Merging of Biomedical Decision Diagrams

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Outline

Motivation

Decision Diagrams

- Important means for decision making

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- Intuitively understandable
- Not only for knowledge engineers

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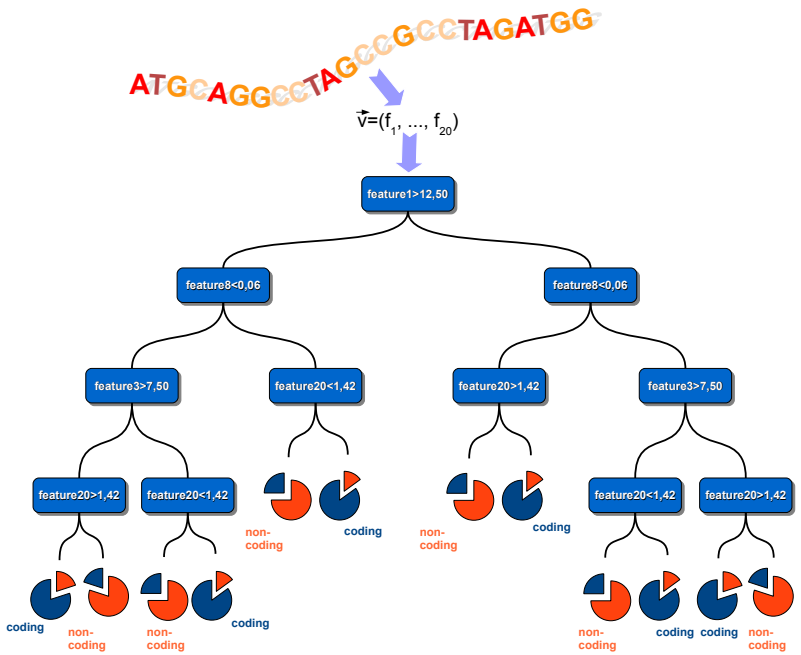
- Intuitively understandable
- Not only for knowledge engineers
- Common in clinical guidelines



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  e.g., TNM system
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Task: Incorporate them into one

Existing Solutions

Decision Procedures

- Leave source diagrams unchanged
- Classification by the following *procedure*:
  1. Classify a case by each diagram
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- We lose the property of intuitive understandability
- $\Rightarrow$ Inappropriate for clinical practice

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Rule-based systems

- Conversion: diagram to production rules
- One rule for each leaf node

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But

- Not human-readable
- Overhead

Therefore

New approach

Merge several decision diagrams

- into a standalone one
- without referring to original training data
- without the overhead of translating them into rule-based systems

Decision Diagrams

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$$D = \left\langle V, E, l_c, l_e, \mathcal{M}^{\mathcal{Q}} \right\rangle,$$

where
V ... set of nodes and
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$\mathcal{M}^{\mathcal{Q}}$: The meaning function of a query language $\mathcal{Q}$ is of kind
$\mathcal{M}^{\mathcal{Q}} : \Sigma^{\mathcal{Q}} \to 2^{\mathcal{D}}$

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Example evaluation: We want to classify 7 and start in root node r. $7 \in \mathcal{M}^F(f_1)$ but $7 \notin \mathcal{M}^F(f_2)$, therefore we choose edge (r, p) and end up in node p. $l_c(p) = prime$.

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An n-ary decision diagram merging operator

$$\circ^n : \underbrace{\top_{\mathcal{D},\mathcal{C}} \times \top_{\mathcal{D},\mathcal{C}} \times \cdots \times \top_{\mathcal{D},\mathcal{C}}}_{n \text{ times}} \rightarrow \top_{\mathcal{D},\mathcal{C}}$$

maps n input classifiers (over $\mathcal{D}$ and $\mathcal{C}$) onto a new diagram.

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Example merging operators

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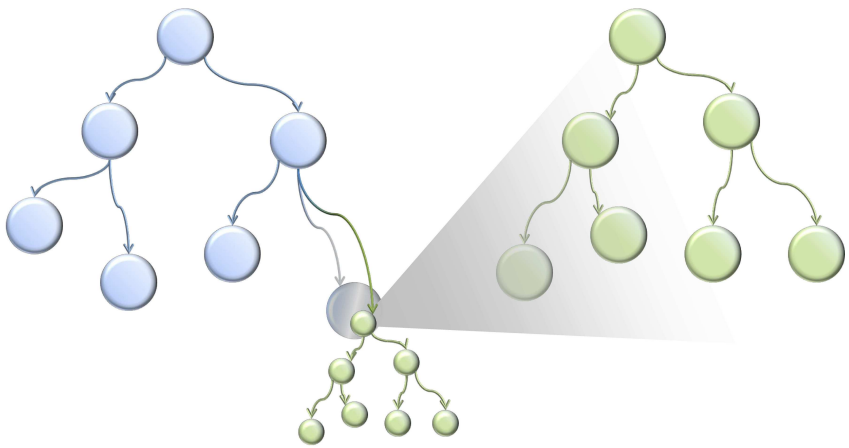

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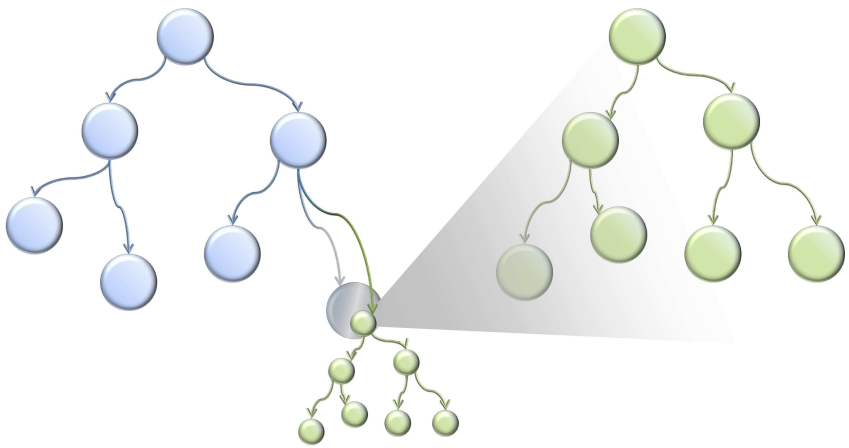

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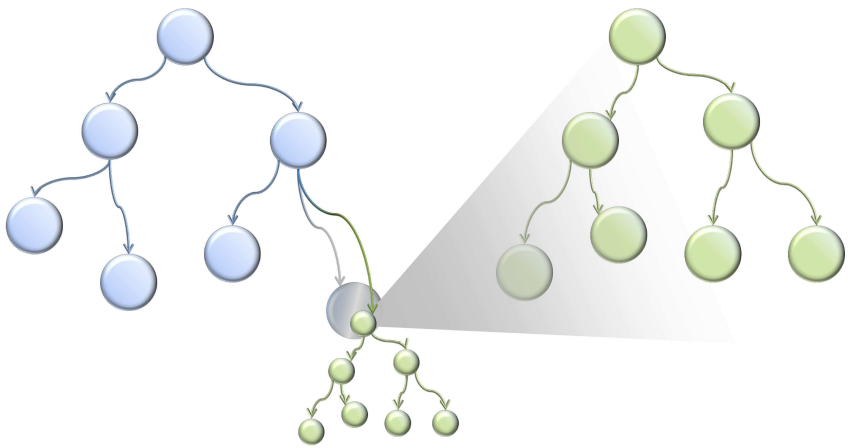

- user preferences
  “In doubt, classify it as X rather than Y.”
  (Sometimes one wrong decision is more serious than the other one)

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Operators can also assert such properties for their result.

Solution

Bad approach: Develop merging operators for the most general task variant, i.e.,

- general decision diagrams
- without any assumptions about node degrees or variable ordering

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- order the nodes

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Merging operators

- n-ary merging operators ($n > 1$) for actual merging task
- they are much simpler if we can make assumptions about the input

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Therefore the plugin consists of

- 1. A tool for conversion of decision diagrams
- 2. Predefined operators

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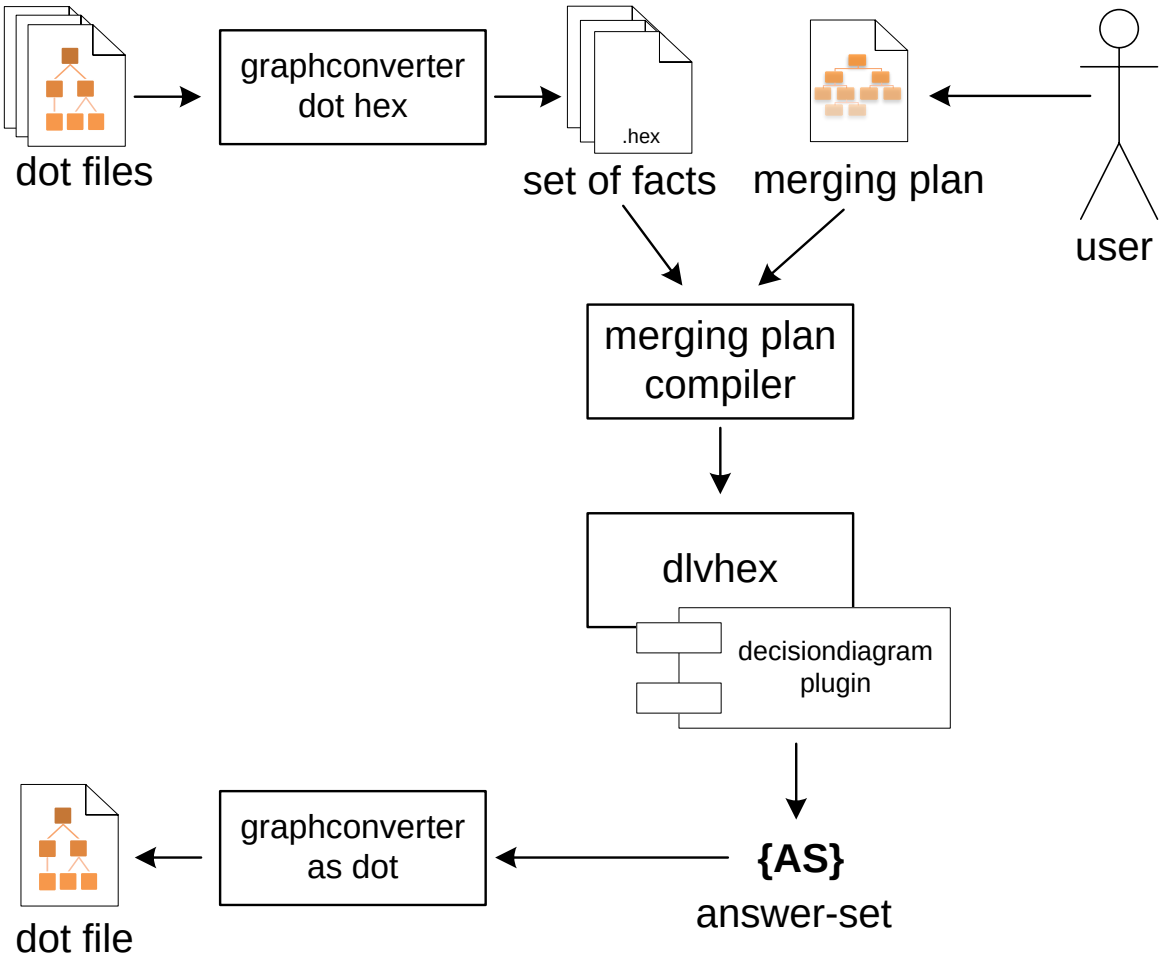
Typical call

- Conversion of input diagrams `X`:
  ```
  $ graphconverter dot hex < diagX.dot > diagX.hex
  ```
- Merging:
  ```
  $ dlvhex --merging diags.mp > out.as
  ```
- Conversion of output diagrams:
  ```
  $ graphconverter as dot < out.as > out.dot
  ```

Implementation



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- Input diagrams, training set and merging strategies can be edited quickly without redoing manual remerging
- When best settings have been found, one can consider application-specific reimplementation due to performance reasons

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Application Scenario

- DNA classification
- Given a sequence $S \in \{A, C, G, T\}^*$
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- Features are statistically motivated (incorporating biological knowledge)

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Examples

- Triplet ATG more frequent in coding sequences
- In coding sequences, the base at first codon position is frequently a purine base

DNA Classification

The role of the merging framework

- Train *multiple* decision trees for the task
- Merge them afterwards

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- Train *multiple* decision trees for the task
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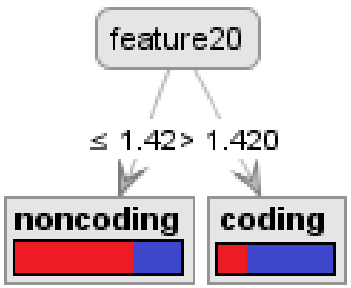
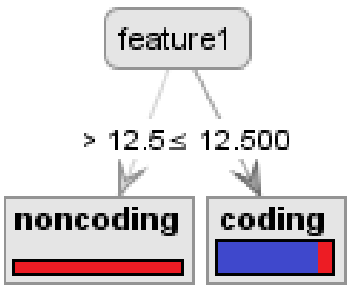
Advantages

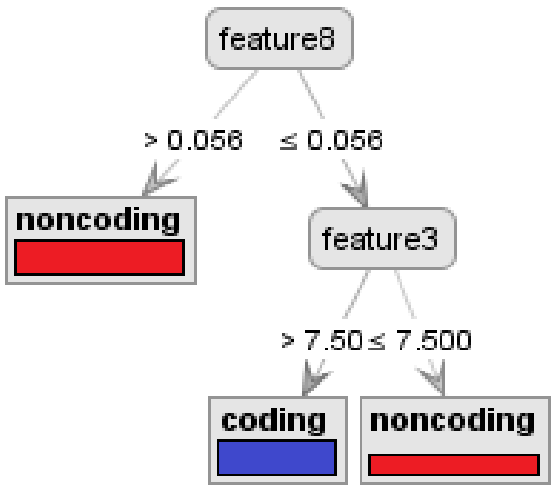
- Better accuracy by using different algorithms
- Parallel computing
- Try out different combinations of training algorithms; no need for manual remerging after each changes

DNA Classification

Suppose we have 3 trees trained with different algorithms and training sets







Each has accuracy ≈50%

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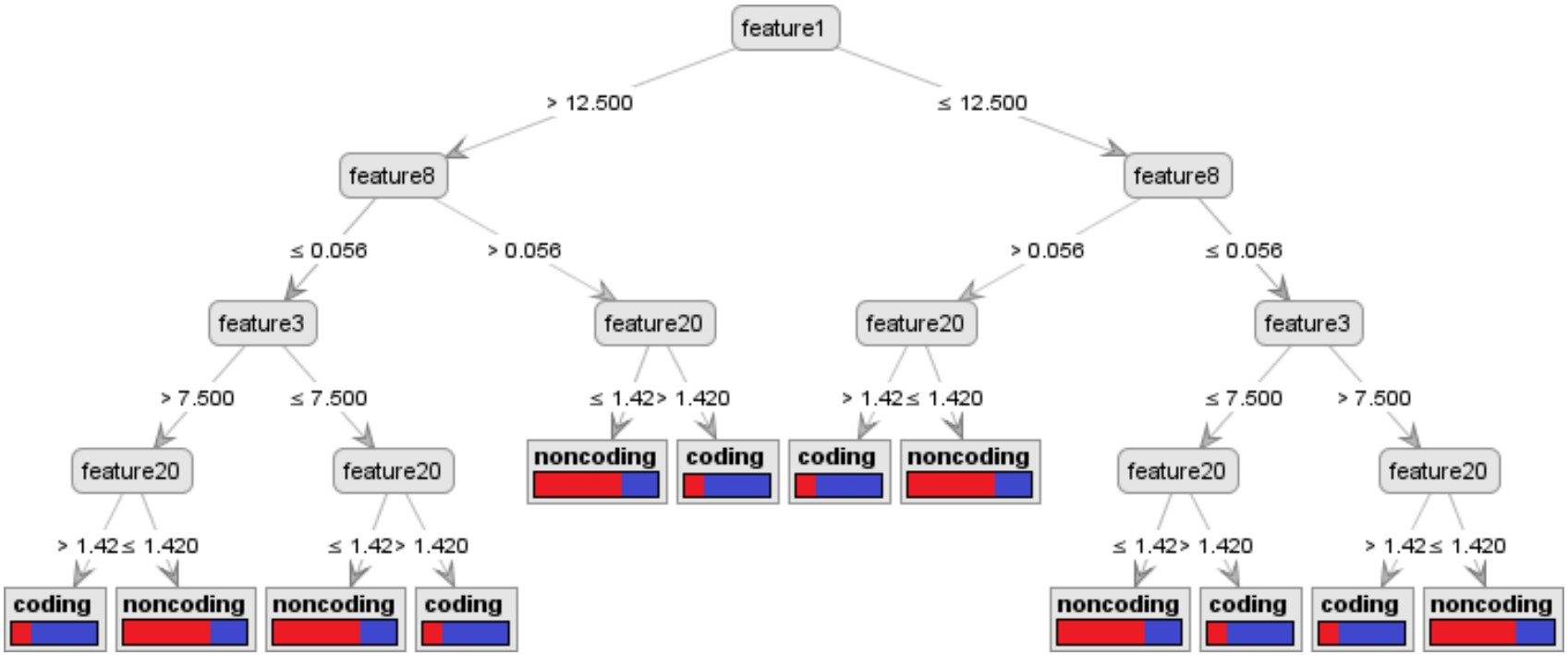
2. Insert second tree into each leaf of the first one (iterate for more than two trees)
3. Weight trees according to size of training set used during training
4. Recompute classification for each (new) leaf according to new distribution

DNA Classification

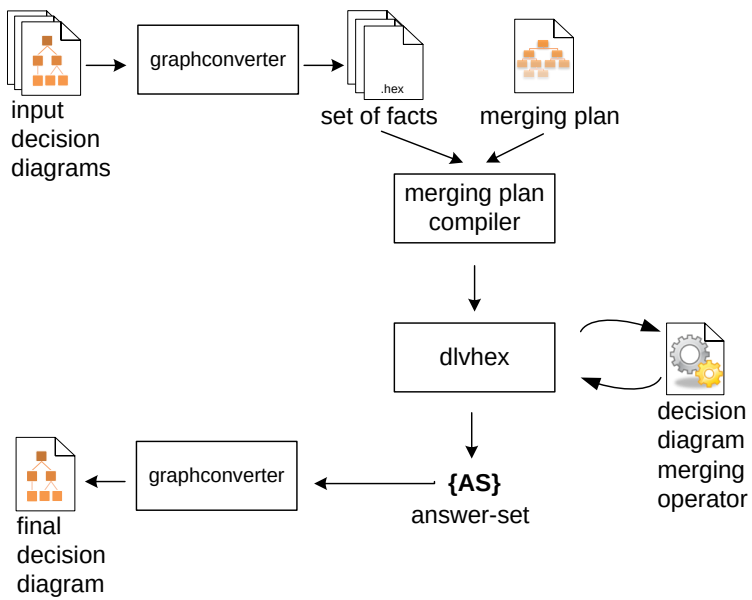
After merging



Accuracy ≈65%

Summary

- Task: Incorporate several decision diagrams into one



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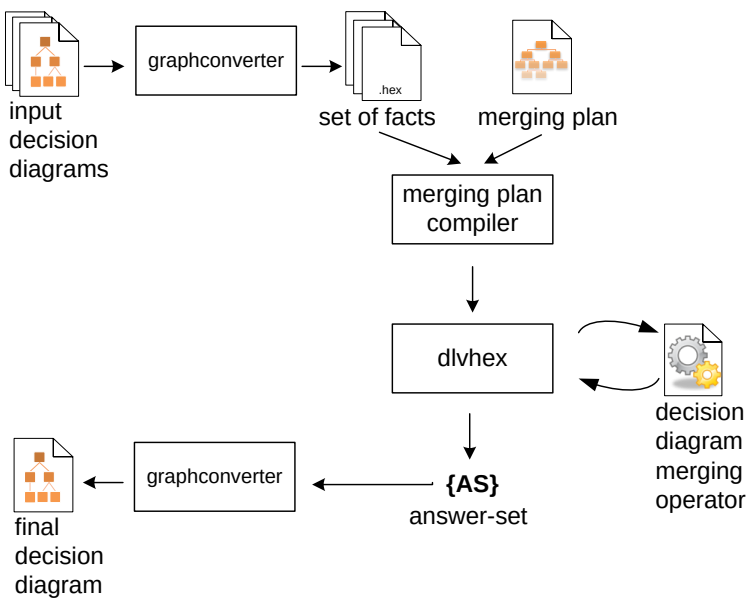
- Approach:
  - implement a plugin that allows decision diagram handling with dlvhex
  - provide predefined operators



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- Approach:
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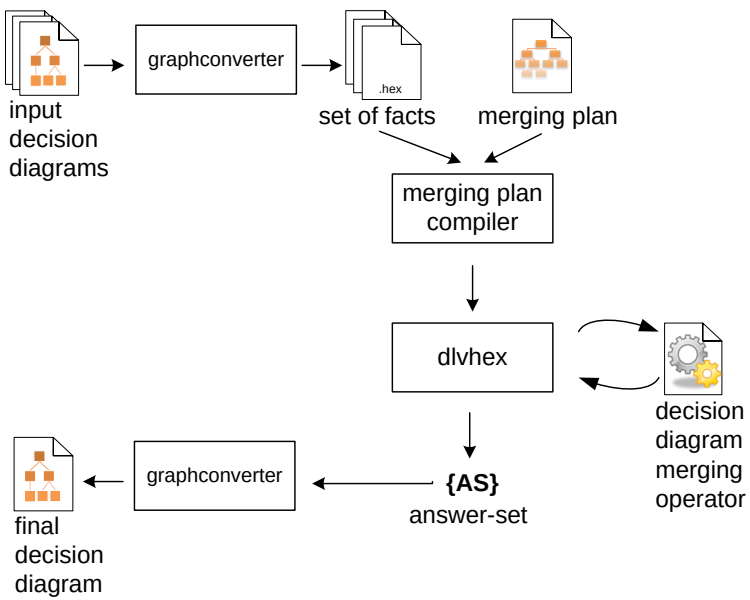
  $\Rightarrow$ dlvhex $\Rightarrow$ answer set $\Rightarrow$
  $\Rightarrow$ `graphconverter` $\Rightarrow$ output diagram



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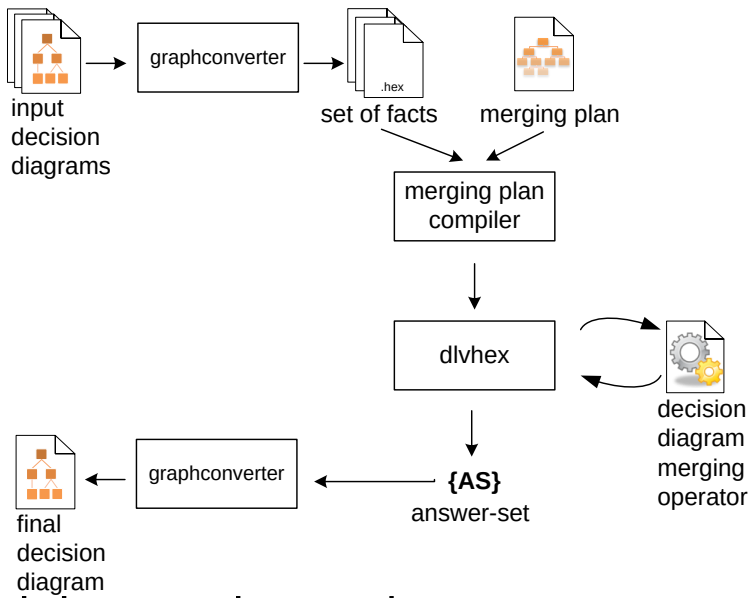

Advantages

- Easy-to-use rapid prototyping tool
- No manual incorporation of diagrams
- Allows changes of the scenario without redoing routine tasks

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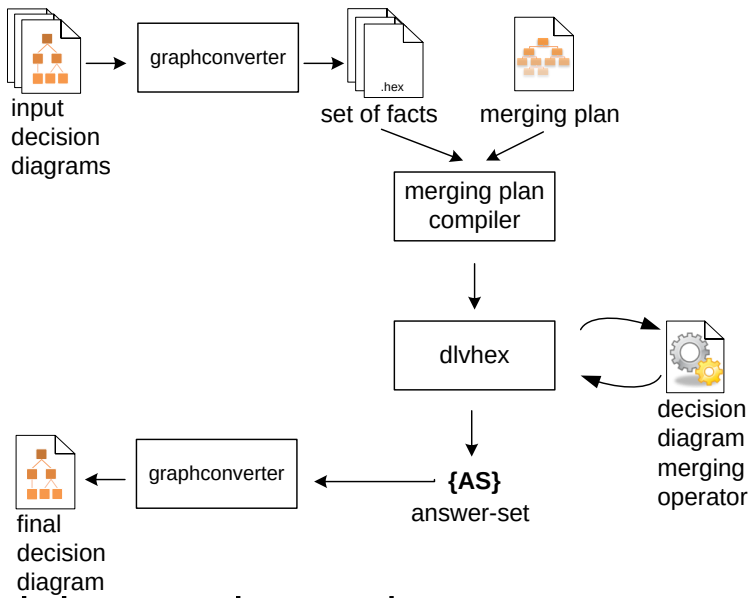

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$\Rightarrow$ dd-plugin = mergingplugin + dd processing with dlvhex + dd operators