

# VisualAI: A Framework for Interactive Abstract Interpretation

Jung Hyun Kim

*SoftSec Lab., KAIST*  
*IS661 Spring, 2024*

# Abstract Interpretation (AI)

# Abstract Interpretation (AI)

- Abstract Interpretation<sup>[1]</sup> (AI): a *sound approximation* of a program.

# Abstract Interpretation (AI)

- Abstract Interpretation<sup>[1]</sup> (AI): a *sound approximation* of a program.

```
int a;  
if (cond) {  
    a = 0;  
} else {  
    a = 1;  
}  
print(a);
```

# Abstract Interpretation (AI)

- Abstract Interpretation<sup>[1]</sup> (AI): a *sound approximation* of a program.

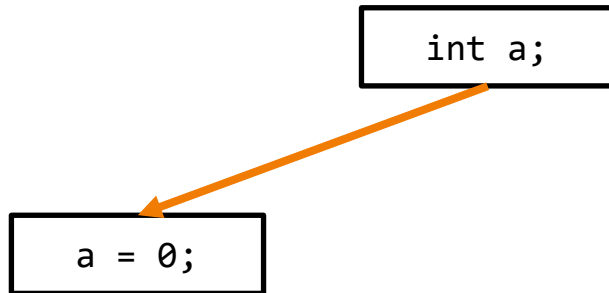
```
int a;  
if (cond) {  
    a = 0;  
} else {  
    a = 1;  
}  
print(a);
```

```
int a;
```

# Abstract Interpretation (AI)

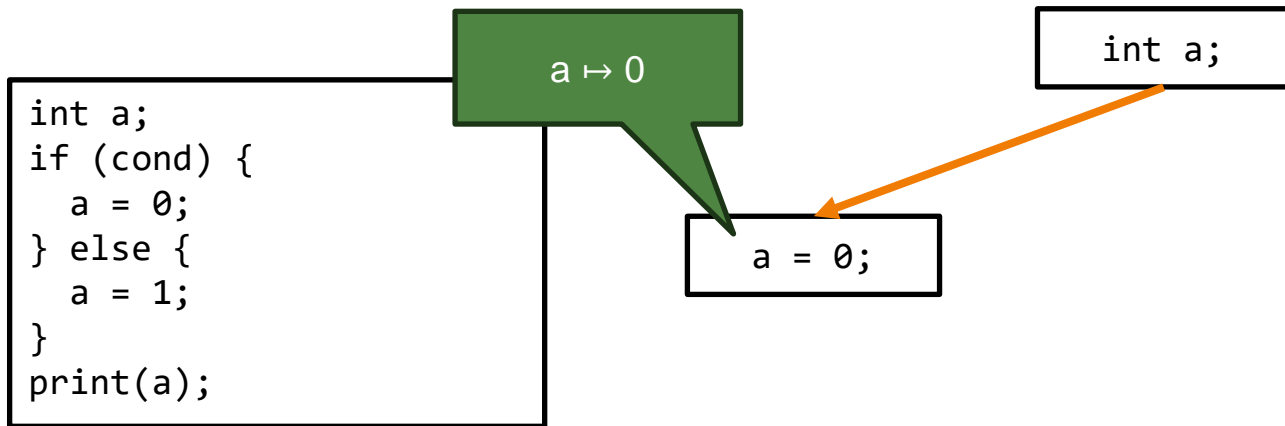
- Abstract Interpretation<sup>[1]</sup> (AI): a *sound approximation* of a program.

```
int a;  
if (cond) {  
    a = 0;  
} else {  
    a = 1;  
}  
print(a);
```



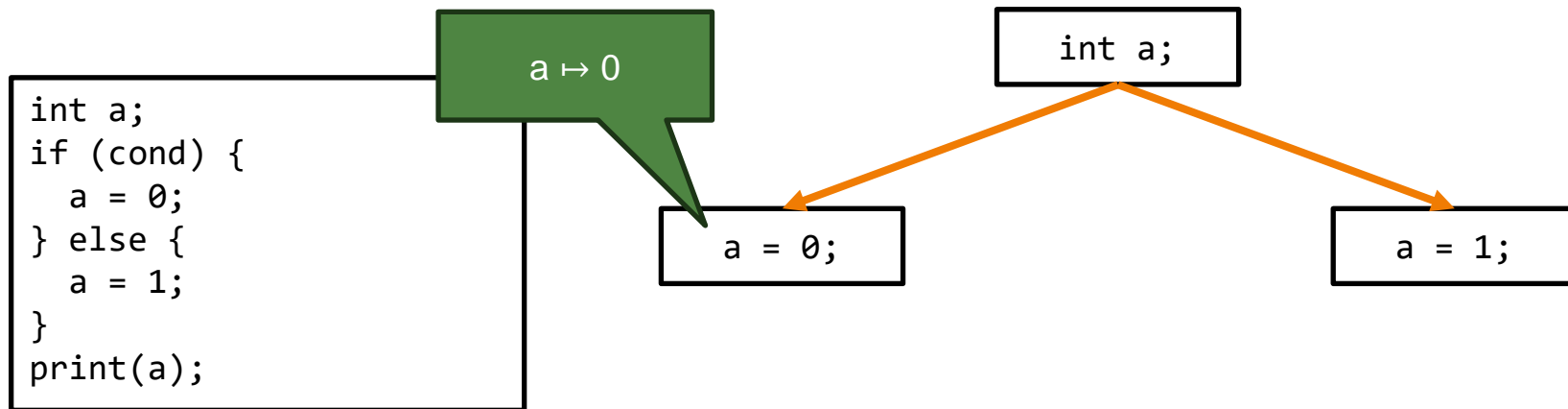
# Abstract Interpretation (AI)

- Abstract Interpretation<sup>[1]</sup> (AI): a *sound approximation* of a program.



# Abstract Interpretation (AI)

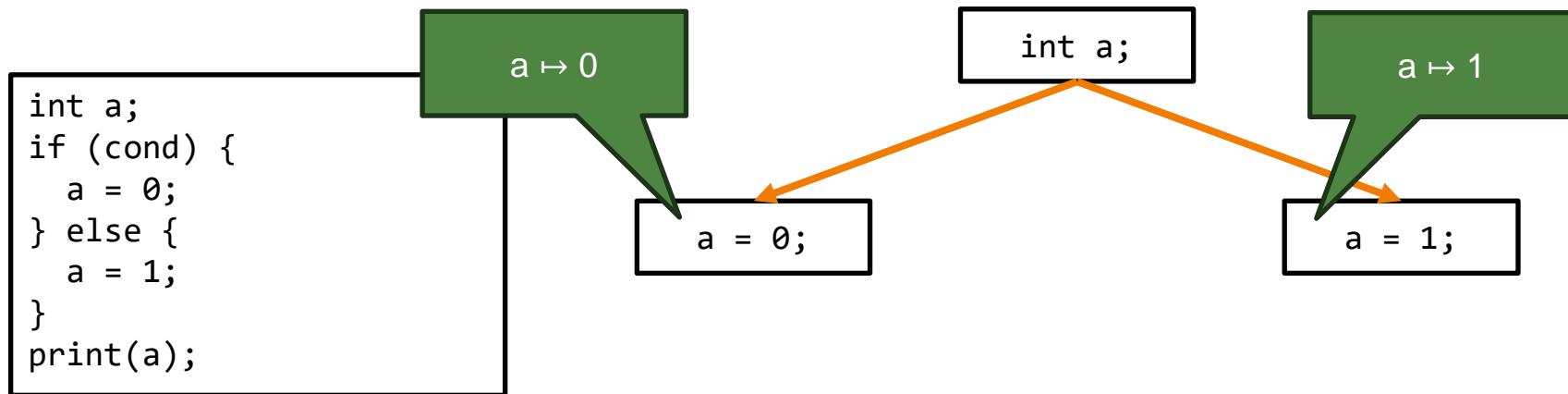
- Abstract Interpretation<sup>[1]</sup> (AI): a *sound approximation* of a program.





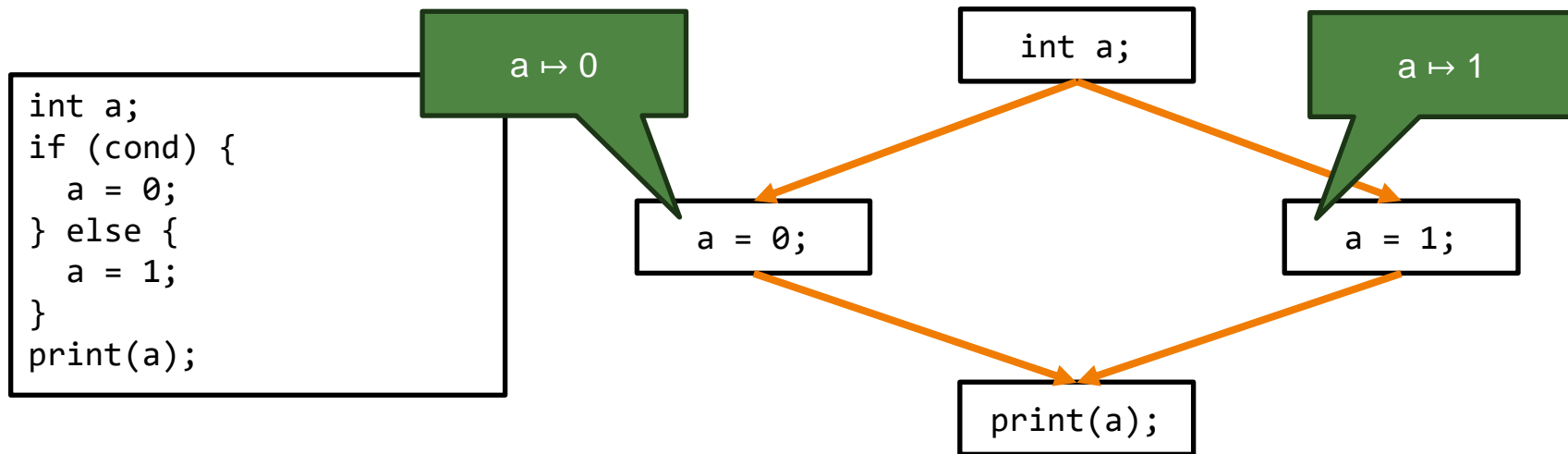
# Abstract Interpretation (AI)

- Abstract Interpretation<sup>[1]</sup> (AI): a *sound approximation* of a program.



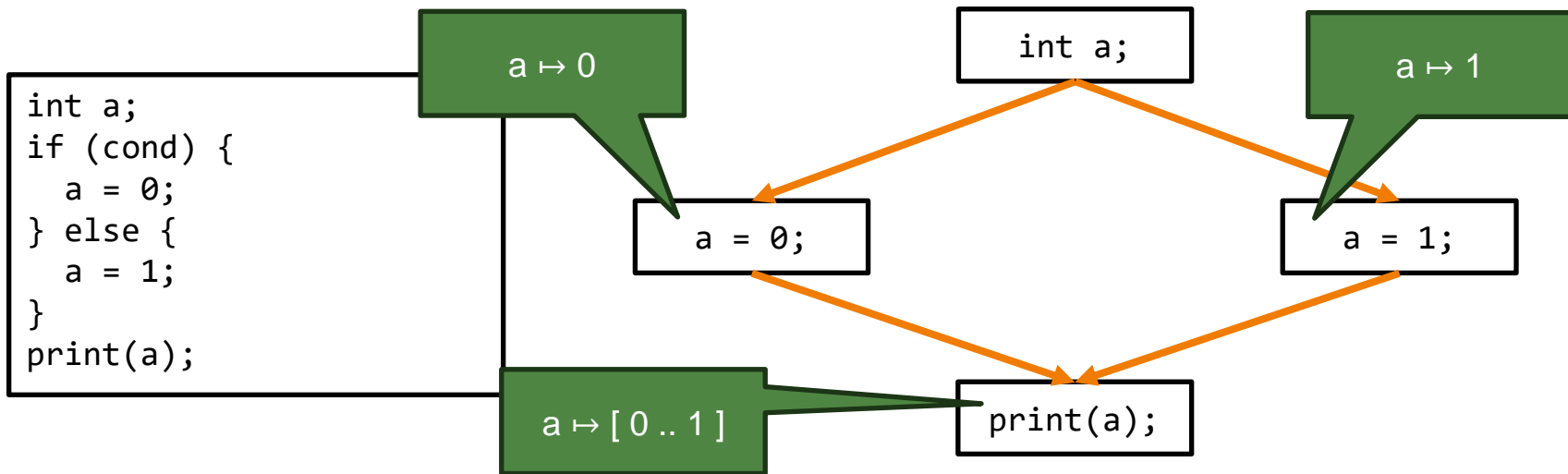
# Abstract Interpretation (AI)

- Abstract Interpretation<sup>[1]</sup> (AI): a *sound approximation* of a program.



# Abstract Interpretation (AI)

- Abstract Interpretation<sup>[1]</sup> (AI): a *sound approximation* of a program.



# Difficulties In Developing AI

# Difficulties In Developing AI

1. It is hard to inspect *the inside of an AI process*.

# Difficulties In Developing AI

1. It is hard to inspect *the inside of an AI process*.



**Lack of  
*Visualization***

# Difficulties In Developing AI

1. It is hard to inspect *the inside of an AI process*.



**Lack of  
*Visualization***

2. It is hard to follow *how states are propagated*.

# Difficulties In Developing AI

1. It is hard to inspect *the inside of an AI process*.

**Lack of  
Visualization**

2. It is hard to follow *how states are propagated*.

**Lack of  
Interaction**



# Interactive AI With Visualization

# Interactive AI With Visualization

- *VisualAI*: An interactive visualizer for AI.

# Interactive AI With Visualization

- *VisualAI*: An interactive visualizer for AI.
  - Visualization: the abstract state, graph, statement, etc.

# Interactive AI With Visualization

- *VisualAI*: An interactive visualizer for AI.
  - Visualization: the abstract state, graph, statement, etc.
  - Interaction: real-time debugging, on-demand information, etc.

# Interactive AI With Visualization

- *VisualAI*: An interactive visualizer for AI.
  - Visualization: the abstract state, graph, statement, etc.
  - Interaction: real-time debugging, on-demand information, etc.
- It helps people understand the internals of an AI.

# Interactive AI With Visualization

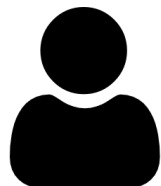
- *VisualAI*: An interactive visualizer for AI.
  - Visualization: the abstract state, graph, statement, etc.
  - Interaction: real-time debugging, on-demand information, etc.
- It helps people understand the internals of an AI.
  - Using *VisualAI*, we found several bugs in our binary analyzer.

# A Demo Video

# Technical Details

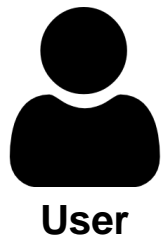


# Technical Details



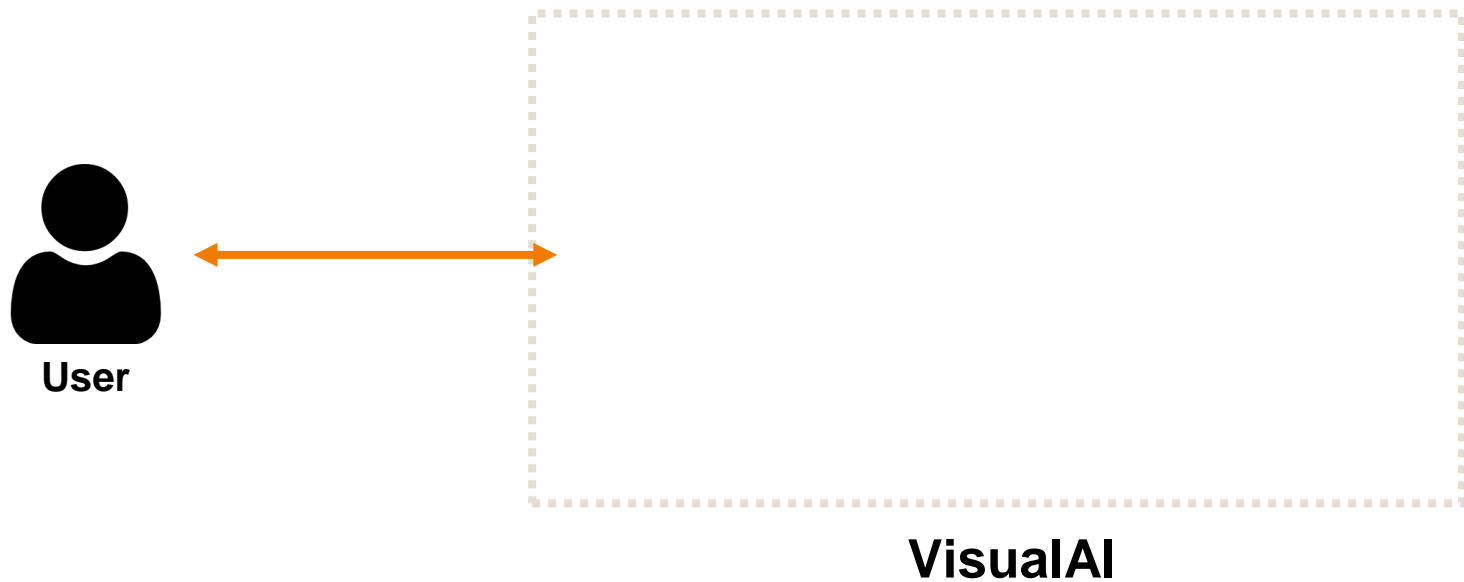
User

# Technical Details

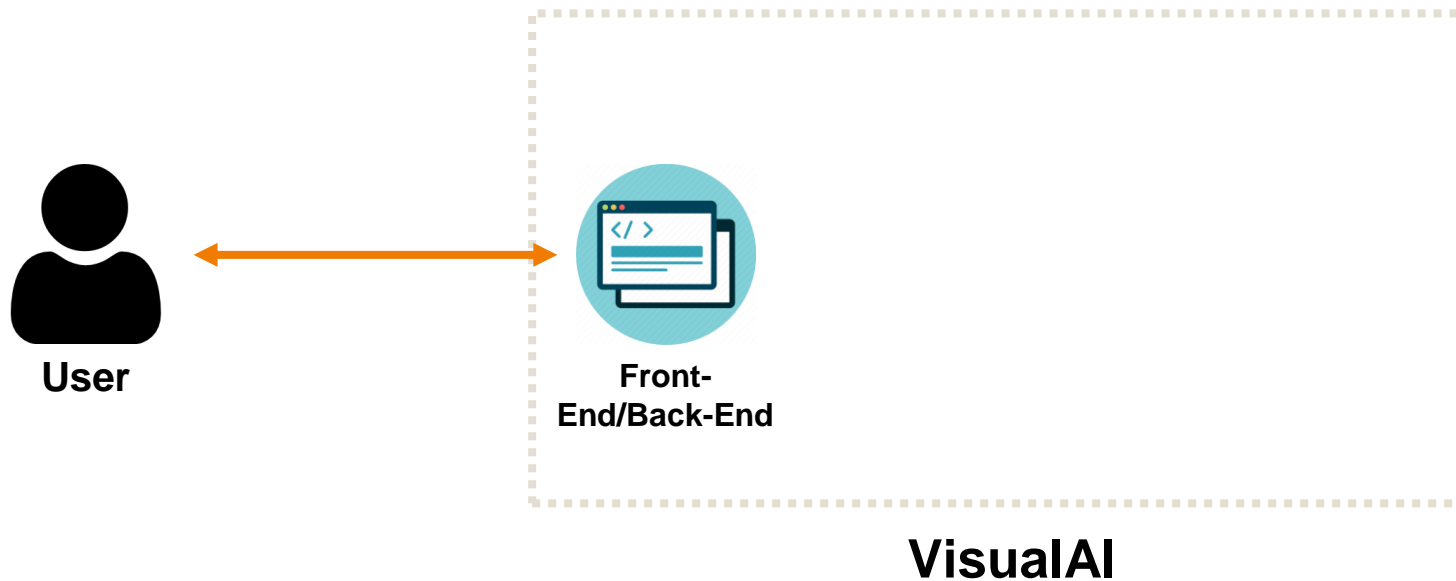


**VisualAI**

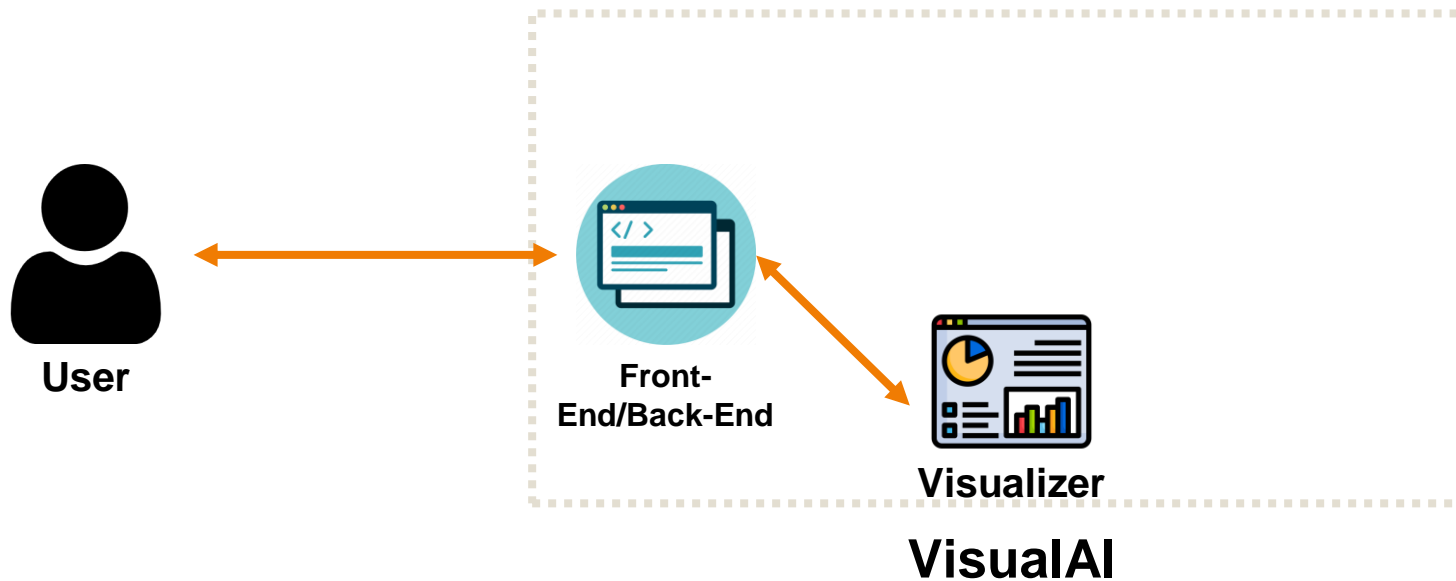
# Technical Details



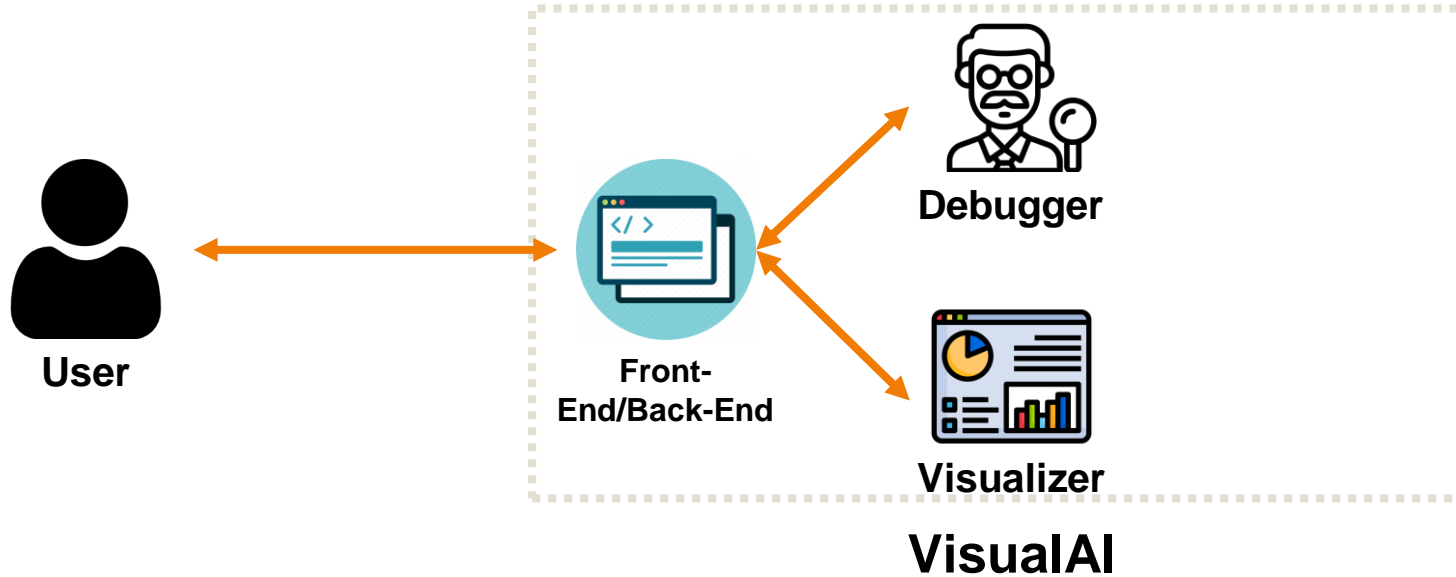
# Technical Details



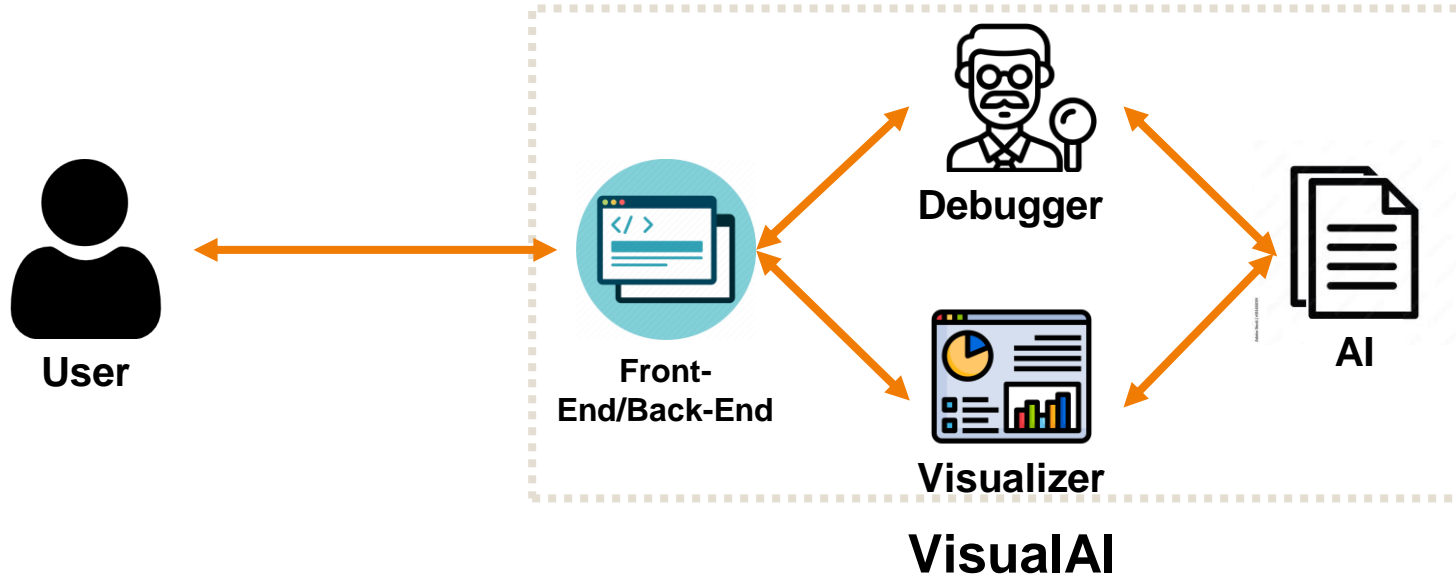
# Technical Details



# Technical Details



# Technical Details



# Technical Details – Front-/Back-End



# Technical Details – Front-/Back-End

- A simple HTML Server using Socket.

# Technical Details – Front-/Back-End

- A simple HTML Server using Socket.
- Provides both *ajax*<sup>[2]</sup> handling and its main page rendering.

# Technical Details – Front-/Back-End

- A simple HTML Server using Socket.
- Provides both *ajax*<sup>[2]</sup> handling and its main page rendering.
  - *ajax*: used for communication between the server and a webpage.

# Technical Details – Front-/Back-End

- A simple HTML Server using Socket.
- Provides both *ajax*<sup>[2]</sup> handling and its main page rendering.
  - *ajax*: used for communication between the server and a webpage.
  - To follow *CORS*<sup>[3]</sup> policy, we must use the *same* origin.

# Technical Details – Front-/Back-End

- A simple HTML Server using Socket.
- Provides both *ajax*<sup>[2]</sup> handling and its main page rendering.
  - *ajax*: used for communication between the server and a webpage.
  - To follow *CORS*<sup>[3]</sup> policy, we must use the *same* origin.
- An *ajax* example:

# Technical Details – Front-/Back-End

- A simple HTML Server using Socket.
- Provides both *ajax*<sup>[2]</sup> handling and its main page rendering.
  - *ajax*: used for communication between the server and a webpage.
  - To follow *CORS*<sup>[3]</sup> policy, we must use the *same* origin.
- An *ajax* example:
  - Requesting a function information from the server.

# Technical Details – Front-/Back-End

- A simple HTML Server using Socket.
- Provides both *ajax*<sup>[2]</sup> handling and its main page rendering.
  - *ajax*: used for communication between the server and a webpage.
  - To follow *CORS*<sup>[3]</sup> policy, we must use the *same* origin.
- An *ajax* example:
  - Requesting a function information from the server.
  - Running a single step in an AI.

# Technical Details – Front-/Back-End

- A simple HTML Server using Socket.
- Provides both *ajax*<sup>[2]</sup> handling and its main page rendering.
  - *ajax*: used for communication between the server and a webpage.
  - To follow *CORS*<sup>[3]</sup> policy, we must use the *same* origin.
- An *ajax* example:
  - Requesting a function information from the server.
  - Running a single step in an AI.
  - Fetching the current state of a specific vertex.



# Technical Details – Visualizer

# Technical Details – Visualizer

- *d3.js*<sup>[4]</sup>: a visualization library for web applications.

# Technical Details – Visualizer

- *d3.js*<sup>[4]</sup>: a visualization library for web applications.
- Implemented in a single HTML file with 500 LOC.

# Technical Details – Visualizer

- *d3.js*<sup>[4]</sup>: a visualization library for web applications.
- Implemented in a single HTML file with 500 LOC.
  - Most features were implemented in *javascript*.

# Technical Details – Visualizer

- *d3.js*<sup>[4]</sup>: a visualization library for web applications.
- Implemented in a single HTML file with 500 LOC.
  - Most features were implemented in *javascript*.
- Uses event callbacks for interactive visualization:

# Technical Details – Visualizer

- *d3.js*<sup>[4]</sup>: a visualization library for web applications.
- Implemented in a single HTML file with 500 LOC.
  - Most features were implemented in *javascript*.
- Uses event callbacks for interactive visualization:
  - *Click* for showing the clicked vertex's information.

# Technical Details – Visualizer

- *d3.js*<sup>[4]</sup>: a visualization library for web applications.
- Implemented in a single HTML file with 500 LOC.
  - Most features were implemented in *javascript*.
- Uses event callbacks for interactive visualization:
  - *Click* for showing the clicked vertex's information.
  - *Mouseover* for on-demand information rendering.

# Technical Details – Debugger



# Technical Details – Debugger

- Implemented in *F#*<sup>[5]</sup>.

# Technical Details – Debugger

- Implemented in *F#*<sup>[5]</sup>.
- Modified the previous AI engine to interact with the outside.

# Technical Details – Debugger

- Implemented in  $F\#$ <sup>[5]</sup>.
- Modified the previous AI engine to interact with the outside.
  - Do not calculate its fixpoint in a row; just stop at every step.

# Technical Details – Debugger

- Implemented in  $F\#$ <sup>[5]</sup>.
- Modified the previous AI engine to interact with the outside.
  - Do not calculate its fixpoint in a row; just stop at every step.
- Send the information to the Front-End.

# Technical Details – Debugger

- Implemented in  $F\#$ <sup>[5]</sup>.
- Modified the previous AI engine to interact with the outside.
  - Do not calculate its fixpoint in a row; just stop at every step.
- Send the information to the Front-End.
  - State information.

# Technical Details – Debugger

- Implemented in *F#*<sup>[5]</sup>.
- Modified the previous AI engine to interact with the outside.
  - Do not calculate its fixpoint in a row; just stop at every step.
- Send the information to the Front-End.
  - State information.
  - Statement information.

# Impacts

# Impacts

- Found two critical bugs in an AI implementation.



# Impacts

- Found two critical bugs in an AI implementation.
- Wrong Top Calculation Bug

# Impacts

- Found two critical bugs in an AI implementation.
- Wrong Top Calculation Bug
  - A variable was calculated as Top even though it should not be so.

# Impacts

- Found two critical bugs in an AI implementation.
- Wrong Top Calculation Bug
  - A variable was calculated as Top even though it should not be so.
- Insufficient Sensitivity Bug

# Impacts

- Found two critical bugs in an AI implementation.
- Wrong Top Calculation Bug
  - A variable was calculated as Top even though it should not be so.
- Insufficient Sensitivity Bug
  - Different call contexts were overly merged.

# Impacts

- Found two critical bugs in an AI implementation.
- Wrong Top Calculation Bug
  - A variable was calculated as Top even though it should not be so.
- Insufficient Sensitivity Bug
  - Different call contexts were overly merged.
- With VisualAI, it was easy to track causes of the bugs.

# Future Work

# Future Work

- Visualize def-use (use-def) chains.

# Future Work

- Visualize def-use (use-def) chains.
- Support breakpoints with conditions.



# Future Work

- Visualize def-use (use-def) chains.
- Support breakpoints with conditions.
- Support an instruction-level debugging.

# Question?