossible to implement in an AV system
- There is no correlation to the other categories

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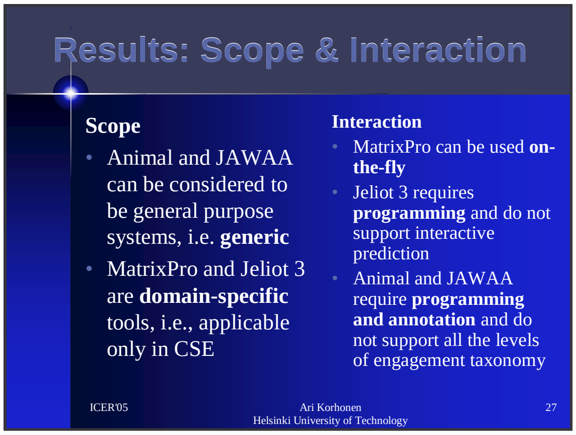

Results: Scope & Interaction

Scope

- Animal and JAWAA can be considered to be general purpose systems, i.e. **generic**
- MatrixPro and Jeliot 3 are **domain-specific** tools, i.e., applicable only in CSE

Interaction

- MatrixPro can be used **on-the-fly**
- Jeliot 3 requires **programming** and do not support interactive prediction
- Animal and JAWAA require **programming and annotation** and do not support all the levels of engagement taxonomy

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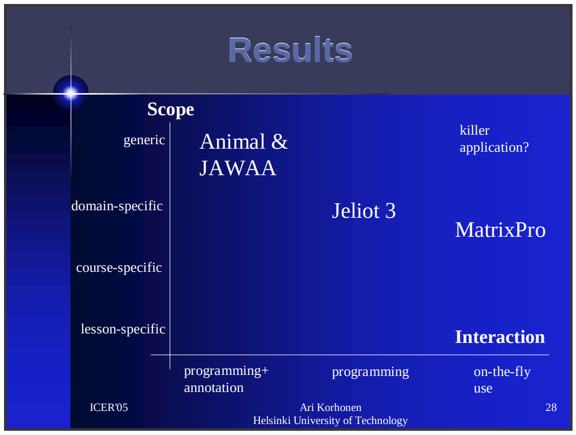

Results

Scope

generic

domain-specific

course-specific

lesson-specific

Animal & JAWAA

killer application?

Jeliot 3

MatrixPro

Interaction

programming+ annotation

programming

on-the-fly use

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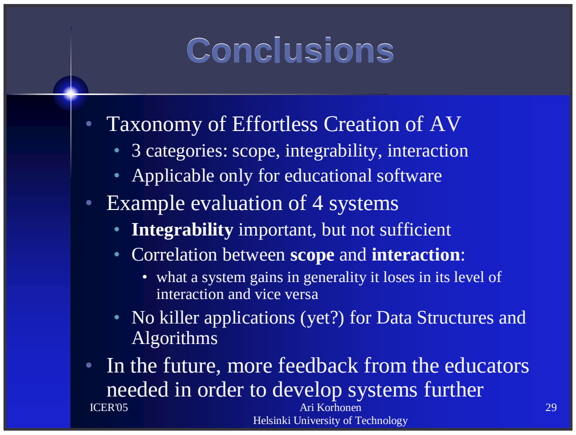

Conclusions

- Taxonomy of Effortless Creation of AV
  - 3 categories: scope, integrability, interaction
  - Applicable only for educational software
- Example evaluation of 4 systems
  - **Integrability** important, but not sufficient
  - Correlation between **scope** and **interaction**:
    - what a system gains in generality it loses in its level of interaction and vice versa
  - No killer applications (yet?) for Data Structures and Algorithms
- In the future, more feedback from the educators needed in order to develop systems further

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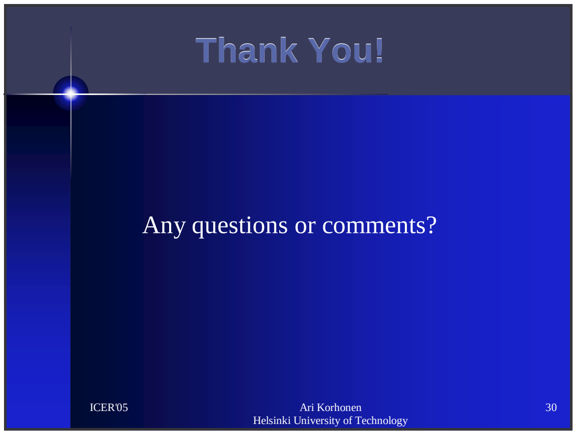

Thank You!

Any questions or comments?

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