



Almond: Keeping the Internet Open with An Open-Source Virtual Assistant

Monica Lam
Computer Science Department
Stanford University
lam@cs.stanford.edu

With Giovanni Campagna, Michael Fischer, Mehrad Moradshahi, Rakesh Ramesh, Richard Socher, Silei Xu, Richard Yang
Sponsors: AVG, Google, HTC, Hitachi, ING Direct, Nokia, Samsung, Sony Ericsson, UST Global

Consumer Privacy at Stake

- Facebook owns and sells 2-billion people's personal data
 - Cambridge Analytica incident
- EU GDPR (General Data Protection Regulation)
- There is no meaningful alternative

Unhealthy Commercial Ecosystem

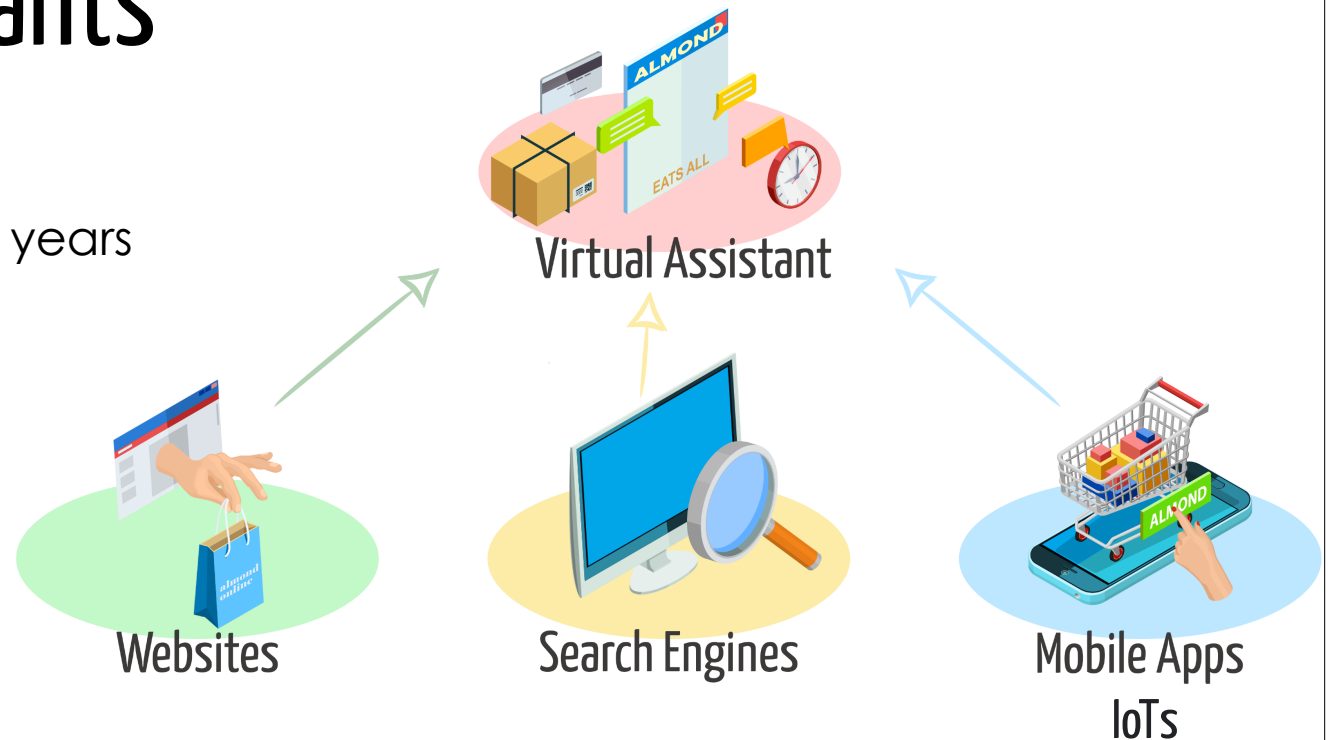
- Platform Monopolies/Duopolies
- Google and Apple app stores: 30% revenues
- Google and Facebook: 60% digital marketing revenues
- Newspaper ad revenues: \$50B (2006) → \$18B (2016)

Monopoly — Open Competition — Innovation?

Virtual Assistants

50 millions in 2 years

Internet: 50 millions in 4 years



<https://techcrunch.com/2018/03/07/47-3-million-u-s-adults-have-access-to-a-smart-speaker-report-says/>

Virtual Assistants

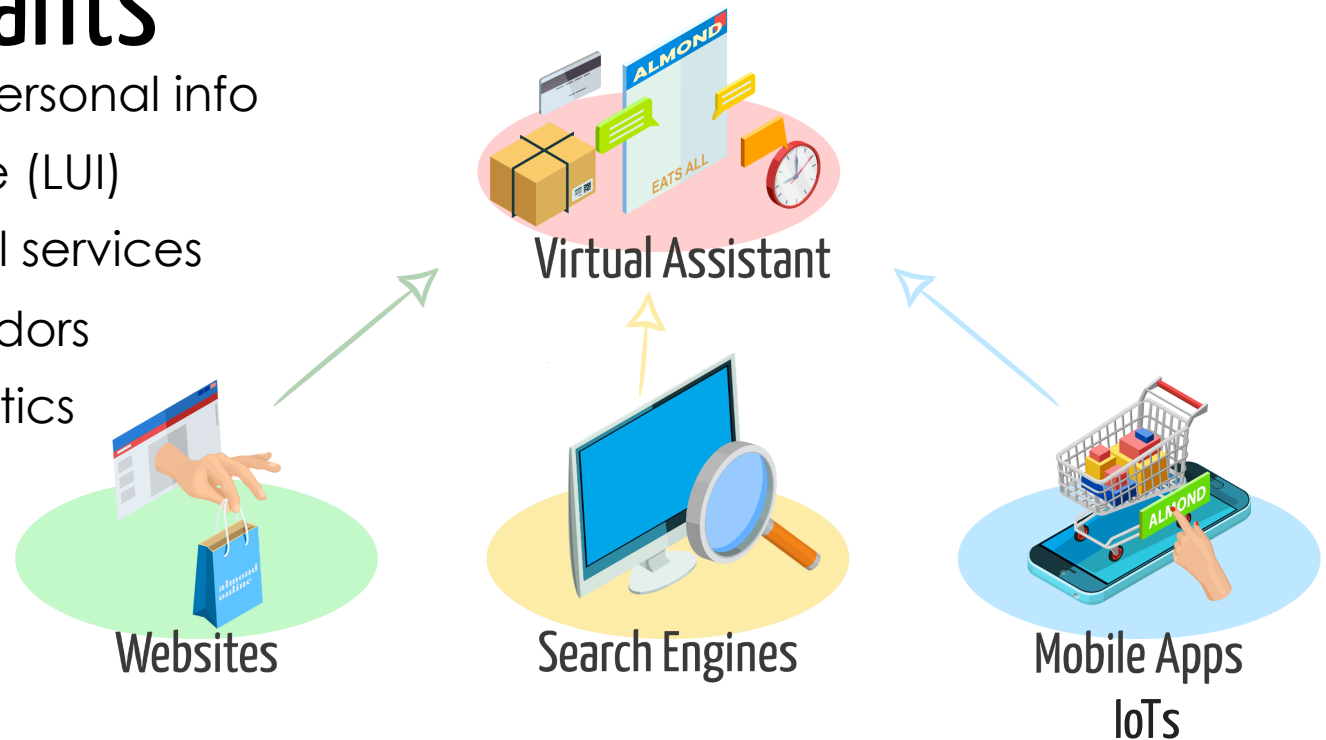
Personalized: sees all personal info

Linguistic User Interface (LUI)

Intermediates all digital services

Controls choice of vendors

Human behavior analytics



Amazon, Facebook, Google Combined!

Mobile & Ubiquitous: Graphical->Linguistic

Graphical Web	Linguistic Web
Graphical user interface (GUI)	Linguistic user interface (LUI)
Browser	Virtual Assistant
Web page addresses	Intents
Hosted by owners	Hosted by virtual assistants
Open Platform	Proprietary Platform? (like AOL?)

We are witnessing the start of proprietary linguistic webs.

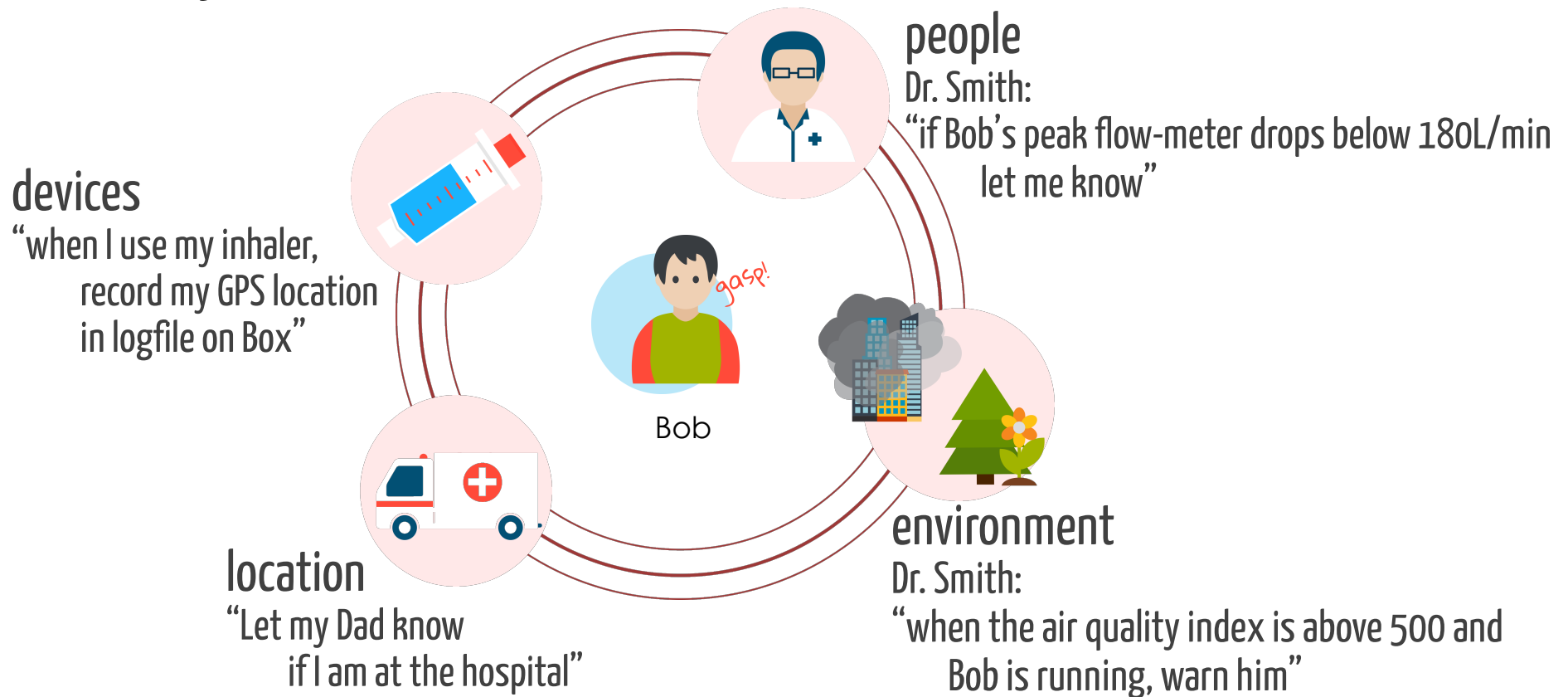


Almond Vision:

- **Open-source best virtual assistant technology**
- **Privacy: open federated virtual assistants -> choice**
- **New capability: Put users back in the driver seat!**
 - Connect disparate resources
 - Share them with “who, what, when, where, how”

“Program” our virtual assistant in natural language!

Example: Asthma Patient

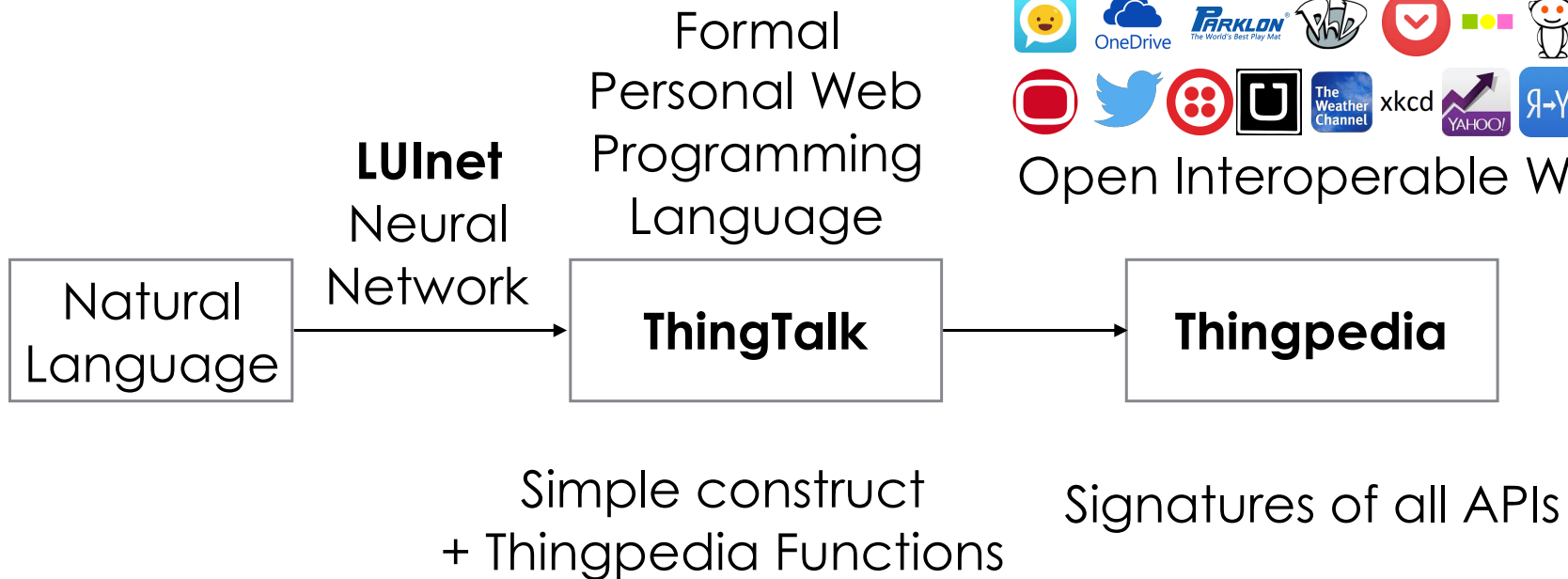


Impact of Natural Language Programming

- Power of language
- Consumers: today's software cannot satisfy the long tail of user needs
- Professionals: automate their own repetitive tasks
- Big data analytics + privacy

Technology of Natural Language Programming

Core Concepts



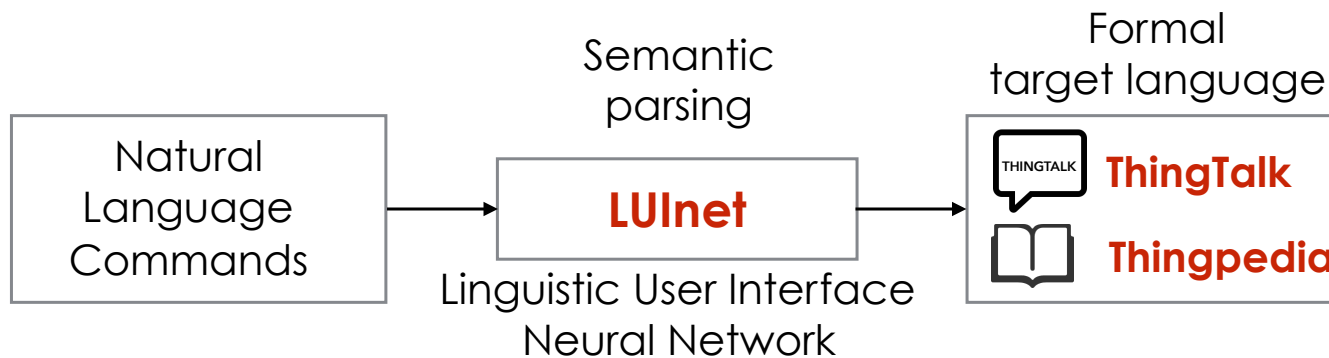
Natural Language Programming

“When I use my inhaler,
get my GPS location, if it is not home,
write it to logfile in Box.”

- Event-driven program
- Multiple function calls
- Parameter passing
- Filters on values



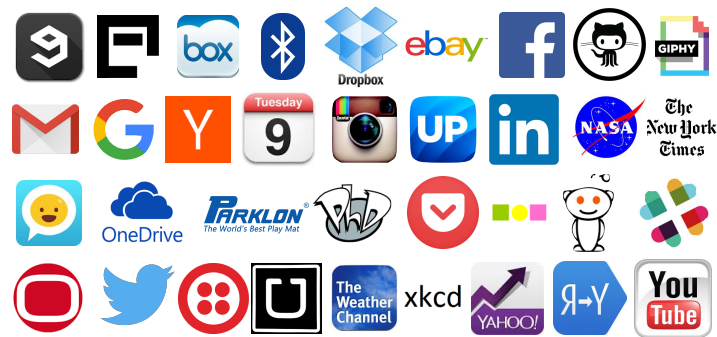
Almond: 1st Programmable Virtual Assistant



“When I use my inhaler,
get my GPS location, if it is not home,
write it to logfile in Box.”


```
monitor @Inhaler-use(),  
=> @GPS(), location <> “home”  
=> @Box-write(file=“logfile”, data=location)
```

Thingpedia: Encyclopedia of Things



> 60 devices / 200 functions

- **Interoperability**
 - API signatures + corresponding NL
 - Not just intents
- **Open repository**
 - Available to Alexa, Google Assistant, ...

	Natural Language	API Signatures
WHEN	@Stanford tweets	Monitor (@home_timeline(), ...) author=="Stanford")
GET	tweets matching "#Cardinal"	search(...), contains (hashtag, ...)
DO	tweet "Stanford won!"	post (status)

ALMOND

🔗 Examples

Tweet the latest NASA Astronomy Picture of the Day
Auto reply to my emails
Set my phone to vibrate every day at 9 am
Turn on my TV if there is a person in the room
Translate Washington Post headlines to "Chinese"
Post my new Instagram pictures on Twitter
get a snapshot from my security camera every hour
Play some video from YouTube on my TV
Send me a daily cat picture

🚲 Almond Bike Market

WHEN: monitor second hand bike posts
WHEN: monitor bike posts of brand __
WHEN: monitor bikes for __
GET: search second hand bikes
GET: search bike posts of brand __
GET: search bikes for __
DO: post on almond bike market
DO: post a bike for __ dollars on almond bike market

♥ Almond Dates

WHEN: monitor date posts on almond dates
WHEN: monitor date posts about __
GET: search partners on almond dates
GET: search __ partners
DO: post on almond dates
DO: post on almond dates to find partners for __

🔍 Bing Search

GET: search __ on bing
GET: search __ images on bing
GET: search images matching __ with size __ x __ on bing

🔊 Bluetooth Speaker

DO: set my speaker as default
DO: play music on my speaker
DO: increase volume on my speaker
DO: decrease volume on my speaker
DO: set volume on my speaker to __%

📏 BodyTrace Scale

WHEN: my weight updates

💧 Dropbox

GET: my dropbox quota
GET: file list in folder __ on dropbox
GET: file named __ on dropbox
DO: move file __ to __ in dropbox
DO: rename file __ in dropbox
DO: create a folder with name __ in my dropbox

📘 Facebook

DO: post on facebook saying __
DO: post a picture on facebook
DO: post a picture on facebook with caption __

🐼 Giphy

GET: a ranDOm gif from giphy
GET: a gif with tag __ from giphy

🔗 Github

WHEN: a new issue opened in github repository __
WHEN: __ opens an issue on github
WHEN: user __ opens an issue in github repository __
WHEN: there is a new commit for github repository __
WHEN: user __ commits in github repository __
WHEN: a new milestone is created in github repository __
WHEN: user __ create a new milestone in github repository __

WHEN: there is a new comment in github repository __
WHEN: user __ comments on some issue in repository __
WHEN: there is a new comment on issue __ in repository __
DO: add email __ to my github account
DO: comment on issue __ in github repository __

✉ Gmail

WHEN: receive an email on gmail
WHEN: receive an email from __ on gmail
WHEN: receive an email marked as important
WHEN: receive an email marked as important from __
WHEN: receive an email in category primary
WHEN: receive an email from __ in category primary
GET: the latest email
GET: the latest email with label __
GET: the latest email from __
GET: the latest email with subject __
DO: send an email to __ with subject __ with message __
DO: send a picture to __ with subject __

📁 Google Drive

WHEN: a new file or folder is created on google drive
DO: create a new file with name __ on google drive

📅 Holidays Calendar

WHEN: it's an holiday in the uk
WHEN: it's an holiday in the us
GET: the next uk holiday
GET: the next us holiday

📅 iCalendar Events

WHEN: an event on my calendar begins
WHEN: an event on my calendar at location __ begins
WHEN: an event on my calendar organized by __ begins
GET: list my calendar events
GET: my calendar events organized by __
GET: my calendar events at __

🐼 Imgflip Meme Generator

GET: all meme templates
GET: meme template named __
GET: generate meme on template __ with text __ at the top and text __ at the bottom

📷 Instagram

WHEN: i upload a picture on instagram
WHEN: i upload a picture with filter __ on instagram
GET: my recent instagram pictures
GET: __ many recent instagram pictures
GET: my instagram pictures with filter __

💪 Jawbone UP

WHEN: my steps on activity tracker updates
WHEN: i walked for __ steps
WHEN: i walked for __ distance
WHEN: my weight updates on my fitness tracker
WHEN: my weight is __ on my fitness tracker
WHEN: my bmi is __ on my fitness tracker
WHEN: my body fat is __ on my fitness tracker
WHEN: my heart rate updates
WHEN: my heart rate is __
WHEN: my sleep status updates on my sleep tracker
WHEN: i sleep for __ time

📺 LG WebOS TV

DO: turn __ my lg tv
DO: raise the volume of my lg tv
DO: lower the volume of my lg tv
DO: set the volume of my lg tv to __
DO: mute my lg tv

DO: unmute my lg tv
DO: play link __ on my lg tv

🔗 LinkedIn

GET: my linkedin profile
DO: post __ on linkedin

🔗 Miscellaneous Interfaces

WHEN: it's __ o'clock every day
GET: current time
GET: current date
GET: give me a random number
GET: give me a random number between __ and __
DO: debug log __
DO: send me a message __

🔗 NASA Daily

WHEN: an asteroid passes close to earth
GET: nasa's astronomy picture of the day
GET: a picture from curiosity rover
GET: __ many pictures from curiosity rover
GET: a picture from curiosity rover taken on __

🏠 Nest

WHEN: the temperature on my thermostat updates
WHEN: the humidity on my thermostat updates
WHEN: there is a new event detected on my security camera
WHEN: my security camera detects something and has person is __
WHEN: my security camera detects something and has motion is __
WHEN: my security camera detects something and has sound is __
GET: the temperature on my thermostat
GET: the humidity on my thermostat
GET: the state of my hvac
GET: my security camera live feed
GET: me a snapshot of my security camera
DO: set temperature to __ on my thermostat
DO: set my temperature between __ and __ on my thermostat
DO: set my hvac to __
DO: turn __ my security camera

🔗 Omlet

WHEN: i receive a message on omlet
WHEN: i receive a message on omlet in feed __
WHEN: i receive a __ message on omlet
DO: send an omlet to __ saying __
DO: send a picture on omlet to __ with caption __

📁 OneDrive

WHEN: a new file is created on onedrive
WHEN: a file is modified on onedrive
WHEN: file __ on onedrive is modified
DO: create a new file on onedrive named __ containing __
DO: delete __ from my onedrive
DO: rename __ to __ on my onedrive
DO: upload a picture to onedrive with name __

🌸 Parklon Iris Warm Water Mat

DO: turn __ my heatpad
DO: turn __ my parklon heatpad

🔗 PhD Comics

WHEN: there is a new post on phd comics

🔗 Philips Hue

DO: turn __ my lightbulb
DO: disco lights
DO: flash the lightbulb

📞 Phone Companion

WHEN: my location changes
WHEN: i receive a sms

WHEN: i receive a sms from __
DO: show a popup with title __ and body __
DO: send an sms to __ saying __
DO: set my phone to __
DO: call number __
DO: call 911

🔗 Reddit Frontpage

WHEN: reddit front page updates
WHEN: a new post in category __ reaches reddit front page
WHEN: a new post from user __ reaches reddit front page

🔗 RSS Feed

WHEN: there is a new post on rss feed

🔗 Slack

WHEN: i receive a message on slack
WHEN: i receive a message from __ on slack
WHEN: i receive a message in channel __ on slack
DO: send a message on slack to __ saying __
DO: set the purpose for channel __ to __ on slack
DO: set the topic for channel __ to __ on slack
DO: set me as __ on slack
DO: send a picture on slack to __ saying __

🔗 SportRadar

WHEN: nba team __ plays
WHEN: nba team __ plays against __
WHEN: nba team __ plays and the game is __
WHEN: nba team __ a game
WHEN: eu soccer team __ plays
WHEN: eu soccer team __ plays against __
WHEN: eu soccer team __ plays and the game is __
WHEN: eu soccer team __ a game
WHEN: us soccer team __ plays
WHEN: us soccer team __ plays against __
WHEN: us soccer team __ plays and the game is __
WHEN: us soccer team __ a game
WHEN: monitor eu soccer games of tournament __
WHEN: monitor us soccer games of tournament __
WHEN: mlb team __ plays
WHEN: mlb team __ plays against __
WHEN: mlb team __ plays and the game is __
WHEN: mlb team __ a game .
WHEN: ncaa mens basketball team __ plays
WHEN: ncaa mens basketball team __ plays against __
WHEN: ncaa mens basketball team __ plays and the game is __
WHEN: ncaa mens basketball team __ a game .
WHEN: ncaafb team __ plays
WHEN: ncaafb team __ plays against __
WHEN: ncaafb team __ plays and the game is __
WHEN: ncaafb team __ a game

🐾 The Cat API

GET: a cat picture
GET: __ many cat pictures

📰 The Wall Street Journal

WHEN: there is a new article in wsj opinions section
WHEN: there is a new article in wsj world news section
WHEN: there is a new article in wsj us business section
WHEN: there is a new article in wsj market news section
WHEN: there is a new article in wsj technology section
WHEN: there is a new article in wsj lifestyle section

📰 The Washington Post

WHEN: there is a new article in washington post __ section
WHEN: there is a new blog post in washington post __ blog

🔗 Tumblr

WHEN: there is a new post in blog __ on tumblr

WHEN: there is a new picture uploaded in blog __ on tumblr
DO: post on tumblr with title __ and body __
DO: post __ on tumblr
DO: post a picture with caption __ on tumblr

🔗 Twitter

WHEN: someone i follow tweets
WHEN: user __ tweets
WHEN: someone replies to user __ on twitter
WHEN: i receive a direct message on twitter
WHEN: i receive a direct message from __ on twitter
WHEN: i tweet
WHEN: i reply to __ on twitter
GET: search for __ on twitter
GET: __ many recent tweets matching __
GET: recent tweets from __
GET: recent tweets from __ matching __
GET: recent tweets in reply to __
GET: recent tweets in reply to __ matching __
GET: search for tweets with hashtag __ on twitter
GET: __ many recent tweets with hashtag __
GET: tweets from __ with hashtag __
GET: tweets with hashtag __ in reply to __
DO: tweet __
DO: send a dm on twitter to __ saying __
DO: tweet a picture with caption __
DO: follow user __ on twitter
DO: unfollow user __ on twitter

🚗 Uber

GET: time estimate for uber
GET: give me a price estimate for uber from __ to __

☁ Weather

WHEN: it's __ at location __
WHEN: monitor weather at __
GET: sunrise and sunset for location __
GET: sunrise and sunset for location __ on date __
GET: moon phase for location __
GET: moon phase for location __ on date __
GET: the weather in __

📺 XKCD

WHEN: a new xkcd is out
WHEN: a new xkcd is out in the what-if section
GET: the latest xkcd
GET: the xkcd number __
GET: a random xkcd

📈 Yahoo Finance

WHEN: the stock price of __ changes
WHEN: stock dividends for __ changes

↔ Yandex Translate

GET: translate __ to __ with yandex
GET: translate __ from __ to __ with yandex
GET: translate __
GET: translate something to __
GET: translate with yandex from __ to __
GET: detect the language of __

📺 Youtube

WHEN: there is a new video from youtube channels i follow
WHEN: there is a new video from youtube channel __
GET: list channels in category __ on youtube
GET: list channels i am subscribed to on youtube
GET: search __ channels on youtube
GET: search a __ video on youtube
GET: search a video from __ matching __ on youtube
GET: search __ many videos matching __ on youtube



ThingTalk Compound Statement

WHEN [FILTERS] → **GET** [FILTERS] → **DO**

FILTERS: =, <, >, <=, >=, <>, contains, starts with, ends with

When I use my inhaler, get my location, save them to Dropbox

If I get taken to a hospital, let my dad know.

When the air quality index is above 500, and I am running, send me an SMS.

When the Bitcoin price reaches \$10,000,
search for a “bitcoin” picture, and tweet it with caption “I’m rich!”

Expressiveness of ThingTalk

- Inspired by IFTTT
- ThingTalk is a superset of IFTTT recipes (2 clauses)
- IFTTT has 250,000 unique recipes
- IFTTT provides a GUI: no formal or natural language
- IFTTT is proprietary: user must share credentials

Real Natural Language Input

When my car is at home, and it is not plugged in,
send me a reminder email

Remind me if my car is not plugged in at home.

If I am not charging my car when it is home, let me know.

Remind me to plug in my car whenever I'm home.

Technical Challenges

- **Natural language training-data acquisition (Liang)**
 - Formal language
 - Natural language templates
 - synthetic sentences
 - paraphrased sentences (and repeat)
- **Co-design of Thingpedia, ThingTalk and LUI net**
 - Combine when + get functions into 1 set
- **Compositionality to handle scale**

LUInet Results

- Dataset (60+ devices, 200+ functions)
 - Synthetic: 515K programs, 2.9M sentences
 - Paraphrased: 175K programs, 400K sentences
- Model:
 - Seq2seq bi-LSTM with attention, pointer network
- Accuracy: 89%
- Future work: real user input

Sharing with Privacy

Sharing is Broken Today

- Services have limited options
 - With the cost of data ownership
- Sharing credentials

Let your virtual assistant help you share

General+Fine-Grain: ThingTalk Extension

Requester:



GET-PREDICATE [FILTERS]



WHEN [FILTERS] → GET [FILTERS] → DO

FILTERS: =, <, >, <>, <=, >=, contains, starts with, ends with

Let Dr. Smith monitor my peak-flow-meter, if it drops below 180L/min

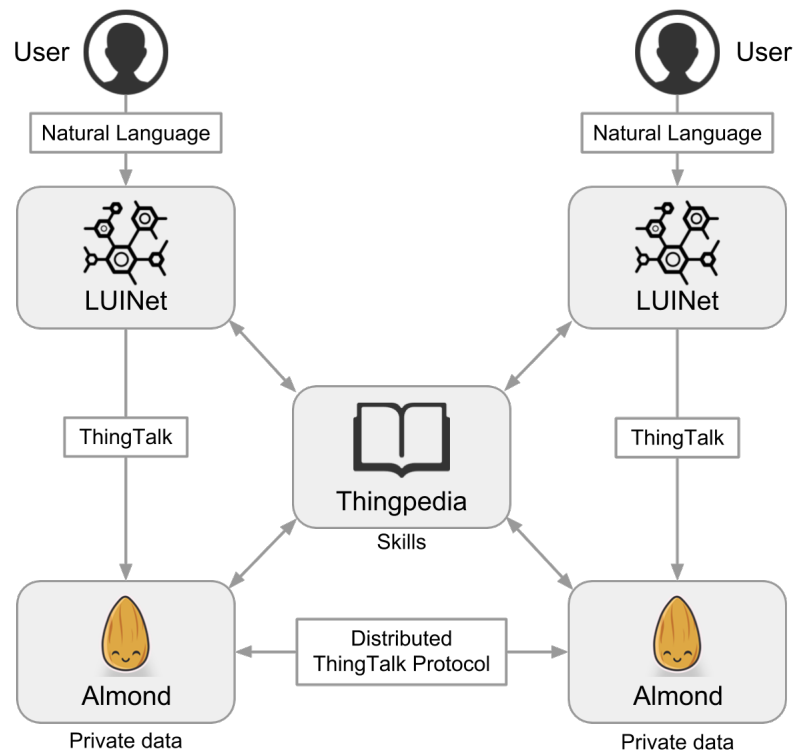
Let my father monitor my security camera for motion,

Let my secretary, whenever I am out of town, read email messages whose subject is marked urgent.

Let my daughter, from 6-8pm, watch Netflix

Let my boyfriend get pictures from my dropbox, taken on Feb 14, and post them on Facebook

Almond: 1st Federated Virtual Assistant



Expressiveness:

Any ThingTalk command

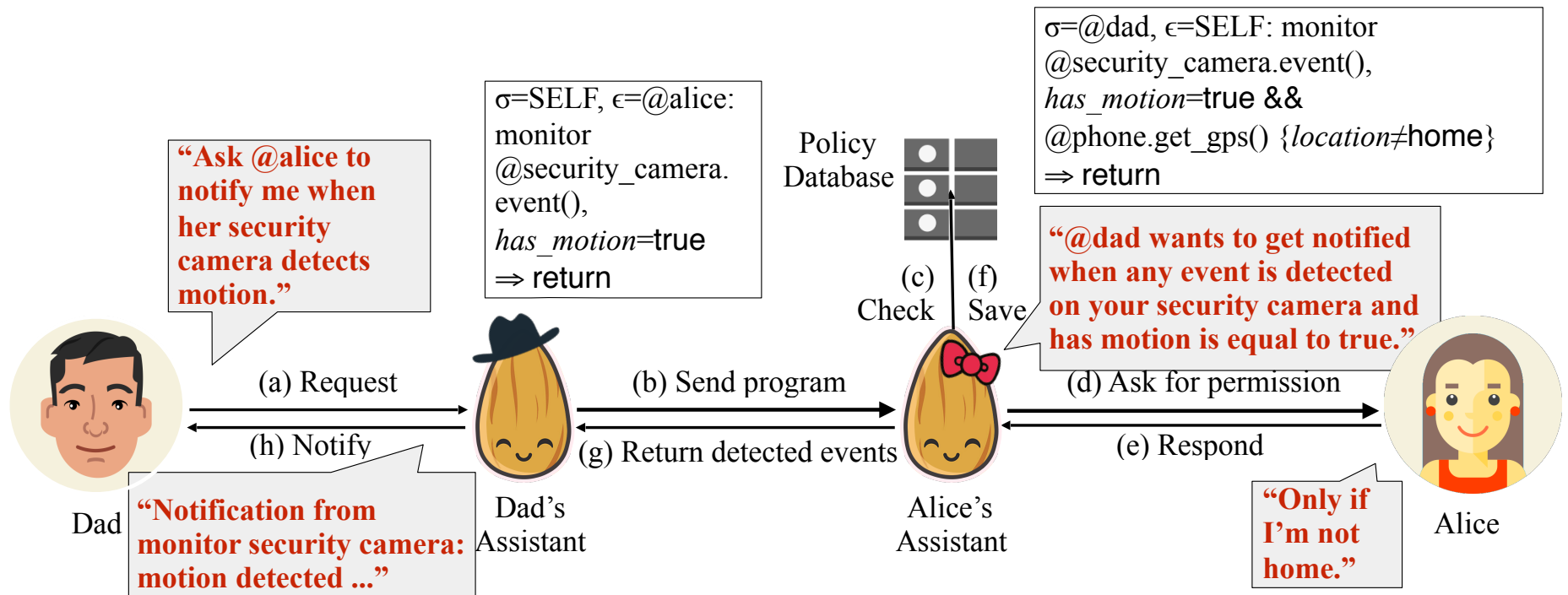
Privacy:

Remote execution model

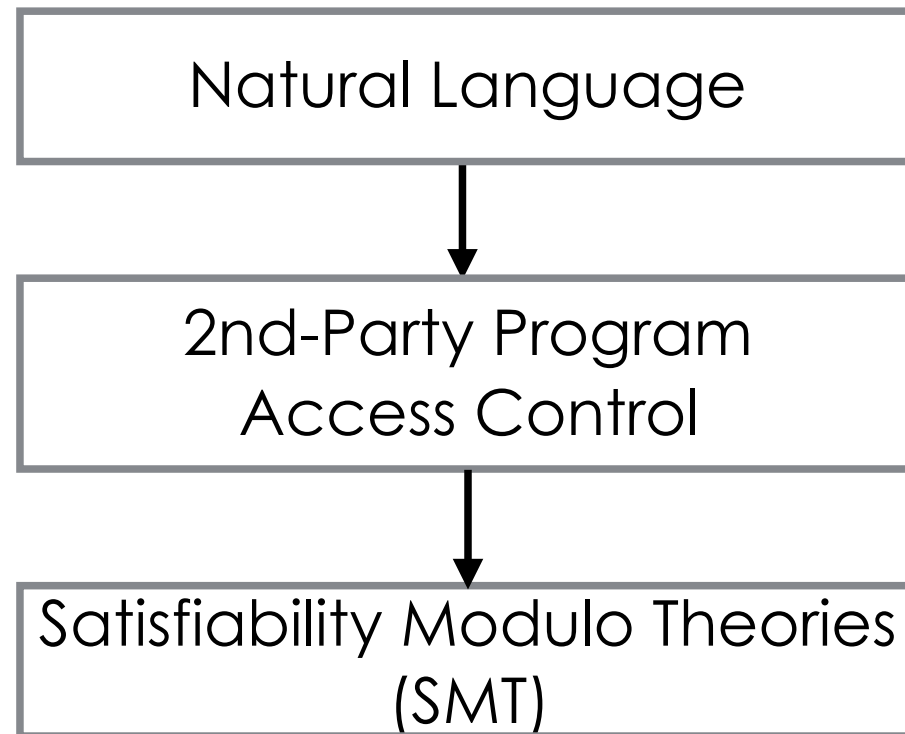
Owner executes requests

Returns need-to-know

Distributed ThingTalk Protocol



Conformance of Access Control



Conformance Algorithm

- SMT: Generalization of boolean satisfiability (SAT) with theories of strings, arrays, ...
- Provably correct programs for conformance, and synthesis of conforming code
- NP-hard, but fast enough in practice

Needs and Acceptance?

Do Consumers Need Access Control?

Role-Based Permission ■

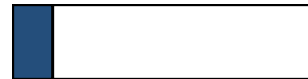
■ **Attribute-Based Permission**

Teenage daughter to use credit card



With a \$20 budget limit
For restaurants only

Amazon courier to unlock door



If the package is over \$1000
If your security camera is on

Friends to access cloud drive



Photos with their faces in them
Photos in a specific folder

Parent/kid to see security cameras



If you are not at home
Cameras facing the front yard/garage

10-year-old kid to use Netflix

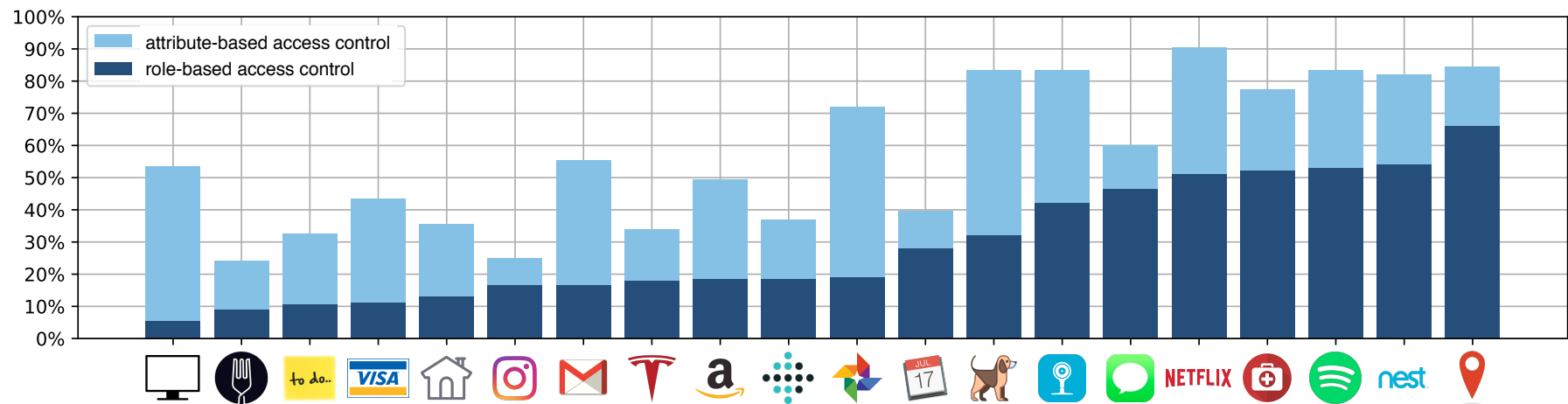


Between 7 PM to 9 PM
Free G or PG rated movies

0% 100%

% People comfortable in giving permission (200 person survey)

More Examples



Willingness to share doubles with attribute-based access control

Expressiveness of ThingTalk?

Solicit use cases by showing AMT workers 3 examples, without describing ThingTalk or TACL

Enforceable:

Mom: “You need to follow this guy on Twitter, give me your Twitter account”.

Me: “OK, add him but don’t follow any other twitter user”.

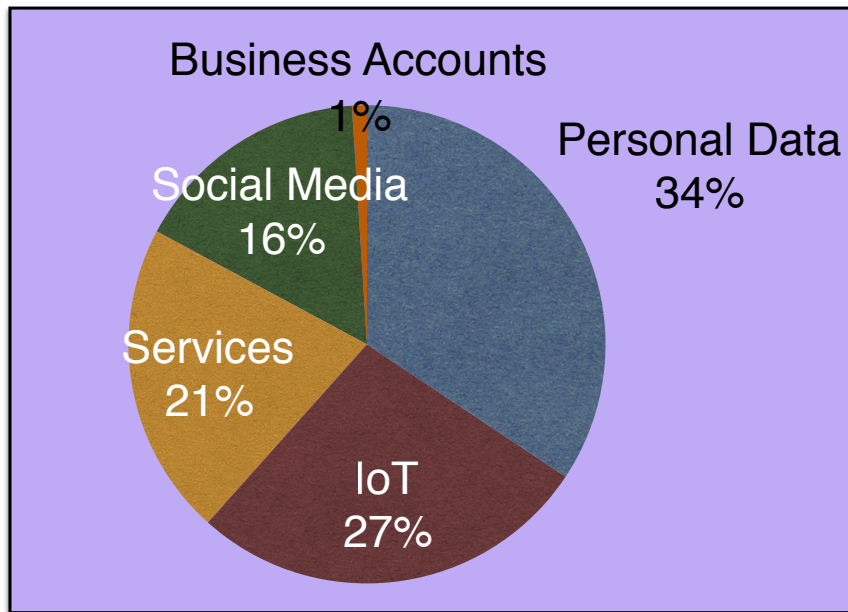
Unenforceable:

Friend: “Can I use your library card?”

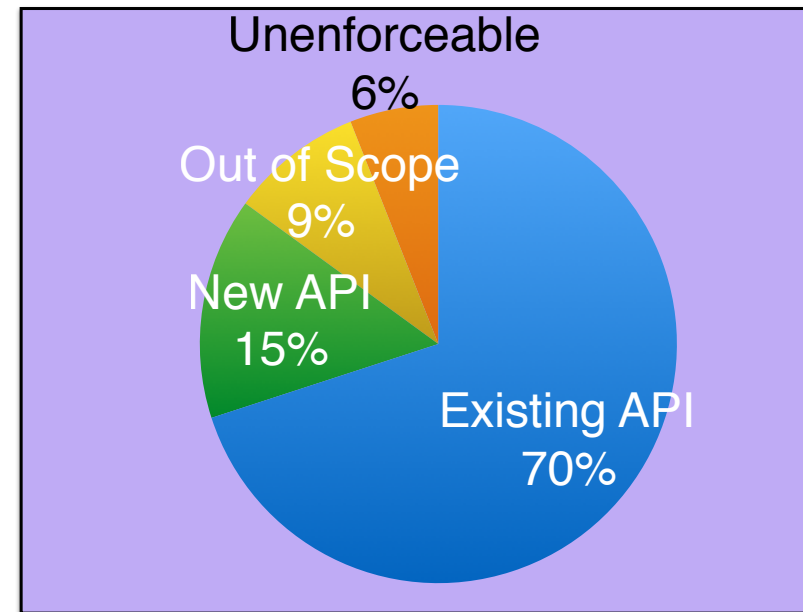
Me: “OK, only if you return the book on time”.

ThingTalk is Expressive

60 workers; 220 suggestions; 85 unique assets



Diverse use cases

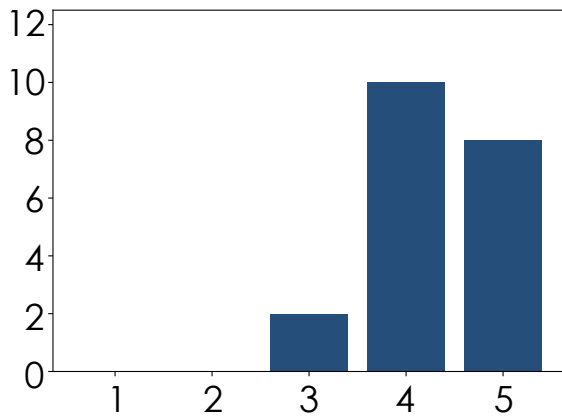


85% in the scope of TACL

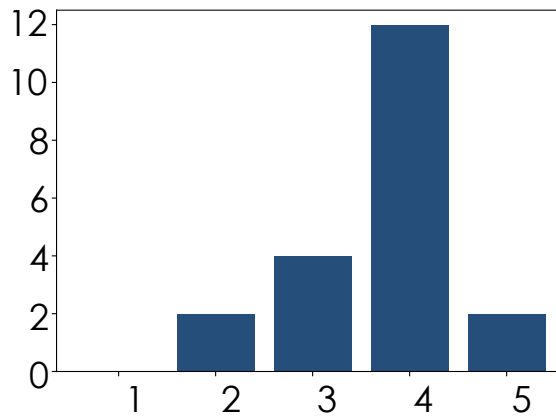
User Study: “Sharing Without Passwords”

Like the concept?

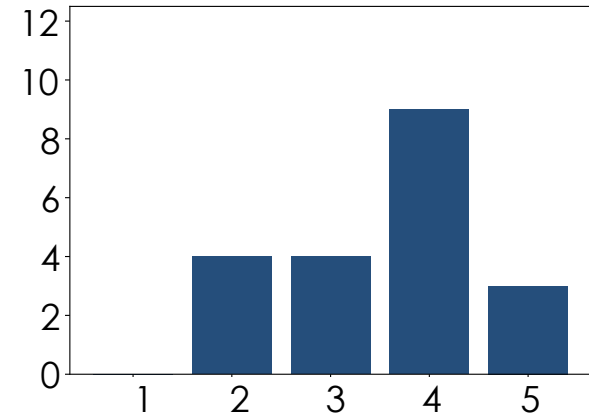
#Users



Like the app?



Use the app?



Ratings

Almond: an Open Virtual Assistant

Interoperable Personal Web	Open, crowdsourced skill repository Personal web language	Thingpedia ThingTalk
Autonomy	Natural language programming	LUI.net
Privacy, Openness	Open-source federated virtual assistants	Almond

Put users back in the driver seat in 5 years!

Last Chance for Privacy and Open Competition



[http: almond.stanford.edu](http://almond.stanford.edu)
Almond virtual assistant in Android

Starting: Massively Open Online Project

Stanford Profs. Bernstein, Boneh, Lam, Landay, Manning, Mazieres, Re

Closing Remarks

