INF FAKULTÄT FÜR INFORMATIK

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Dagstuhl Seminar on Principles of Provenance

Toward Provenance as Cross-cutting Concern

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Agenda

I. Motivation: Flexibility and the illusion of control

II. Our vision: Provenance as cross-cutting concern

III. What is provenance? (For us)

IV. Provenance framework: Covering a broad variety of approaches

V. First prototype HSQL: The benefit of modern software engineering approaches

VI. Future work

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I. Motivation

Provenance gained much attention in the recent past.

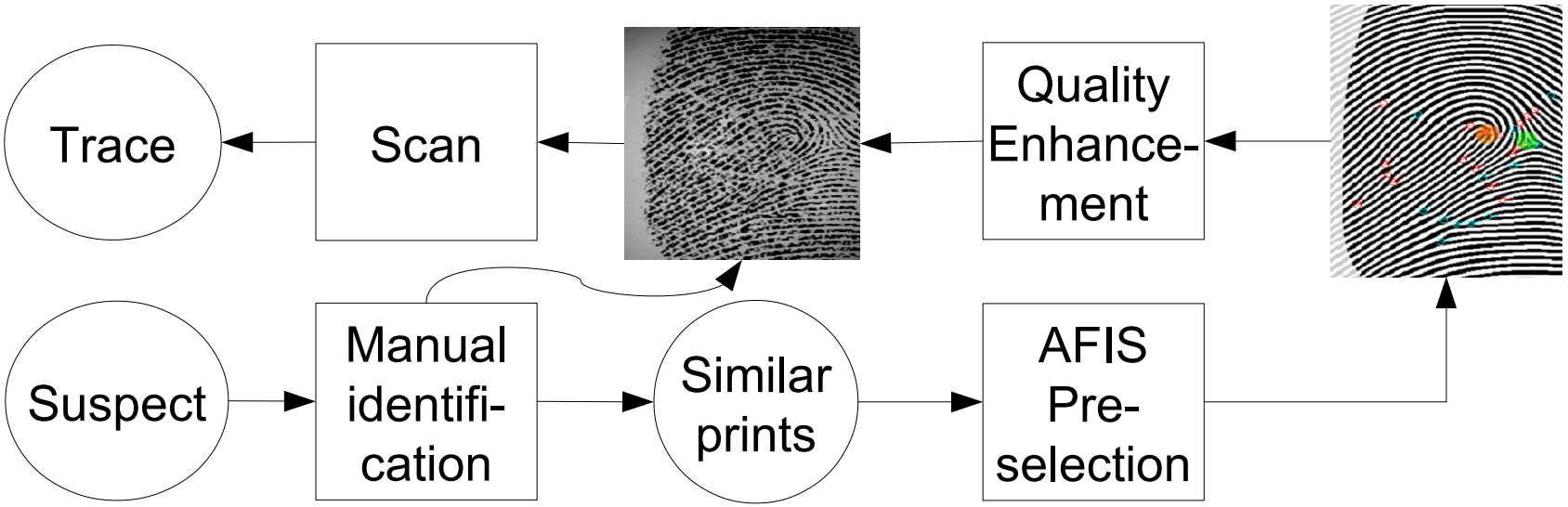
Current provenance capturing

- Database formalisms (Why & Where [1], How [2])
- Domain-specific all-in-one solutions
  - Kepler [3], Karma 2 [4], Panda [5], Taverna 2 [6] etc.

Problems: Inflexible and costly

- Complex IT-infrastructure → Creating domain-specific solutions (and linking them) is inflexible, costly, or even impossible.

Motivating example: DigiDak workflow



- Distributed IT-landscape: Illusion of control
- Privacy issues (missing infos)
- Inter-system provenance
- Fragmentation: Don't need to capture and show all the infos

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II. Our vision: Provenance a cross-cutting concern

In an **ideal** world there would be ...

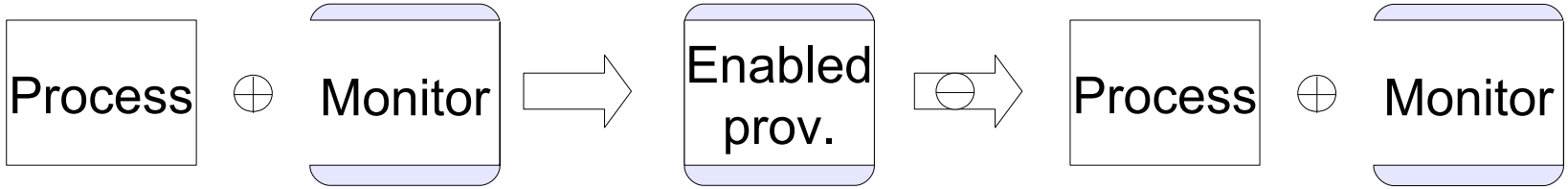
(1) One piece of software (monitor) capturing provenance for all applications → Re-use

(2) No change of original software necessary

(3) Tailored & adaptive provenance capturing

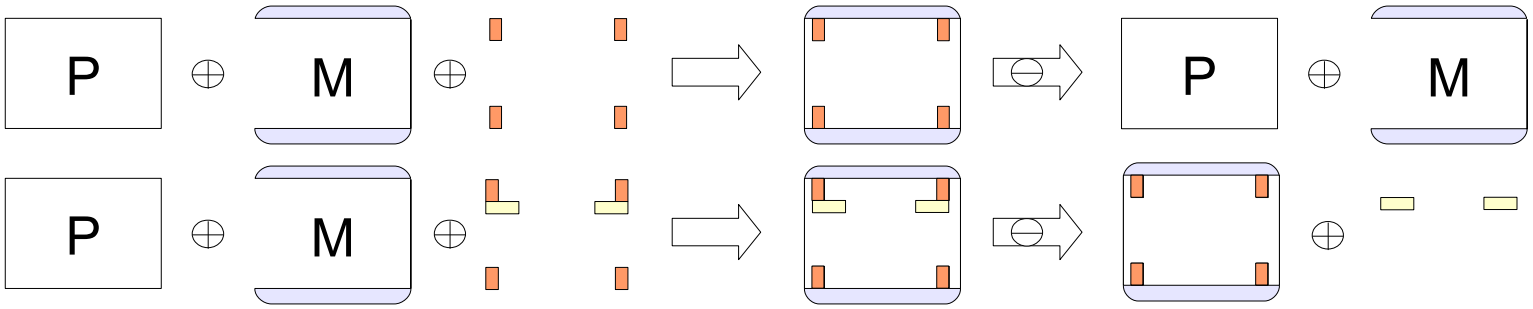
(4) Inter-system, privacy-preserving, and reliable provenance

(5) Minimal overhead (performance & storage)



Our vision – now more realistic

Issue	Goal	ToDo
(1) Re-use of concepts	Re-use of general concepts (Framework)	Identify commonalities in provenance capturing
(2) Invasive	Minimal invasive	Identify and evaluate different approaches
(3) Tailored implementation	Configurations (build-time variability)	Implementation based on (1)
(4) Trust	Configurations	Implementation based on (1)
(5) Overhead	Minimization	As for (2)



III. What is provenance? (For us)

- Term used in many communities
  - Databases [1,2]
  - (scientific) workflows [3,4,5,6]
  - Source code ownership [7]
  - ...

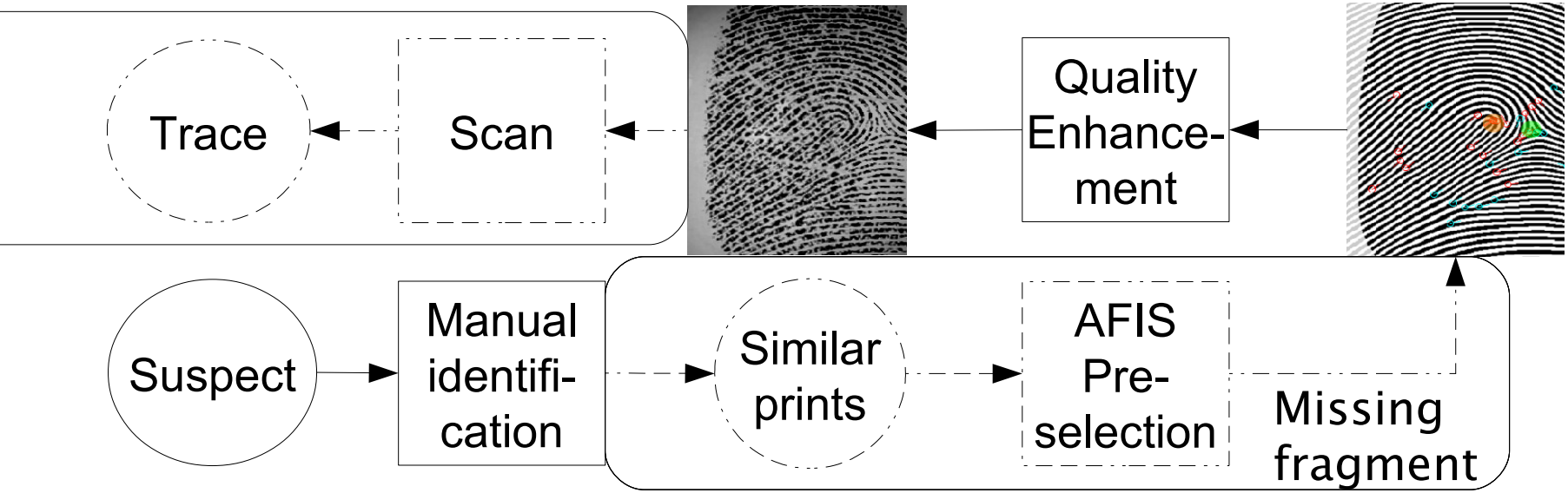
→ No clear definition.

- What is provenance used for?
  (1) Explaining data origin & derivation history
  (2) Computation of subsequent results (propagation)

What is provenance – Identifying commonalities

- General properties
  - Unchangeable [8]
  - Fragmentary [9,10,11] (granularity)
  - Uncertainty [12,13,14]

} Dimensions of provenance



What is provenance? – Dimensions of provenance

Dimensions form a hierarchical framework [15]

Fragmentation

- **Workflow:** OPM [16], similar to user views [17]
- **Existence:**
  - Recomputation: Black box similar to [18]
  - Grey box: Lineage [19]/ Endogenous input [20]
  - Paths – Why/(How)
- **Value origin:** Where

Uncertainty

- Simple annotations
- Integrity (also for linking)
- Authenticity

Building the re-computation entry

Using the structure of an (object-oriented) program

```
public class foo {
    private int memOne;
    private foo2 mem2;//never used

    RetType[] somefunc(int arg1){
        RetType[] ret = new RetType[arg1];
        memOne++;
        for (int i=0;i<arg1;i++)
            ret[i] = new RetType(memOne);
        return ret;
    }
}
```

- On entry (method call)
  - CalledBy
  - Input: arguments + members
  - CurrentValues: arguments

On leave (after return)

- Output: return value & modified Complex artifacts
- Map every `ret[i]` to `ret`
- Not changed members

This is also done for the constructor calls of every `ret[i]` → no total black box

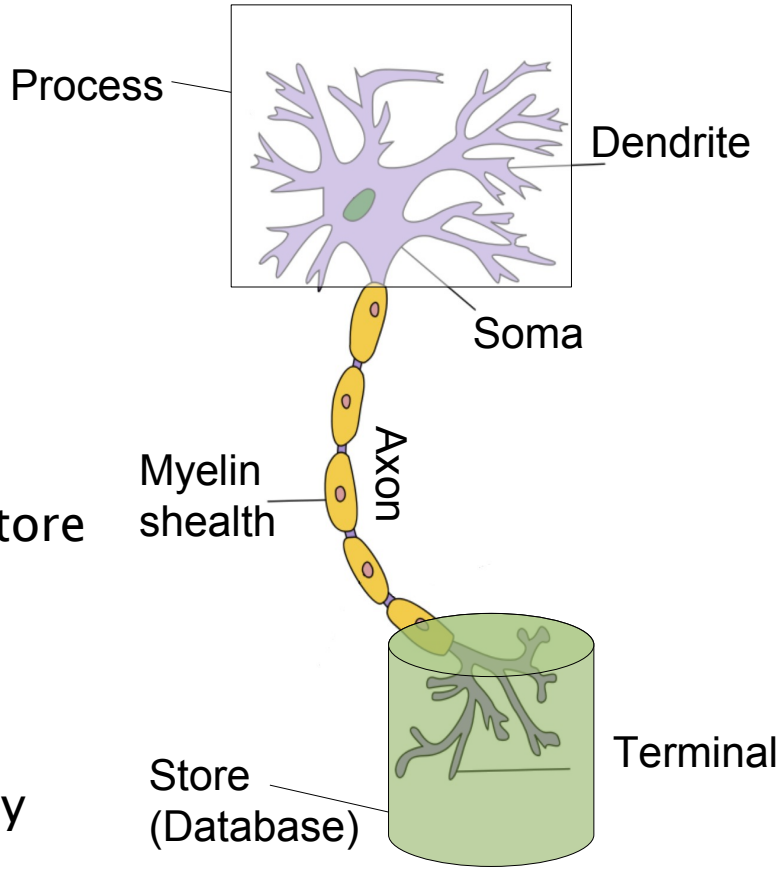
Problem: Invisible input

IV. Implementation – General re-use architecture

- Inspired by neurons: Re-use of single parts

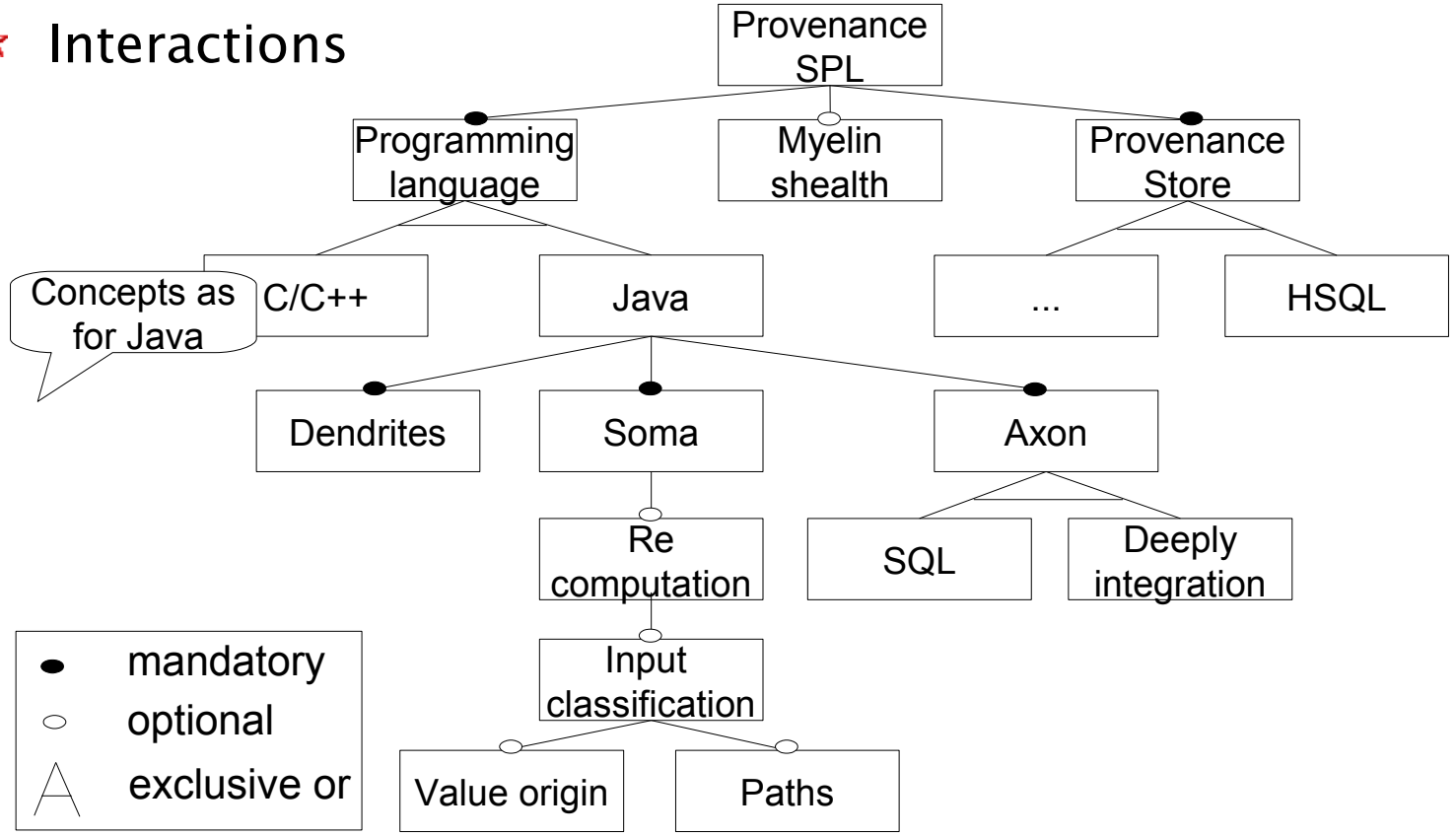
Increased re-use

- Dendrite
  - Collecting provenance
  - Mapping infos to soma types
  - Application specific (invasive parts)
- Soma
  - Mapping infos to axon type
  - Language specific
- Axon – Transport to provenance store
- Terminal – Mapping to store types
  - SQL or
  - Deeply integrated
- Myelin shealth – Ensuring reliability



Implementation Provenance Framework

- Application-specific dendrites
- Interactions



Implementing dendrites – Possible techniques

- Reference implementation
  - Maximum invasive
  - Maximum effort
  - Default performance
  - Default granularity
  - Minimum re-use
- Promising approaches
  - Annotation-based
  - Aspect-oriented progr. (AOP)
- Possibly to consider as well
  - Feature-oriented progr. (FOP)
  - Composition (Superimposition)

Reference: Using ifs

```
if (PROV_SOMA){
    //do something
}
//original code
if (PROV_SOMA && not PROV_LINEAGE{
    //do something different
}
```

Annotations (with colors)

```
//original code
someMethodCall();
//(invasive) provenance part
//do something
//again the original code
```

Aspects

```
//similar to triggers
pointcut someName : (whenToFire);

after() someName {
    //do something
}
```

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V. First prototype – Where to start?

- Programming languages requires tools → Java
  - Annotation based: CIDE [21]
  - AOP: AspectJ [22]
  - FOP: Fuji [23]
  - Superimposition: FeatureHouse [24]
- Complex application
  - Represent different kinds of application → DBMS
  - Documentation etc. → HyperSQL 2.2.6 (cur. 2.2.8)
- Other nice points: Re-use
  - Re-use as provenance storage (small axons)
  - Transaction management
  - Different table types

V. First prototype – Dendrite implementation

- Reference approach
  - Permanently modifies source
  - Changes visibility of fields
  - Expression based

```
private Result getSingleResult(Session session, int maxRows) {

    int[]                limits    = getLimits(session, maxRows);
    //XXX @BEGIN Provenance
    if (PROV_RECOMPUTATION)
    {
        de.ovgu.provenance.Monitors.addInputTables(this, limits[2]);
    }
    //END Provenance
```

- Annotation based
  - Permanent modification, but less invasive
    → Automatically create original system
  - Changes visibility of fields
  - Non expression-based
    → more flexible

```
private Result getSingleResult(Session session, int maxRows) {

    int[]                limits    = getLimits(session, maxRows);
    de.ovgu.provenance.Monitors.addInputTables(this, limits[2]);
    Re"[QualifiedName] - Preview not supported."buildResult(session, limits[2]);
    Ro                                          r.getNavigator();
       Features:
    if - Recomputation_source
```

V. First prototype – Implementation examples

AspectJ

- No source modification
- Separation in invasive parts and mapping
- Re-use advices
- Pointcuts can match groups of functions
- Pointcut needs entry-points (e.g., function calss) → less flexible
- ... and some bugs in AspectJ & respective Eclipse plug-ins

```
pointcut re() : execution (* foo.*(..));

before() : re(){
    System.out.println("Entered");
    String functionName     = thisJoinPointStaticPart.
    Object[] args           = thisJoinPoint.getArgs();
    //save values
    long localID = id++;
    activeFunc = localID;
}

after() returning(test.RetType[] R) : re(){
    System.out.println("Leaving");
    activeFunc--;
    Object[] args           = thisJoinPoint.getArgs();
    //compare args
    //add Re and changed complex args to return types
}
```

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V. First prototype – Reliability (myelin shealth)

- Simple annotations: Additional key-value pairs for the re-computation entry (requires additional dendrites)
- Integrity – Cryptographic hash sums of primitive values (e.g., tables or tuples)
  - MD5, SHA-family
  - Problem granularity
- Authenticity – Digital signatures
- Privacy preserving provenance linking
  - Use hash sums (be aware of collisions)
  - Keep sums after deletion
- Special case multimedia data – Invertible watermarks [25]

V. First prototype – Current status HSQL prototype

- Reference approach (IF's)
  - Fragmentation: Lineage (tuple level)
  - No myelin shealth
- Using CIDE – Same status as reference approach
- AspectJ – General aspect (Recomputation aspect)
  - Tracking *all* arguments from the function call & current status of *all* class members
  - Problems with call of static methods or fields
  - No thread support
  - Possible scenario: Track provenance from SQL to HDD-access

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VI. Future work

- Finishing first prototype
  - Esp. myelin shealth
  - Documentation + Open source access
- Evaluation for each approach (Dendrites)
  - Effort to implement/invasiveness
  - First *isolated* overhead determination
- Additional applications (simulation of complex systems)
  - Postgres
  - Set up complex infrastructures
  - Real-scenarios and workloads
- Severe question: What is the same?

Thank you for your attention.

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Figures

Slide 5&9 SfinGe – Synthetic Fingerprint Generator, University of Bologna, Version 4.0 (Demo), 2009

Slide 11 http://upload.wikimedia.org/wikipedia/commons/thumb/b/bc/Neuron_Hand-tuned.svg/800px-Neuron_Hand-tuned.svg.png