KarDo: Configuration Independent Automation by Non-Experts

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Users constantly run into computer tasks they don't know how to do

Sync with iPod

Enable security on wireless router

Defragment hard drive

Tether to Blackberry

Set up VPN

⋮

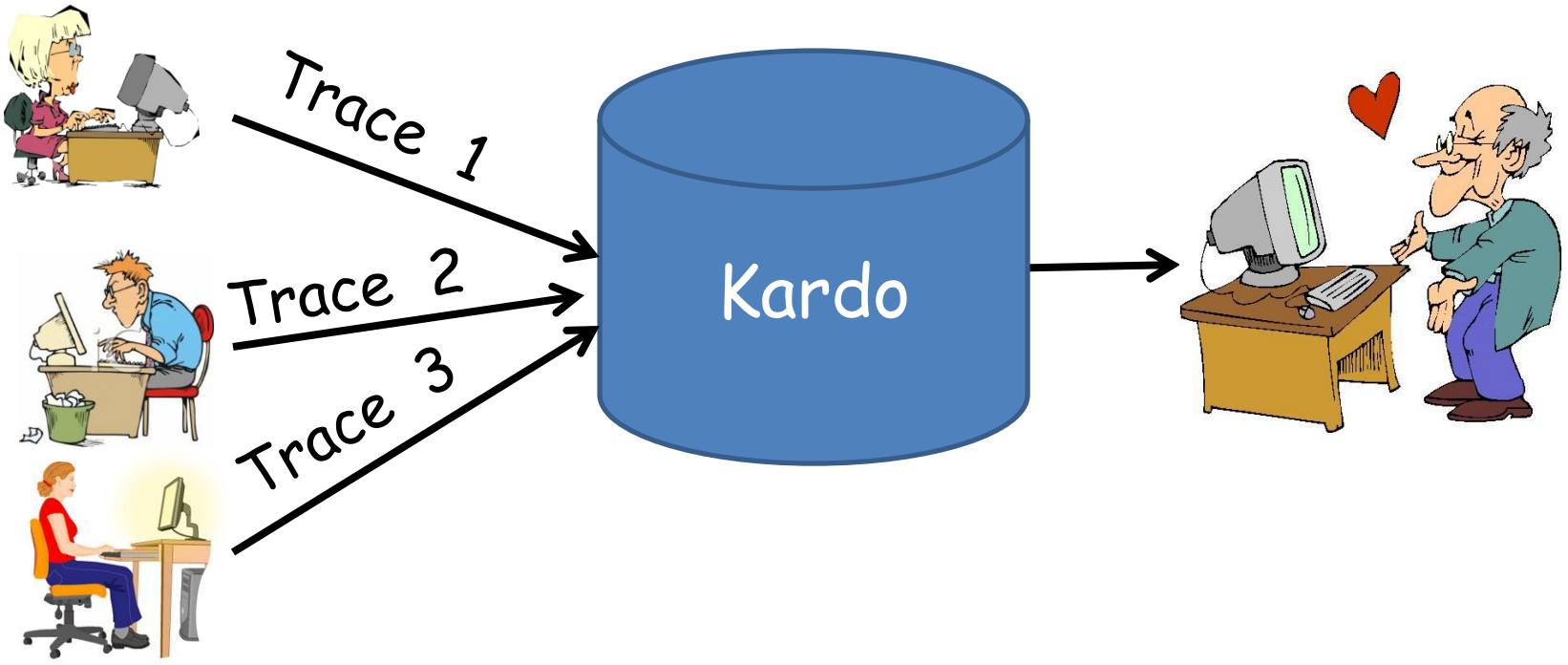
Today, we repeatedly solve the same computer problems

Why?

No easy way to automate across machine configurations!

KarDo

- Observes users actions as they perform a task
- Produces solution that works across configurations



A Naïve Strawman

Collects a separate trace for every possible configuration

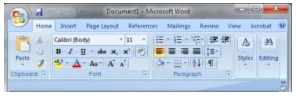
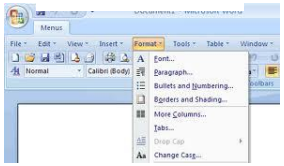
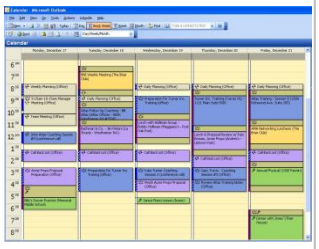
But …

Space of Configurations is Huge

Different Apps

Different App configuration

Different default settings

Config 1	Config 2	Config 3
		 Eudora
		
		

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A task has multiple steps, and multiple options per step

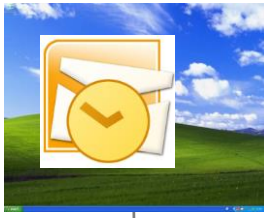
Unlikely to have more than a few traces for the majority of tasks

How do we handle configuration diversity with just a few traces per task?

KarDo Can Generalize Using a Few Traces

Turn on out-of-office e-mails in Outlook

Trace



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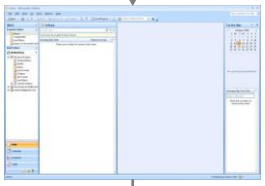

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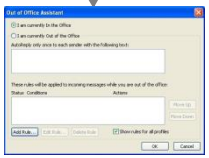
click away Java updater



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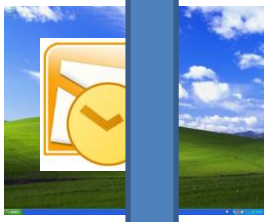

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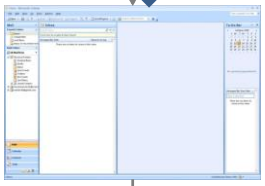

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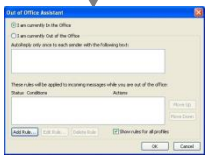
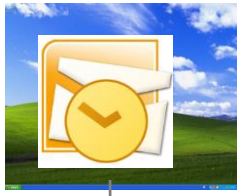


out of office

Automation machine



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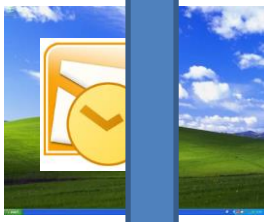

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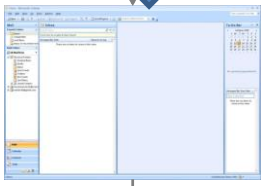
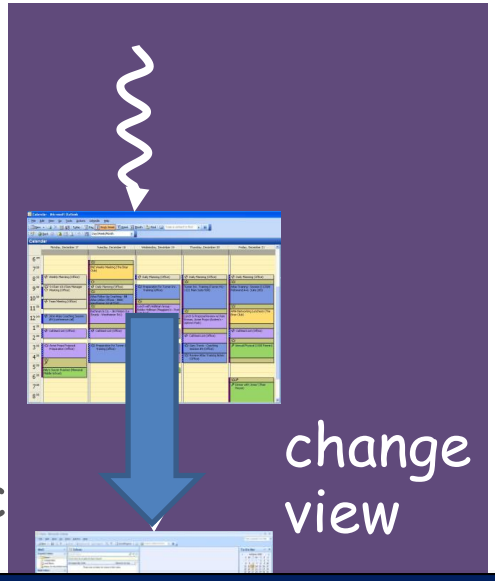


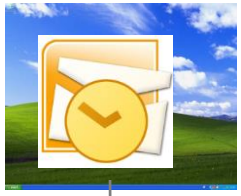
From menu →out of offic

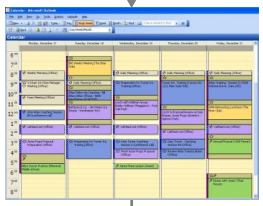
Different Task



change view

Automation machine





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Need far fewer traces!

KarDo Can Generalize Using a Few Traces

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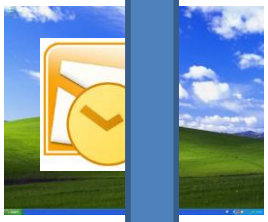

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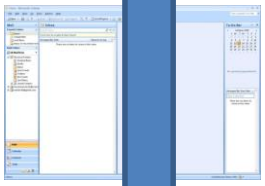

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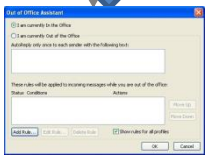
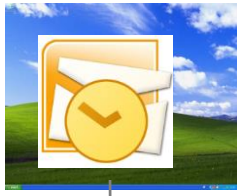
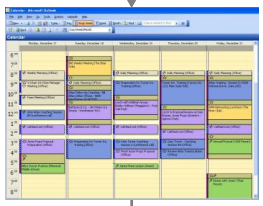
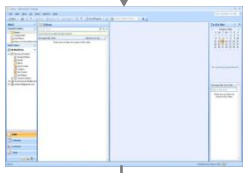


out of office

Automation machine







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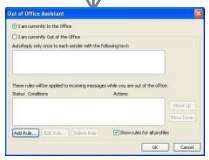
No java updates



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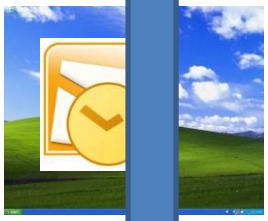
Turn on out-of-office e-mails in Outlook

Trac

Automation machine



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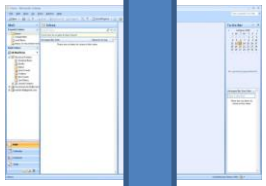

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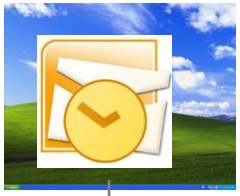
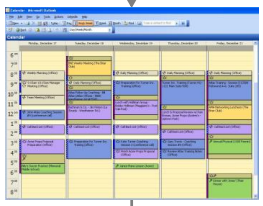
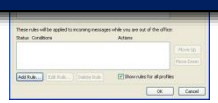






Allows us to remove unnecessary dependencies

Contributions

- A system that automates across configurations, with a few traces per task
- Requires no kernel or app modifications
- Used it to automated tasks from MS Help & eHow

E-mail

Turn off E-mail Read Receipts
Automatically forward e-mail to another address
Restore the unread mail folder
Highlight all messages sent only to me
Change an e-mail filtering rule
Add an e-mail filter rule
Make the recipient column visible in the Inbox
Order e-mail message by sender
Create an Outlook Search Folder
Turn on threaded message viewing in Outlook
Mark all messages as read
Automatically empty deleted items folder
Empty junk e-mail folder
Turn off Junk e-mail filtering
Consider people e-mailed to be safe senders
Send an e-mail with a receipt request
File Outlook contacts by last name
Set Outlook to start in Calendar mode
Add a new RSS feed
Change the Name of an RSS feed
Turn off Outlook Desktop Alerts
Reduce the size of a .pst file
Turn off notification sound
Switch calendar view to 24-hour clock

Web

Browser Install Firefox
Configure SSL proxy
Set Default Http Proxy

Office

Delete a worksheet in Excel
Turn on AutoSave in Excel
Disable add-ins in Word

Networking

Enable firewall exceptions
Enable Windows firewall
Disable Windows firewall notifications
Disable Windows firewall
Disable IPv6 to IPv4 tunnel
Show the current IPv4 routing table
Show the current IPv6 routing table
Use OpenDNS
Stop caching DNS replies
Use Google's public DNS server
Use DNS server from DHCP
Configure system to pick routes based on link speed
Set routing interface metric

System

Analyze hard drive for errors
Defragment hard drive
Enable Automatic Updates
Set Up Remote Desktop
Hide the Outlook icon in the System tray
Change to Classic UI
Delete an Item from the Task Bar
Change desktop background color
Enable Accessibility Options
Auto-Hide the Taskbar
Change date to Long Format
Set Visual Effects for Performance
Set Outlook as default E-mail program
Enable Password on Screen Saver

Contributions

- A system that automates across configurations, with a few traces per task
- Requires no kernel or app modifications
- Used it to automated tasks from MS Help
- Using only 2 traces per task,
  - KarDo automates 84% of configurations
  - A baseline that tries both traces automates only 18% of configurations

KarDo


Tracing User Actions
Generalizing to a Canonical Solution
Replay

Challenge:

OS gives us only mouse clicks and keypresses which are meaningless for other machines

Can't rely on windowing layer:

- many applications use custom widget libraries

Solution:

Accessibility Interface

For each widget:

```
Type: check box
Value: checked
Location: x1,y1, x2,y2
Text: "Enable IMAP"
Window Hierarchy: in view V, in window W,…
```

Uniquely identify each widget

Map mouse clicks & key-presses to GUI actions, which are meaningful across machines

KarDo


Tracing User Actions
Generalizing to a Canonical Solution
Replay

But which action is which?

non-state modifying actions

Update
pending change to state
- e.g. check a check box

Commit
write pending updates to state
- e.g. click "OK" button

State- Modifying
Learn within a task

Navigate
make new widgets available
- e.g. move to a new tab

Non-State-Modifying
Learn across tasks

Challenge:

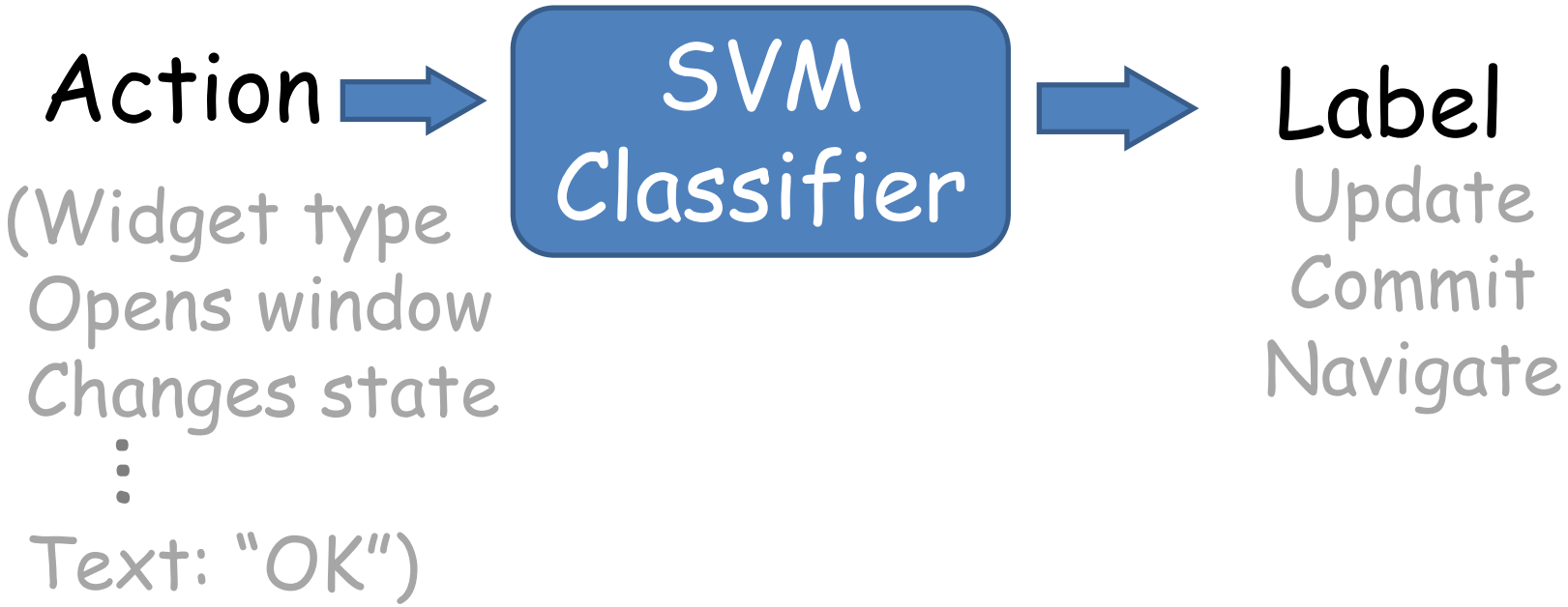
How do we automatically map a GUI action to Update, Commit or Navigate ?

Solution:

Machine Learning Classifier

Solution:

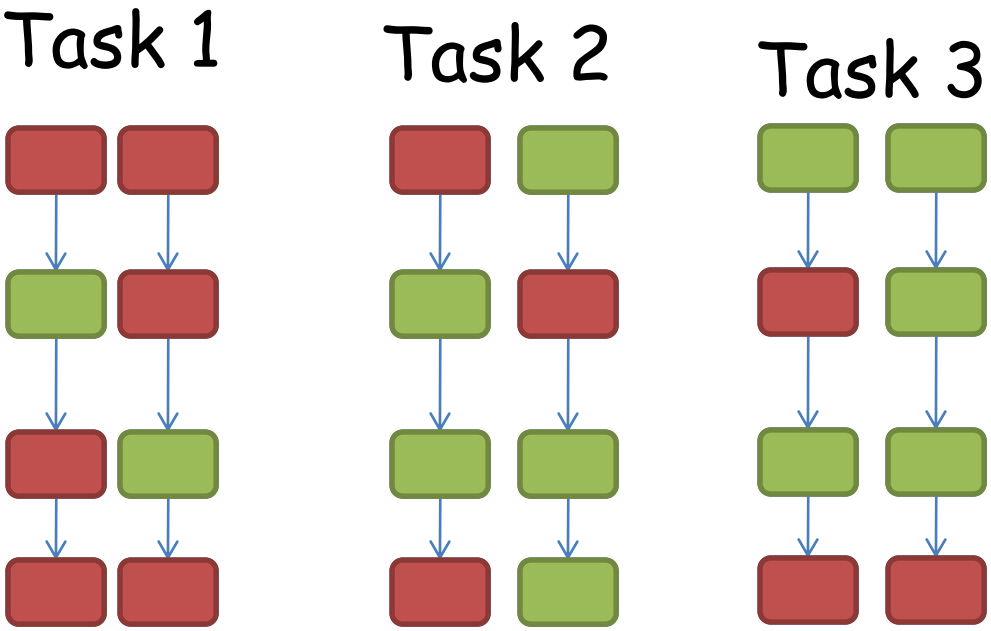
Machine Learning Classifier



We can differentiate state-modifying from non-state modifying

But, how do we generalize across configurations?

KarDo's Generalization Framework



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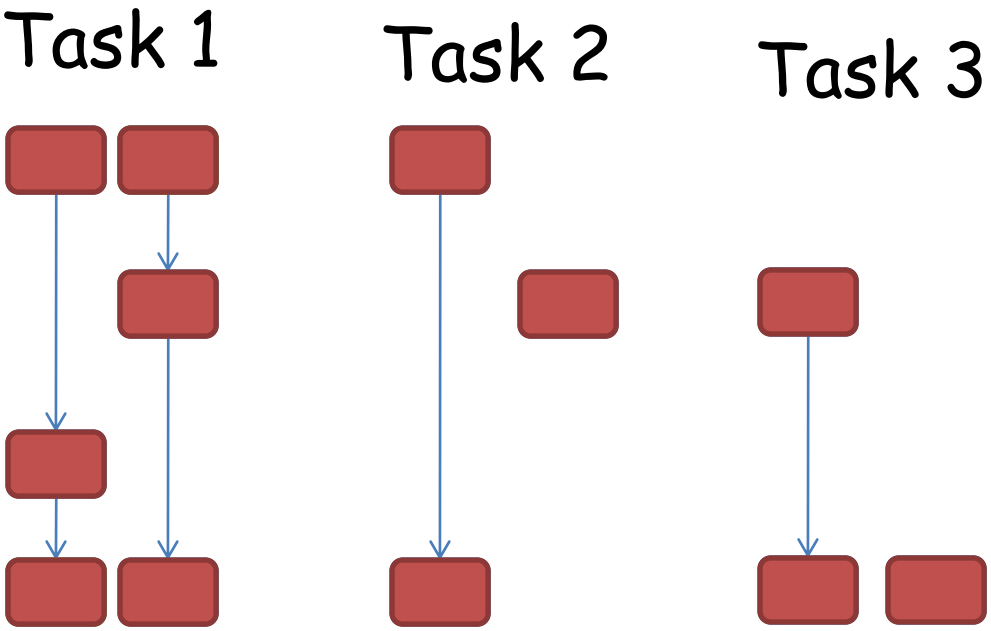
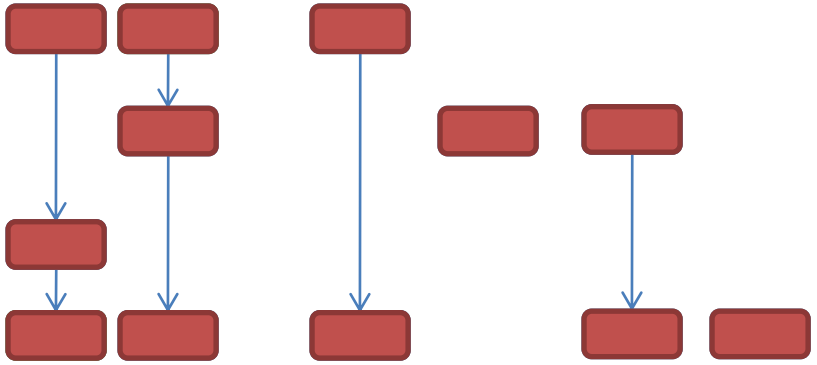


Generalize Navigation across all tasks

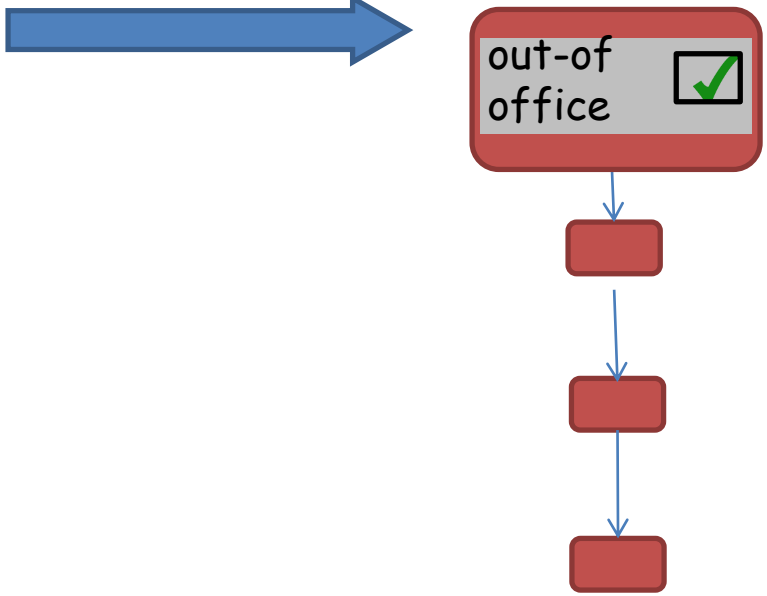
KarDo's Generalization Framework

Generalize State Mods. within a task

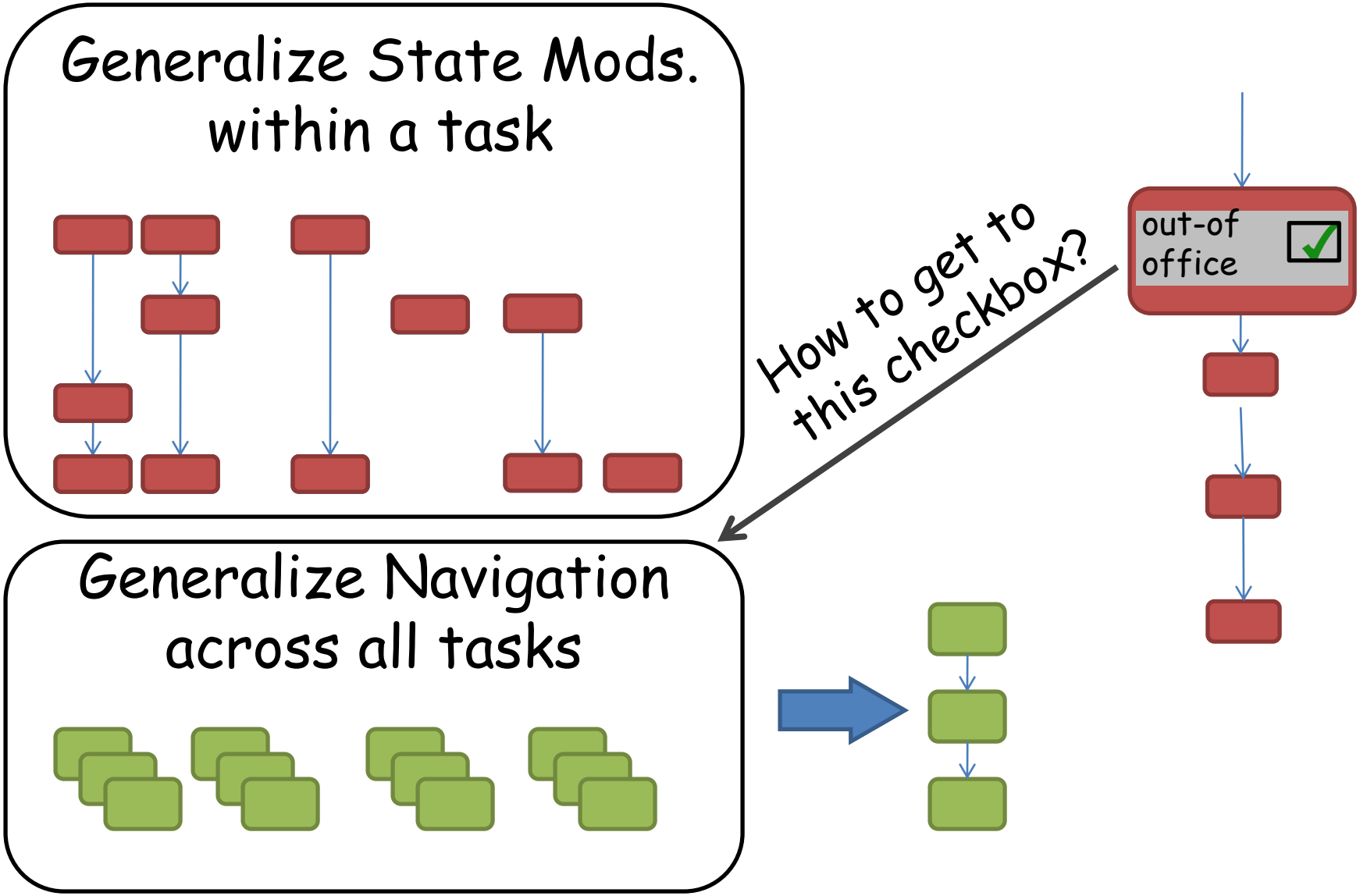


Generalize Navigation across all tasks

Automated solution

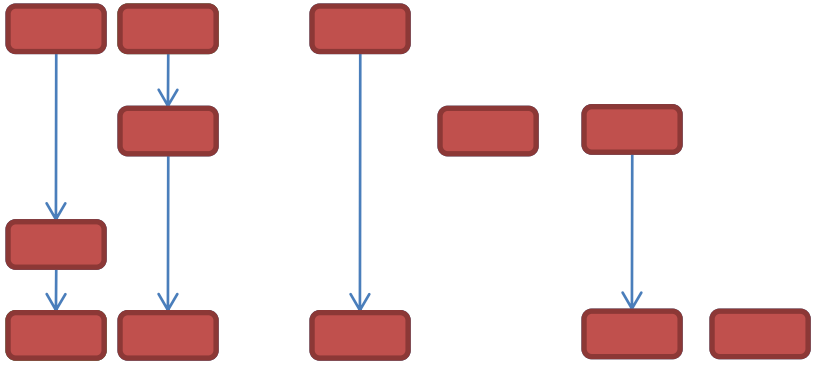


KarDo's Generalization Framework



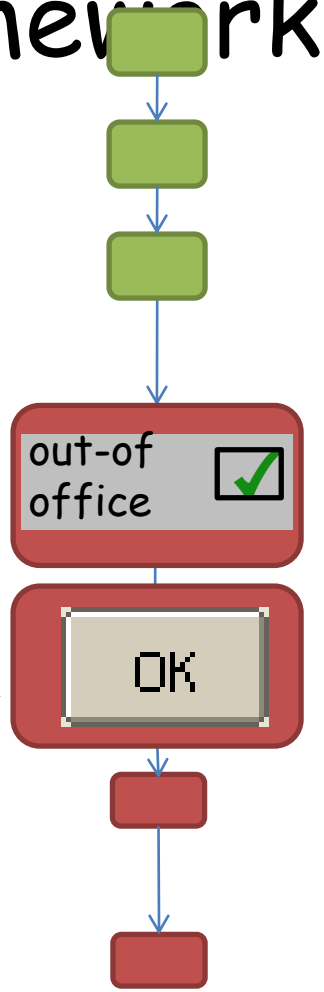
KarDo's Generalization Framework

Generalize State Mods. within a task



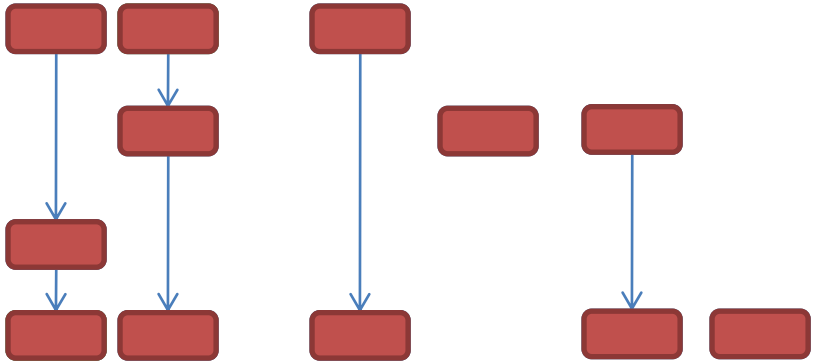
Generalize Navigation across all tasks

How to get to this button?

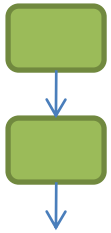


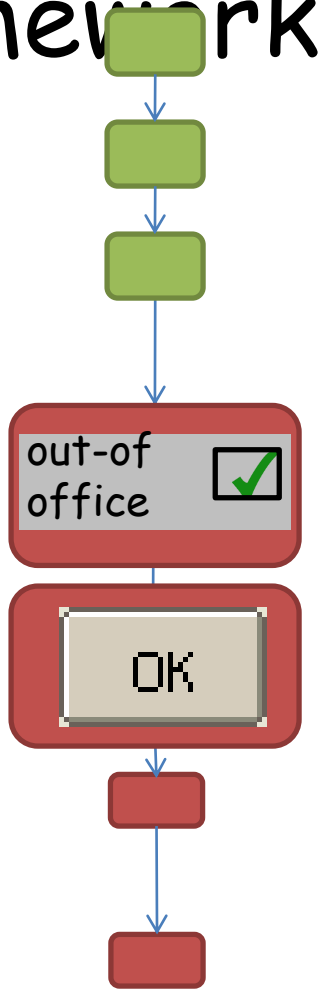
KarDo's Generalization Framework

Generalize State Mods. within a task

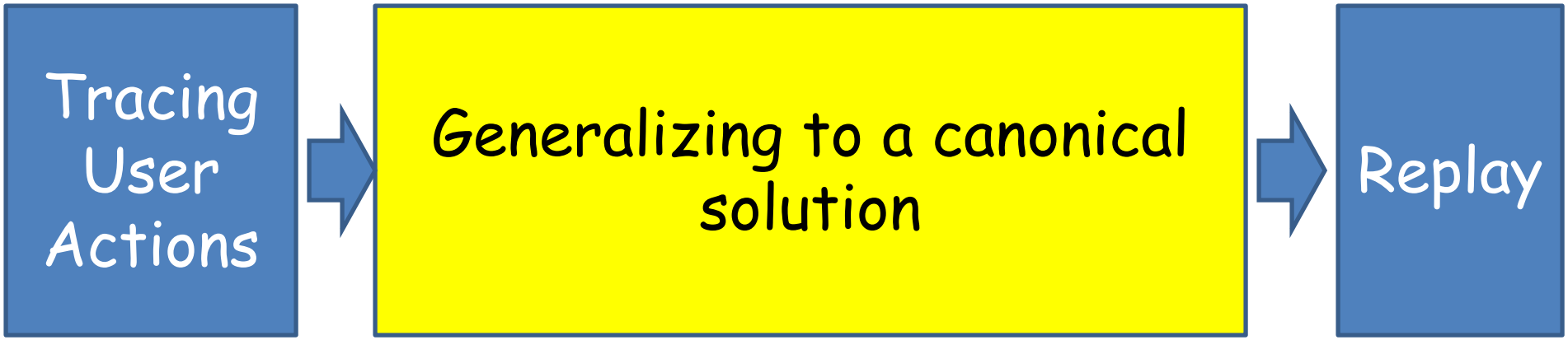


Generalize Navigation across all tasks





KarDo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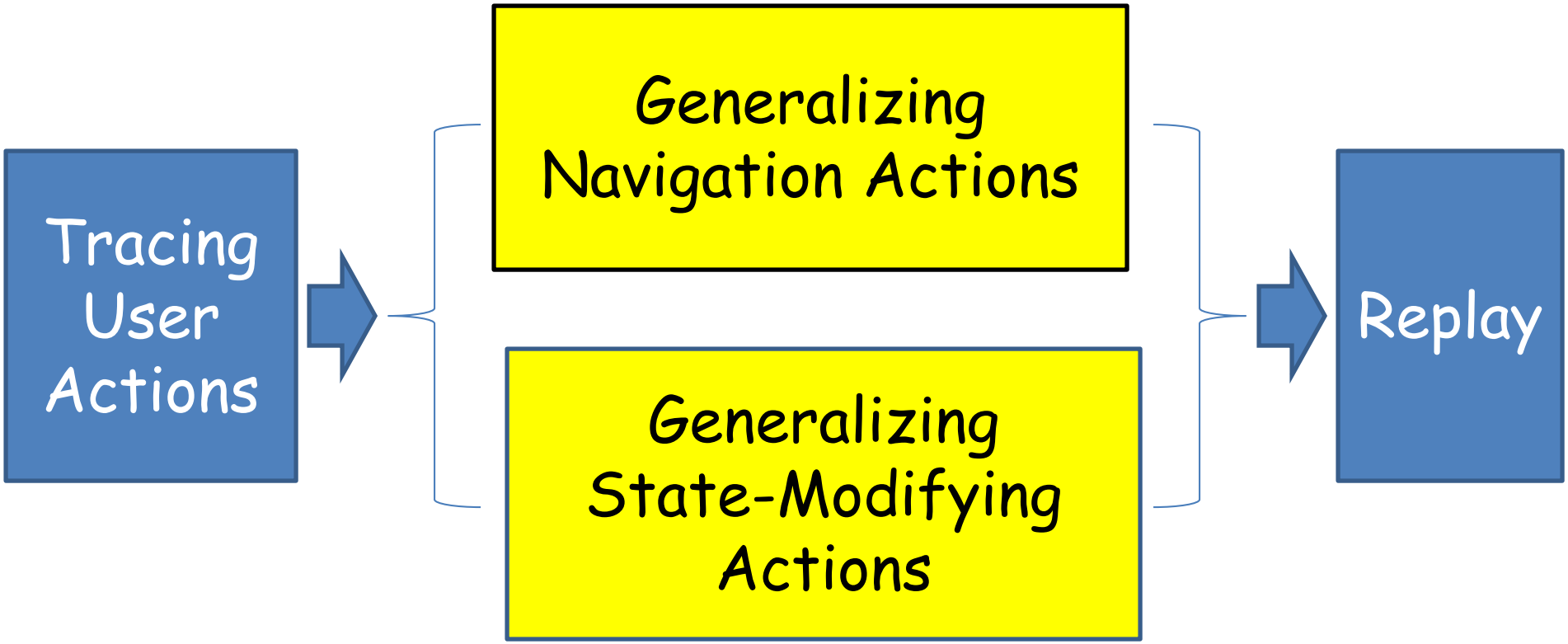
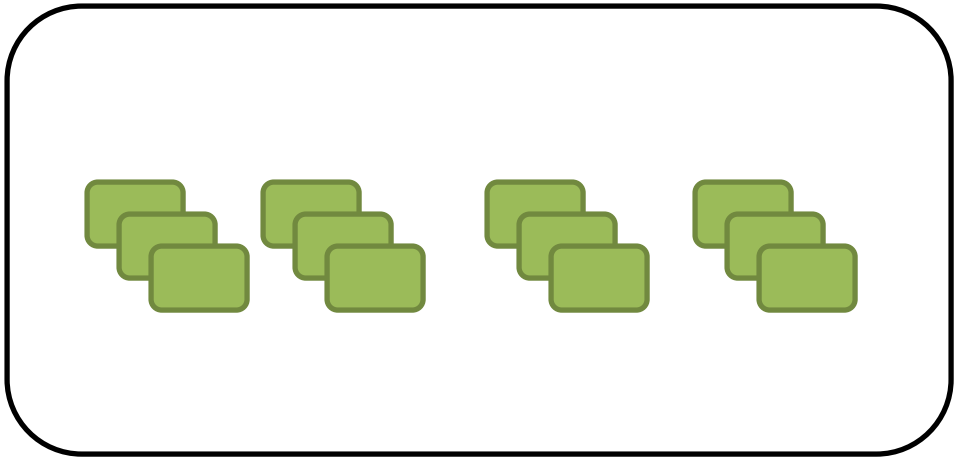
Generalizing to a canonical solution
Replay

KarDo

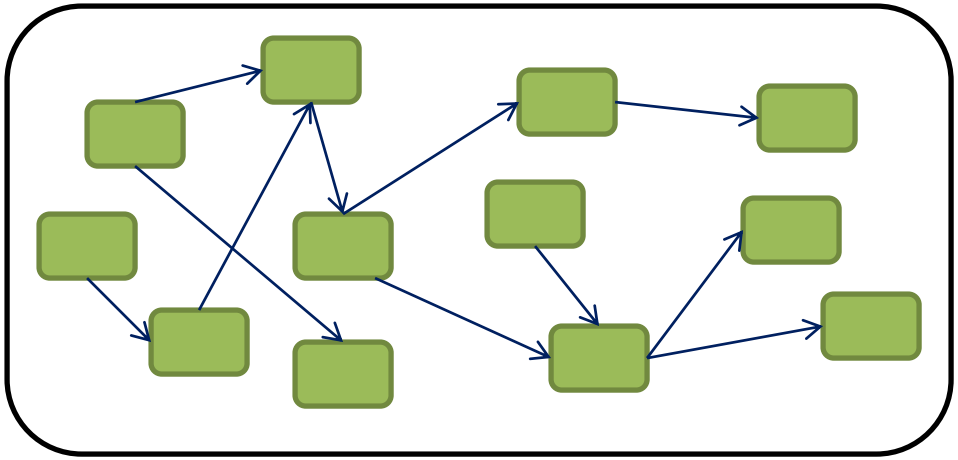

Tracing User Actions
Generalizing Navigation Actions
Generalizing State-Modifying Actions
Replay

Generalizing Navigation



Generalizing Navigation

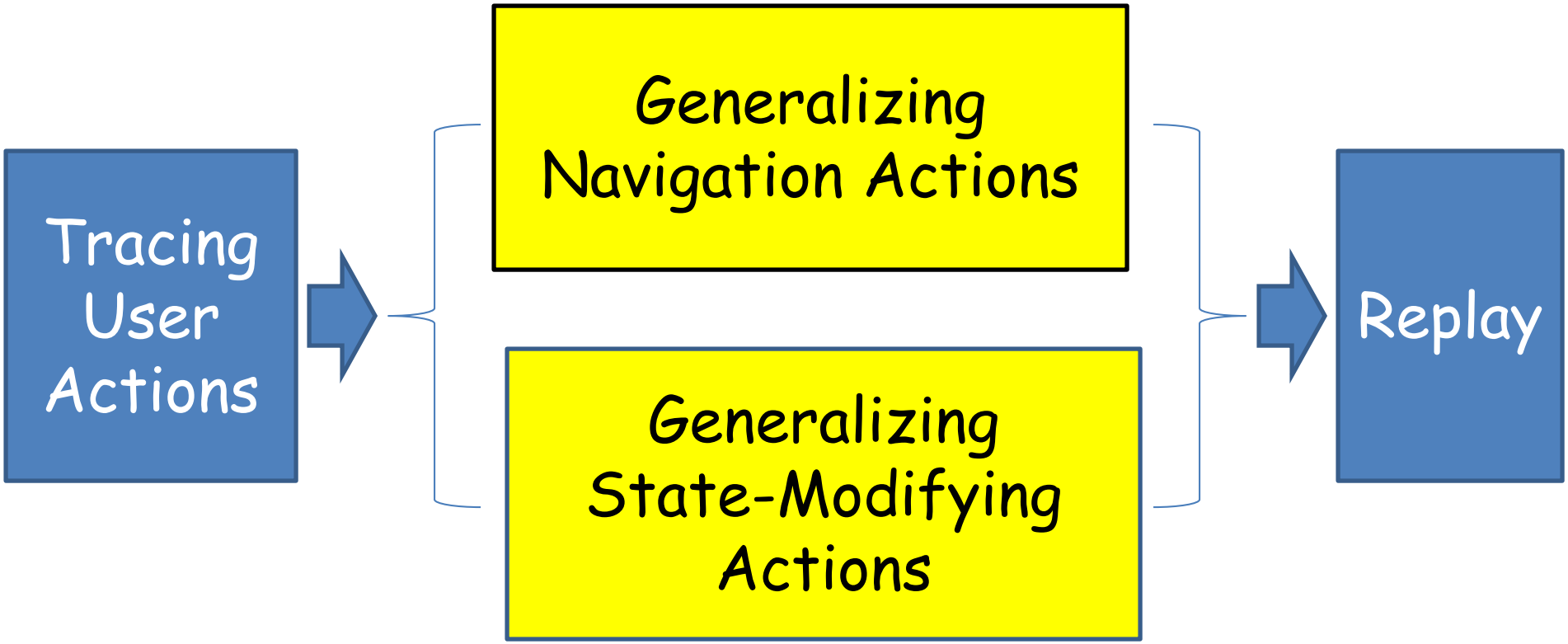
Global Navigation Graph



During replay,

Breadth first search from the widget in automated solution to any widget on the screen

KarDo


Tracing User Actions
Generalizing Navigation Actions
Generalizing State-Modifying Actions
Replay

Generalizing State-Modifying Actions

Are all Update and Commit actions necessary?

Open Word

Copy+Paste in Word → Update

Close Word

Unnecessary

Open Notepad

Copy+Paste into Notepad

Save in Notepad

Close Notepad

Generalizing State-Modifying Actions

Are all Update and Commit actions necessary?

Open Word

Copy+Paste in Word → Update

Close Word

Unnecessary

Open Notepad

Copy+Paste into Notepad → Update

Save in Notepad → Commit

Unnecessary Actions
→ Unnecessary Dependencies

Challenge:

How do we remove unnecessary updates and commits?

Solution Idea:

Remove any action that does not contribute to final system state

Algorithm for Removing Unnecessary Actions

Click **Open Dialog**

Check **Check Box**

Click **OK**

Click **Open Dialog**

Click **OK**

Click **Open Dialog**

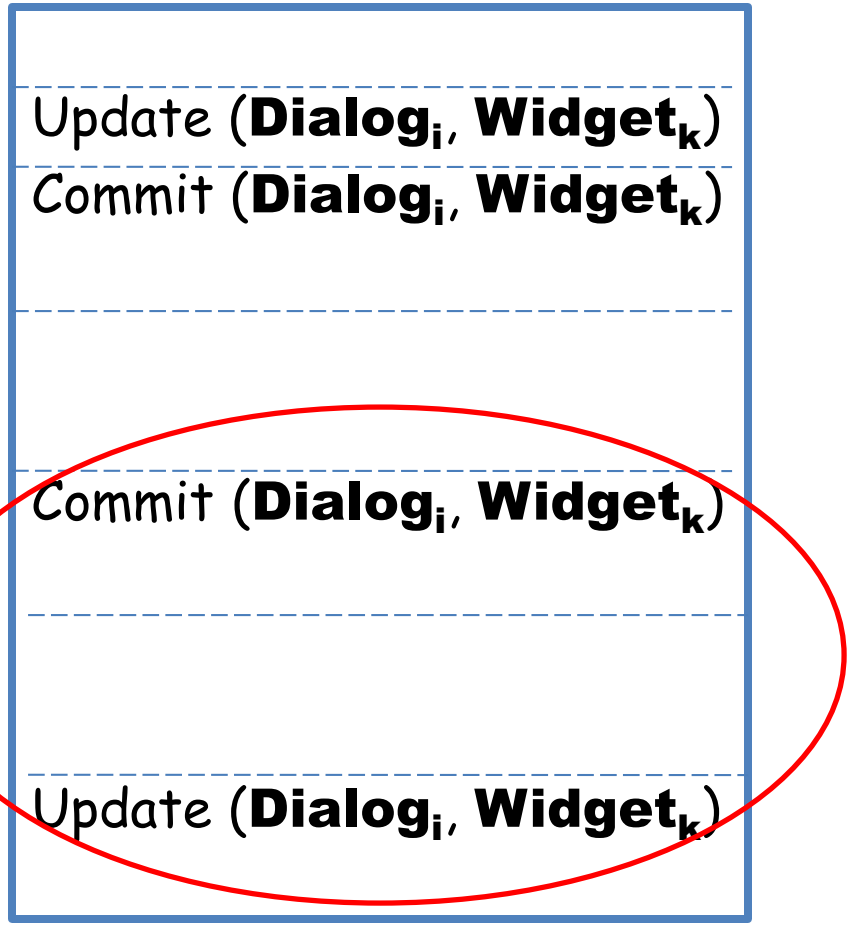
UnCheck **Check Box**

Click **Cancel**

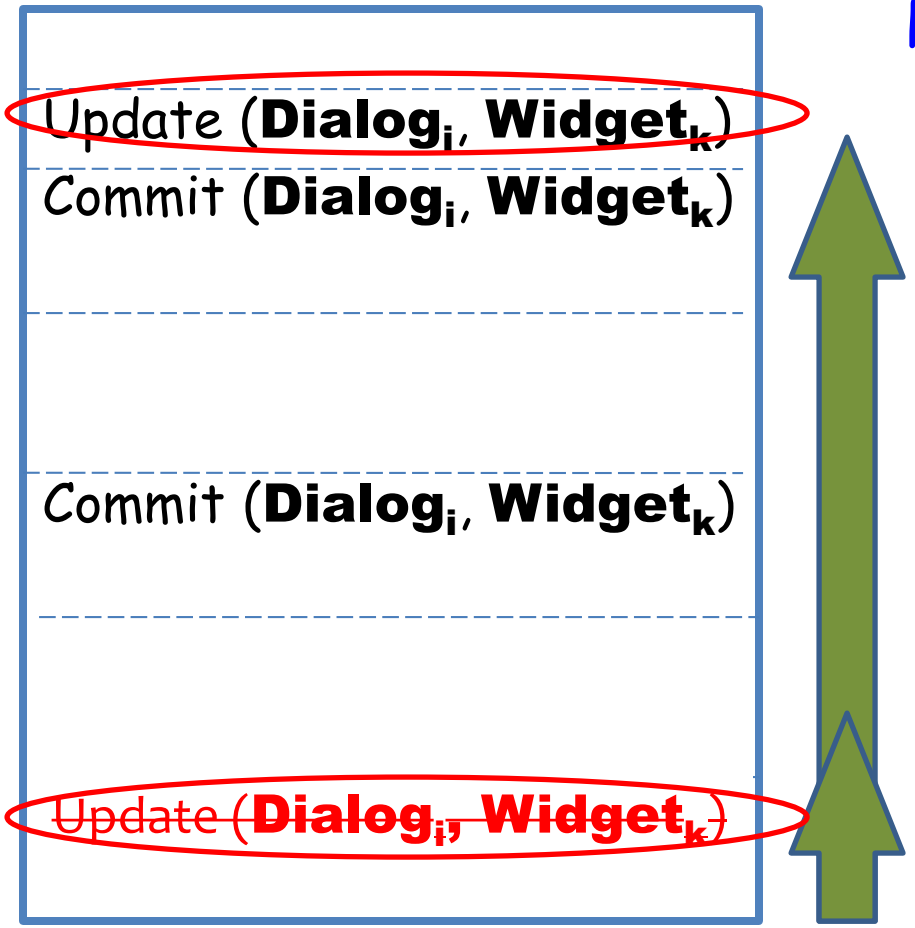
Algorithm for Removing Unnecessary Actions

Navigate to **Dialog$_i$**
Update (**Dialog$_i$**, **Widget$_k$**)
Commit (**Dialog$_i$**, **Widget$_k$**) Navigate to **Main**
Navigate to **Dialog$_i$**
Commit (**Dialog$_i$**, **Widget$_k$**) Navigate to **Main**
Navigate to **Dialog$_i$**
Update (**Dialog$_i$**, **Widget$_k$**)
Navigate to **Main**

Algorithm for Removing Unnecessary Actions



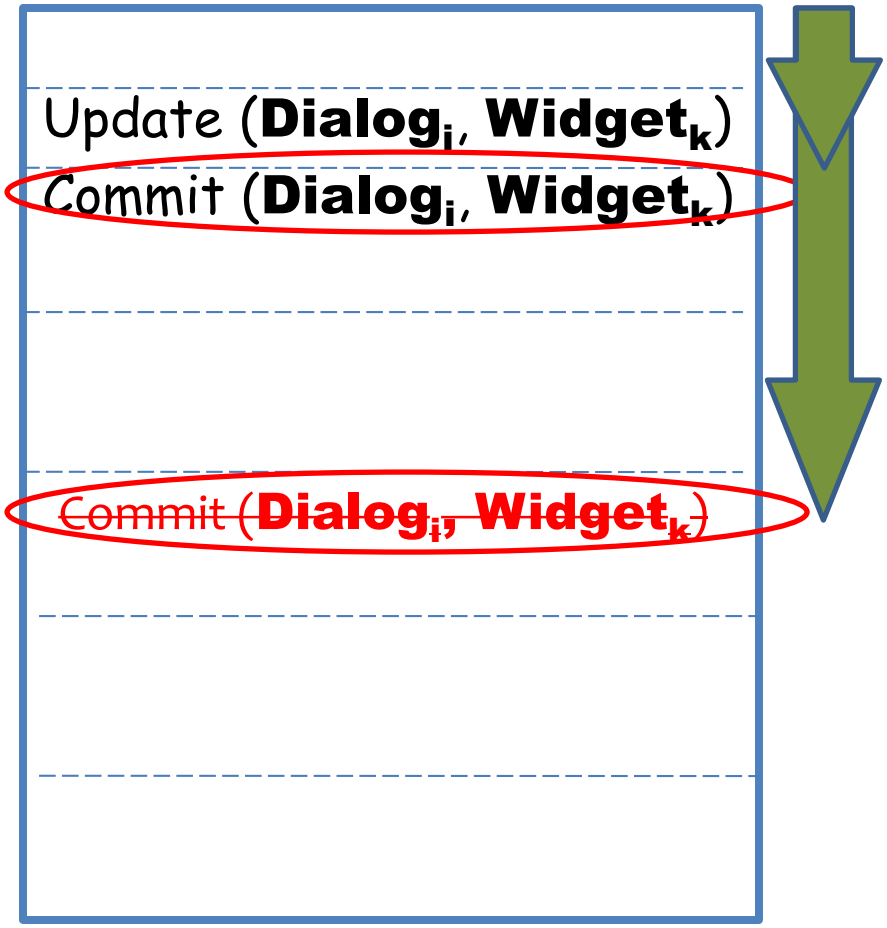
Algorithm for Removing Unnecessary Actions



Pass 1: Unnecessary Updates

Go backwards → Eliminate updates with no commit

Removing Unnecessary Actions



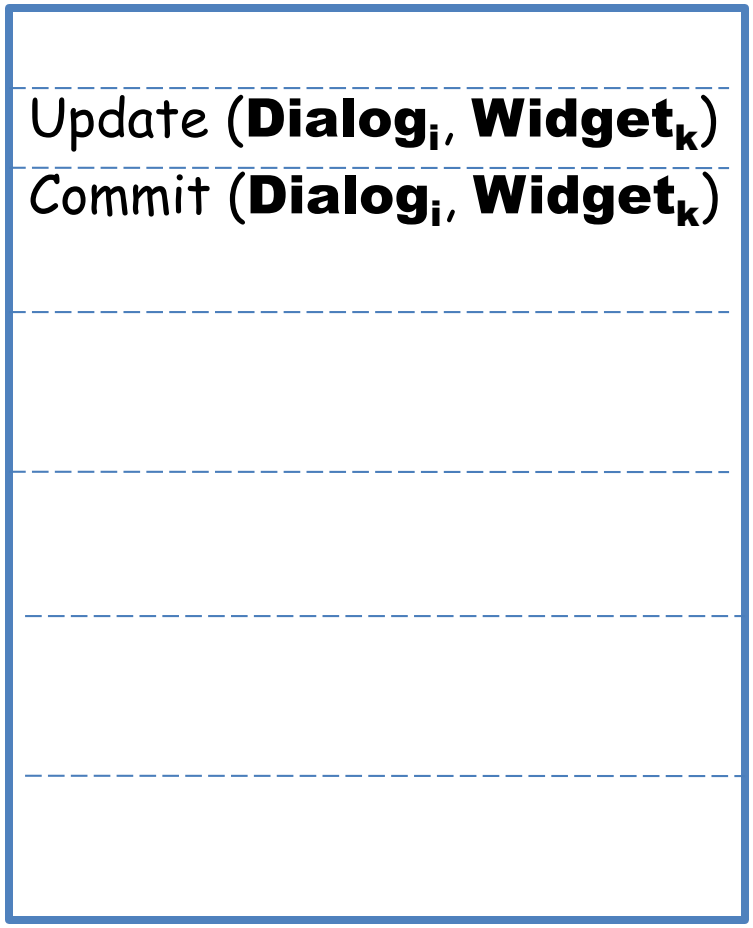
Pass 1: Unnecessary Updates

Go backwards → Eliminate updates with no commit

Pass 2: Unnecessary Commits

Go forwards → Eliminate all commits w/o pending updates

Removing Unnecessary Actions



Pass 1: Unnecessary Updates

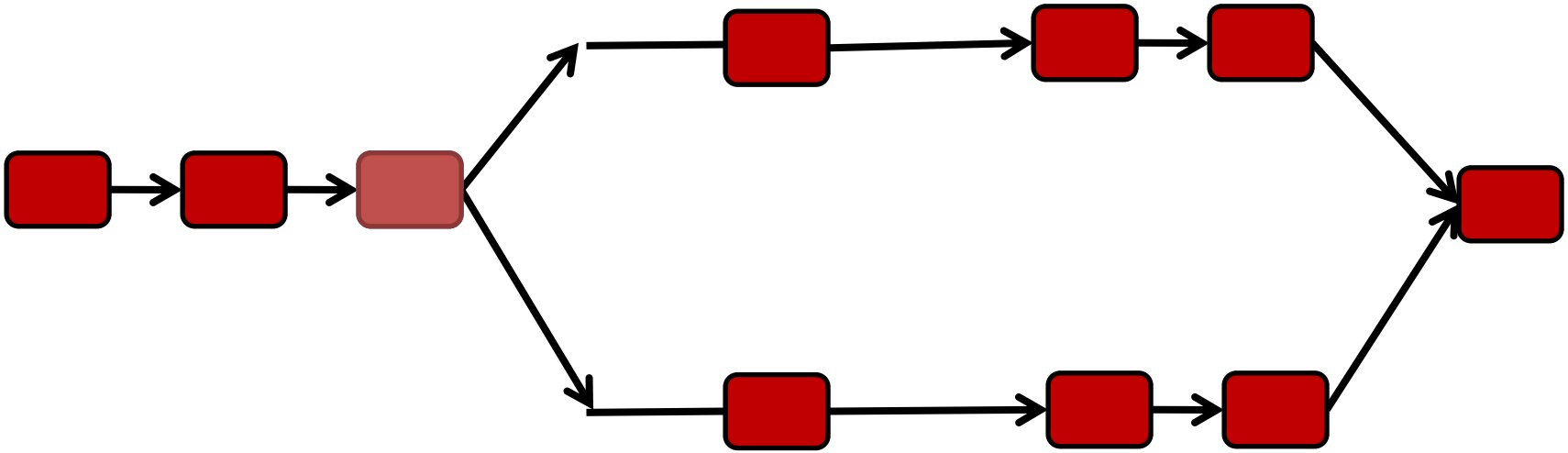
Go backwards → Eliminate updates with no commit

Pass 2: Unnecessary Commits

Go forwards → Eliminate all commits w/o pending updates

Creating a Canonical Solution

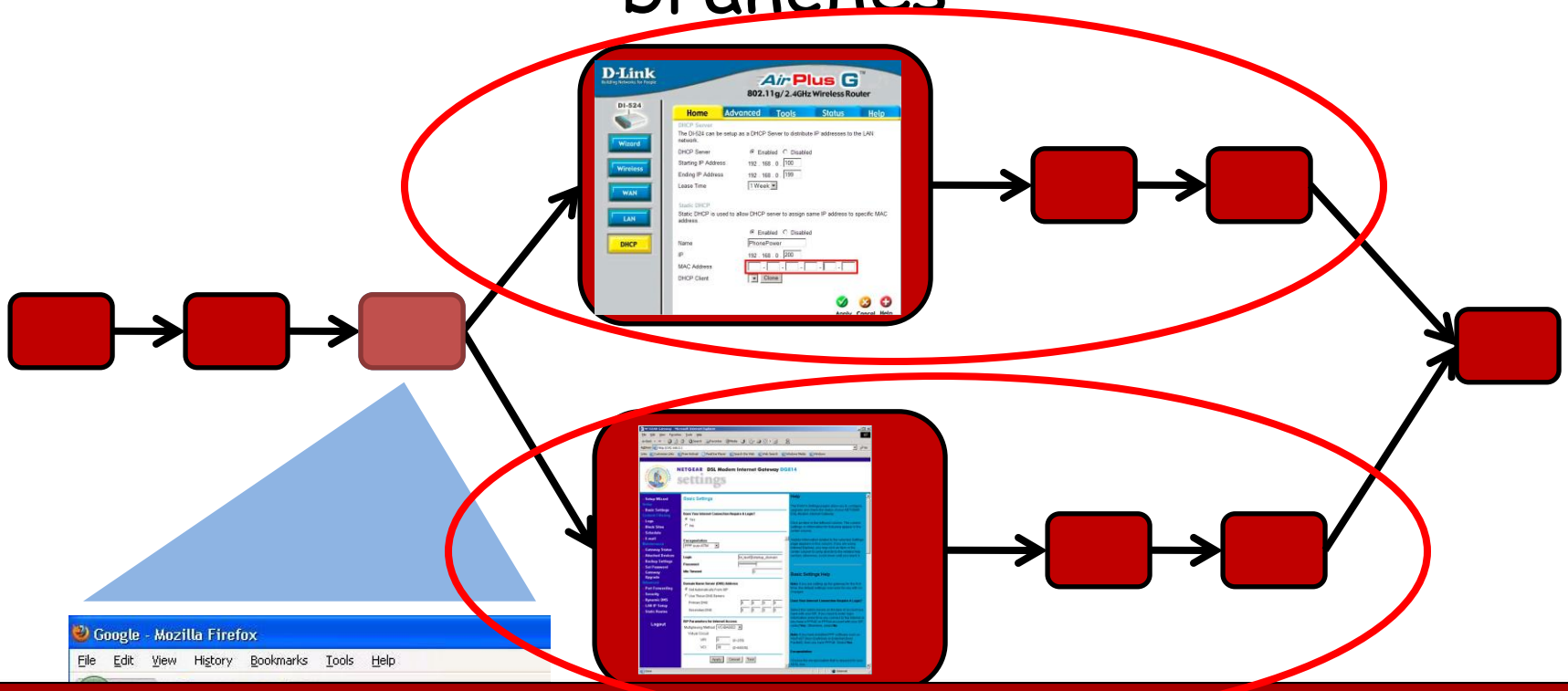
A per task state-modifying graph, with if-then branches



But how do we decide which branch to take for a given configuration?

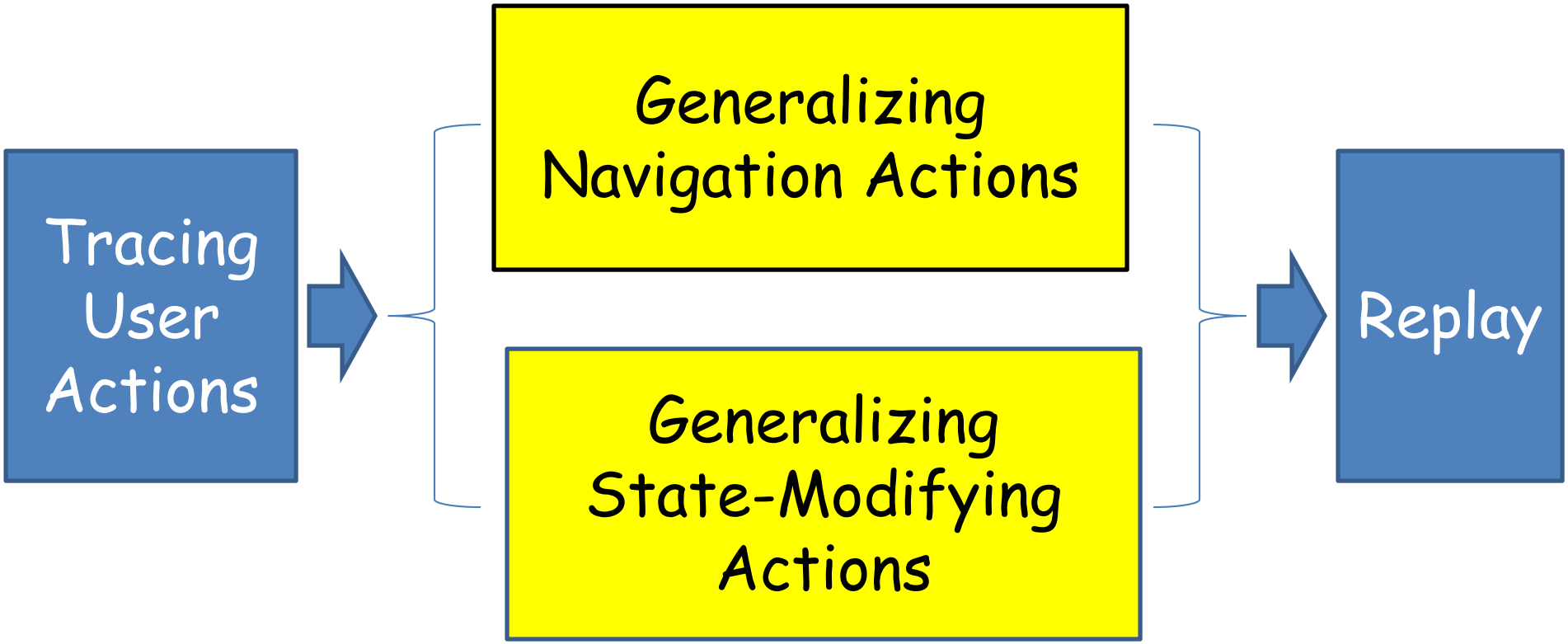
Creating a Canonical Solution

A per task state-modifying graph, with if-then branches

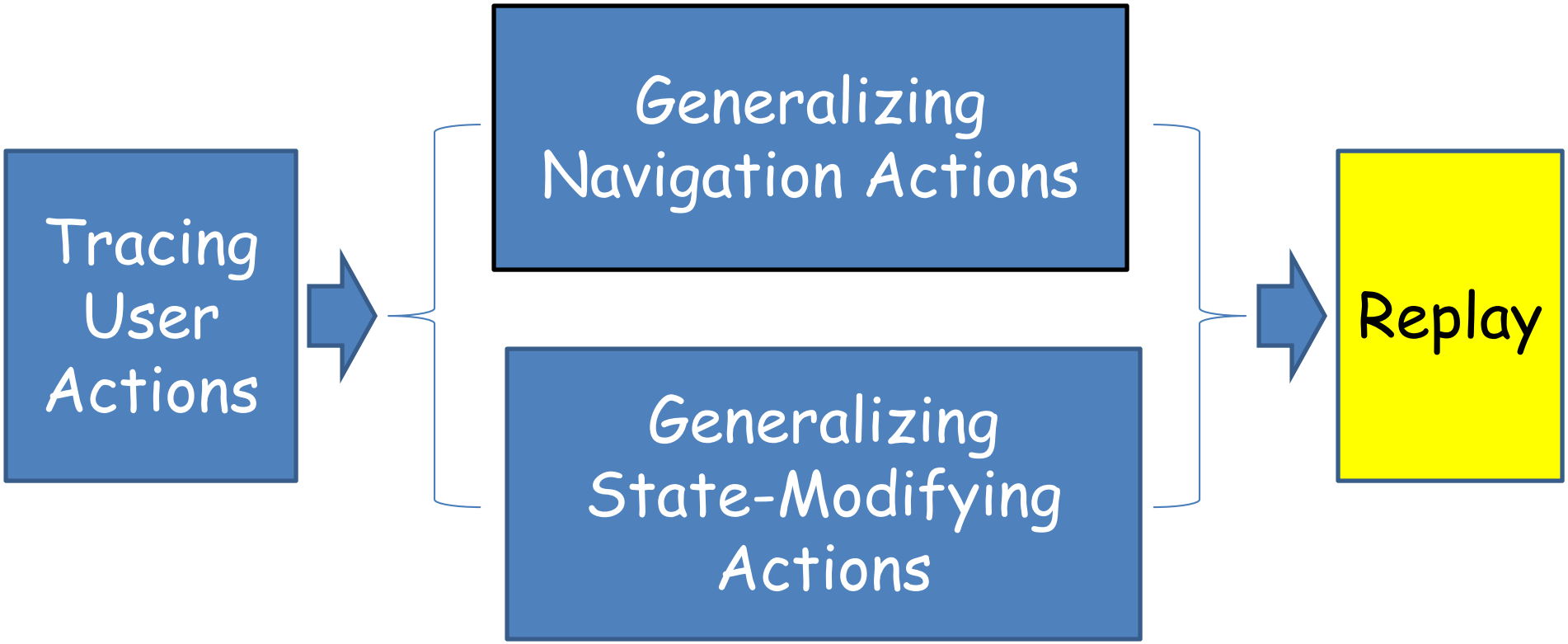


Dynamically evaluate branches

KarDo

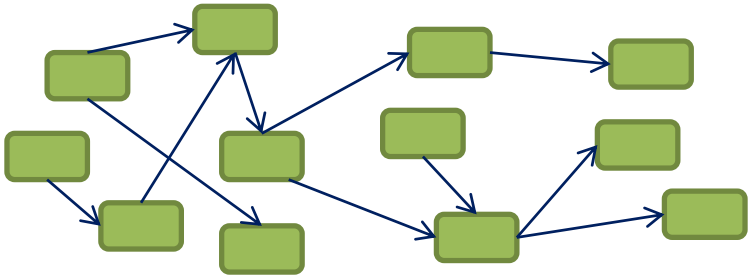

Tracing User Actions
Generalizing Navigation Actions
Generalizing State-Modifying Actions
Replay

KarDo

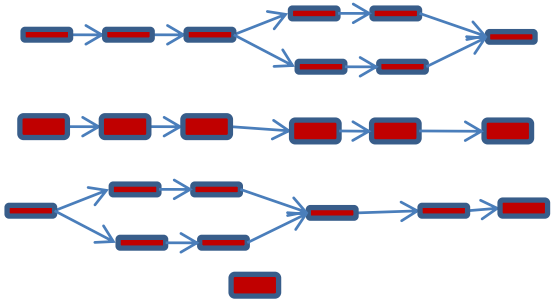

Tracing User Actions
Generalizing Navigation Actions
Generalizing State-Modifying Actions
Replay

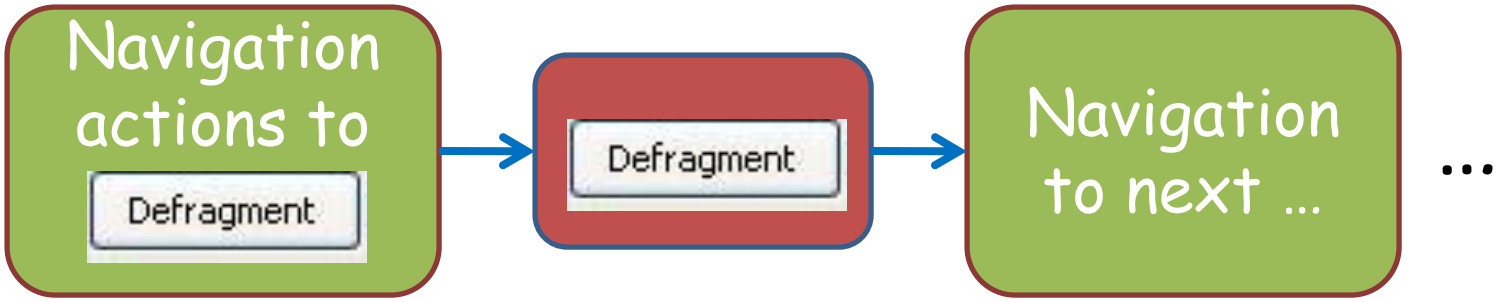
Replay

Global Navigation Graph



Per Task Commit/Update Graph





Experiments

Experimental Setup

- Implemented KarDo as thin client and a server
- Tested on 57 Tasks from eHow and MS Help sites

E-mail

Turn off E-mail Read Receipts
Automatically forward e-mail to another address
Restore the unread mail folder
Highlight all messages sent only to me
Change an e-mail filtering rule
Add an e-mail filter rule
Make the recipient column visible in the Inbox
Order e-mail message by sender
Create an Outlook Search Folder
Turn on threaded message viewing in Outlook
Mark all messages as read
Automatically empty deleted items folder
Empty junk e-mail folder
Turn off Junk e-mail filtering
Consider people e-mailed to be safe senders
Send an e-mail with a receipt request
File Outlook contacts by last name
Set Outlook to start in Calendar mode
Add a new RSS feed
Change the Name of an RSS feed
Turn off Outlook Desktop Alerts
Reduce the size of a .pst file
Turn off notification sound
Switch calendar view to 24-hour clock

Web

Browser Install Firefox
Configure SSL proxy
Set Default Http Proxy

Office

Delete a worksheet in Excel
Turn on AutoSave in Excel
Disable add-ins in Word

Networking

Enable firewall exceptions
Enable Windows firewall
Disable Windows firewall notifications
Disable Windows firewall
Disable IPv6 to IPv4 tunnel
Show the current IPv4 routing table
Show the current IPv6 routing table
Use OpenDNS
Stop caching DNS replies
Use Google's public DNS server
Use DNS server from DHCP
Configure system to pick routes based on link speed
Set routing interface metric

System

Analyze hard drive for errors
Defragment hard drive
Enable Automatic Updates
Set Up Remote Desktop
Hide the Outlook icon in the System tray
Change to Classic UI
Delete an Item from the Task Bar
Change desktop background color
Enable Accessibility Options
Auto-Hide the Taskbar
Change date to Long Format
Set Visual Effects for Performance
Set Outlook as default E-mail program
Enable Password on Screen Saver

Experimental Setup

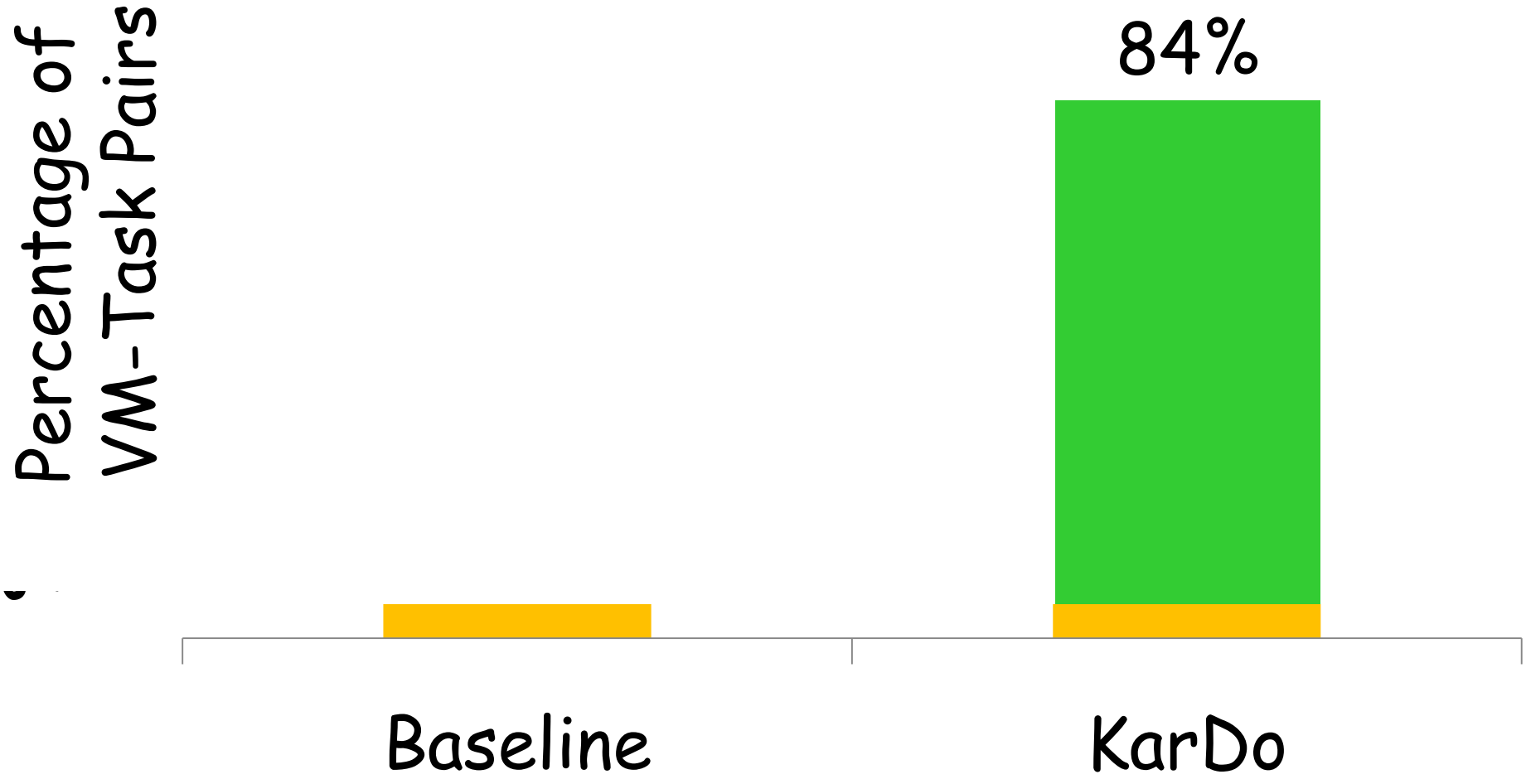
- Implemented KarDo as thin client and a server
- Tested on 57 Tasks from eHow and MS Help sites
- 20 diversely configured VMs
  - 10 training VMs and 10 test VMs
- Each task performed manually on 2 training VMs

Testing

- Given 2 traces, automate using
  - KarDo
  - Baseline that runs both traces and succeeds if either automates the task

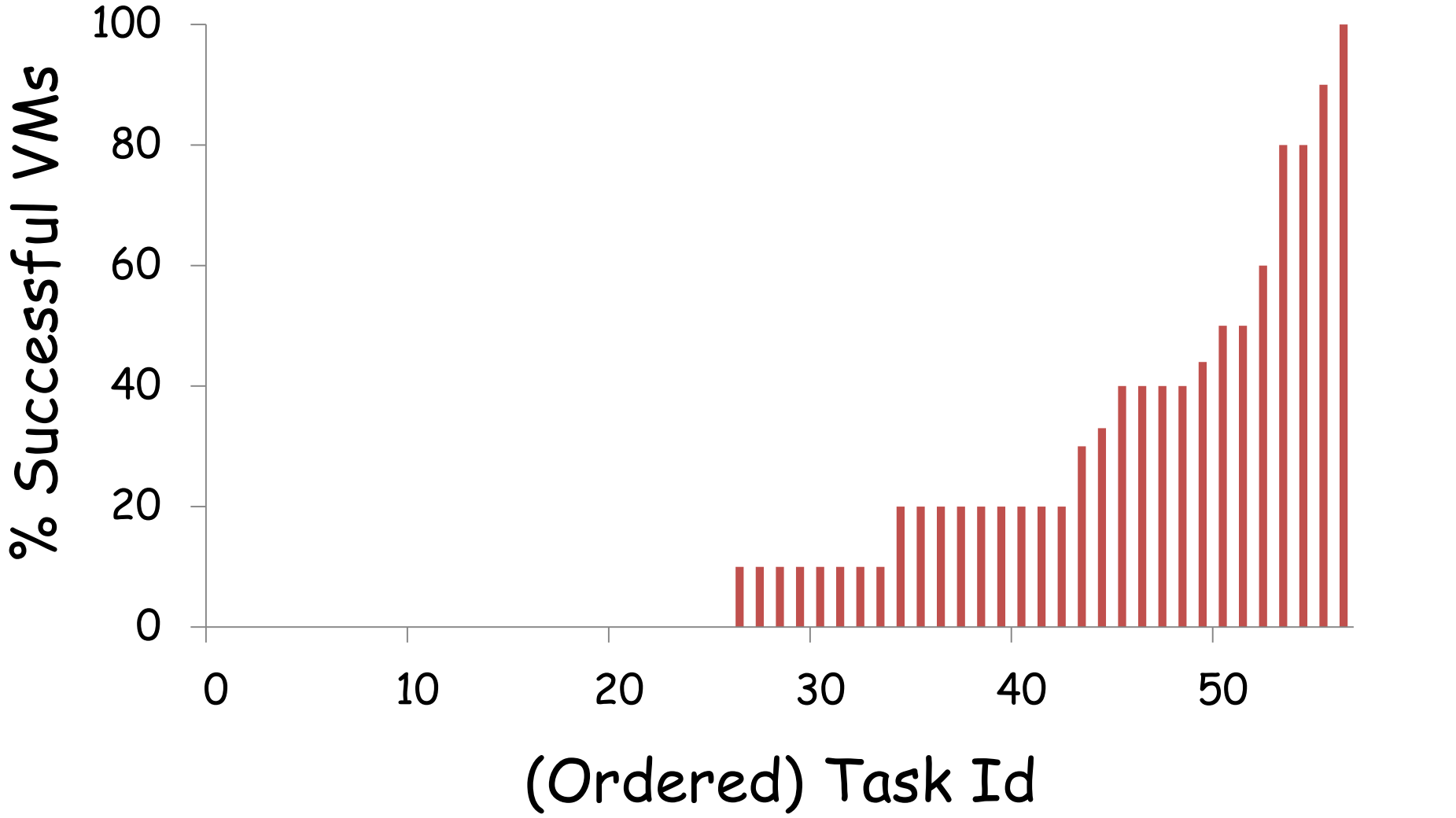
- Test each solution on the 10 test VMs

Automation Success Rate

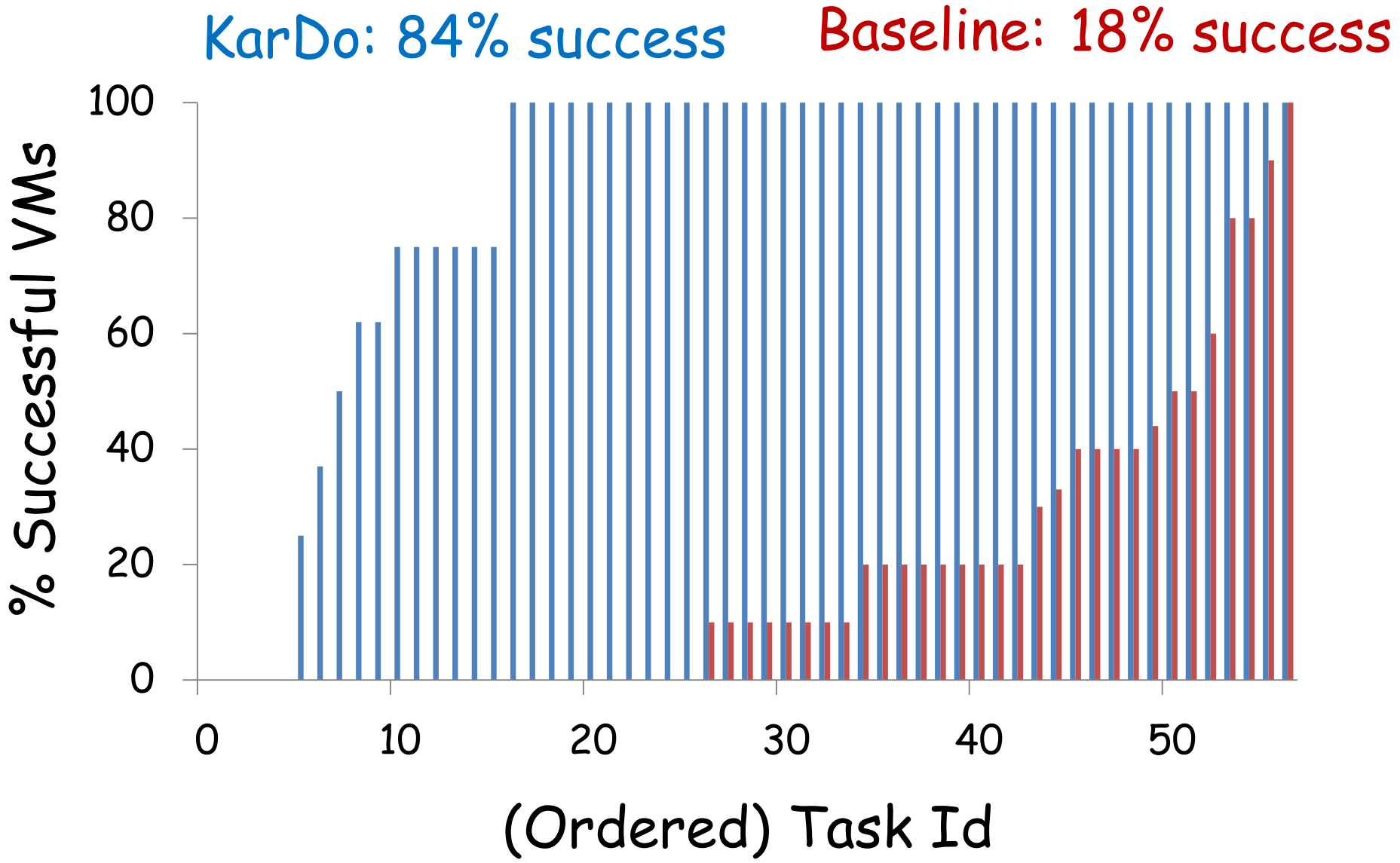


Automation Success Rate

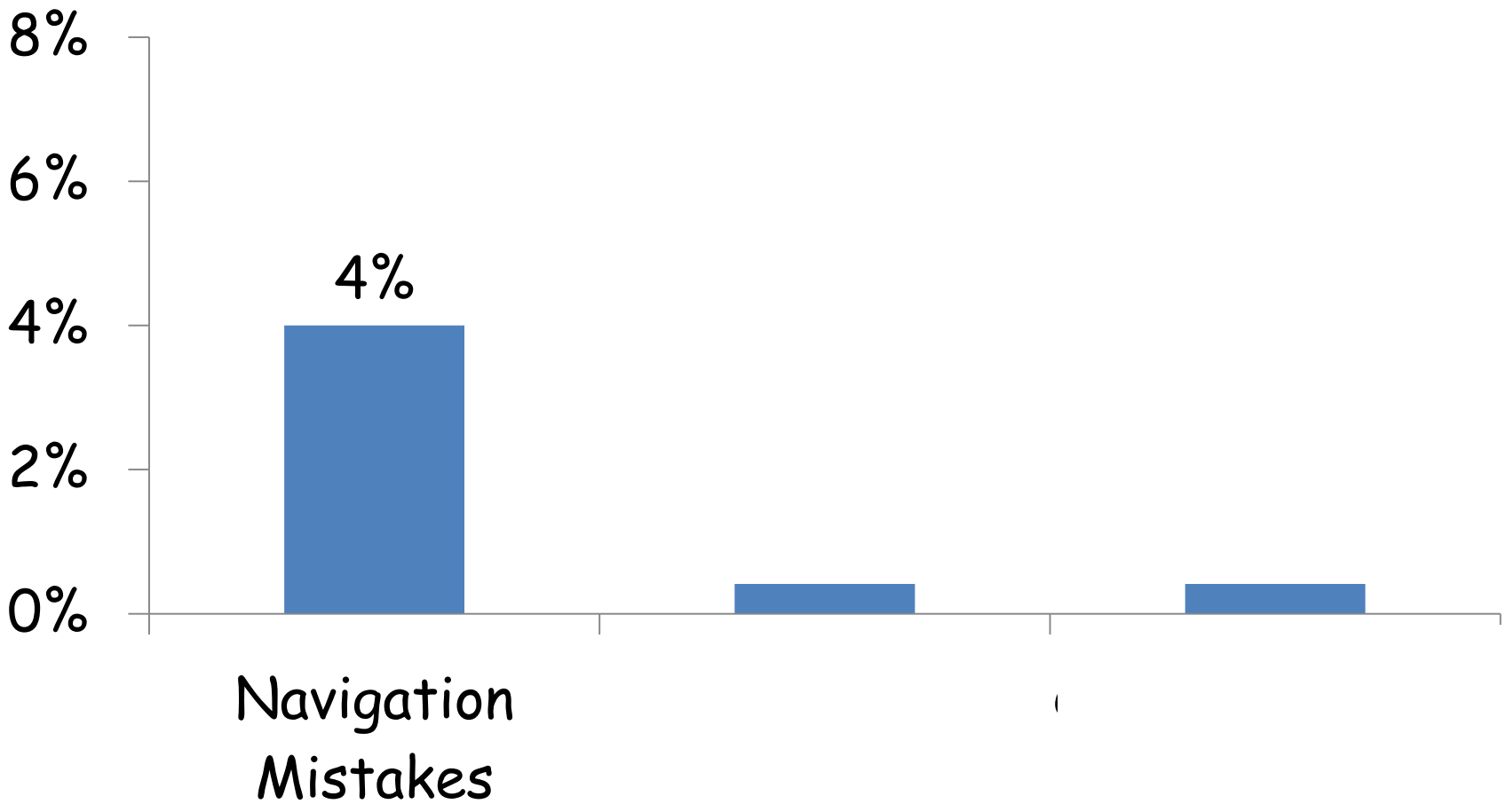
Baseline: 18% success



Automation Success Rate



Errors



Conclusion

- KarDo automates tasks across configurations based on just a few traces
- Using two traces it successfully automated MS and eHow tasks on 84% of configurations
- Applicable to a wide variety of problems:
  - Automated Helpdesk, Automation of repetitive tasks, Automated GUI testing, etc.