Practical Trigger-Action Programming in the Smart Home

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Programming a Smart Home

- Traditional programming languages
- App store
- End-user programming (e.g., “trigger-action”)

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How do we make trigger-action programming in the smart home practical? (...and should we?)
Approach

• **Study 1**: Desired smart-home behaviors

• **Study 2**: Real-world IFTTT.com programs

• **Study 3**: Trigger-action usability
Study 1: Desired Behaviors

“Imagine that you have a home with devices that are Internet-connected and can therefore be given instructions on how to behave. What are five things you would want your home to do?”

• 318 U.S. MTurkers compensated $0.45
  – Ages 18–70 (median 25), 69% male
• Two coders classified each behavior
Programming?

• Over half of behaviors were programming
  – e.g., “I would like my home to automatically clean the floors on a daily basis while no one is in the room”

• Remaining behaviors:
  – Remote operation
  – Automatic adjustments
  – Specialized functionality
Triggers' Level of Abstraction

• 31 triggers were sensors in the engineering sense (e.g., doorbell, light, moisture)

• 26 triggers were activities / states (e.g., “when I pick up my toothbrush”)

• 14 triggers required complex decision making
  – “I would like to be notified when my pool chemicals drop lower than normal”
  – “Turn off the air conditioning when it senses I'm cold and shivering at night”
  – Hunger, cooked, dirtiness, discomfort
Study 2: IFTTT Analysis

Scraped all 67,169 programs shared publicly on IFTTT.com by 35,295 different authors
Combinatorics (Triggers)
Study 3: Usability Test

- We built an interface styled after IFTTT.com
  - *Simple* version: 1 trigger, 1 action
  - *Complex* version: 2+ triggers, 2+ actions
Study 3: Usability Test

- Participants tried to program 10 tasks:
  - 6 could be solved with either interface
  - 2 could not be solved
  - 2 could be solved with complex interface
- 226 U.S. MTurkers compensated $2.00
  - Ages 18–67 (median 30), 47% male
  - 72% had no prior programming experience
Results

• Most tasks solved by 80%+ of participants
Results

• Most tasks solved by 80%+ of participants

“Turn on the lights when the sun sets.” (D)
Results

• Most tasks solved by 80%+ of participants

“The lighting in my bedroom should be on when I am there and off when I am not there.” (G)
Results

• Most tasks solved by 80%+ of participants

“If it is 10:00pm and my bedroom door is closed and the lights are off, turn the television off.” (I)
Results

• Examined correlation between demographics and success / time

• Older participants less successful and took longer than younger participants

• Prior programming experience and gender not significant factors
Results

- Significant learning effect
Results

• Significant learning effect
Results

- Significant learning effect
Limitations

- Did not investigate any competing approaches to smart-home programming
- Hypothetical smart home
- IFTTT and MTurk communities are self-selected early adopters (not necessarily generalizable)
Conclusions

• Most desired behaviors involved programming
• Triggers with complex decision making
• Diversity of behaviors → end-user programming
• Participants 80%+ successful on most tasks
  - Including non-programmers
  - Including multiple triggers / actions
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