CS 525M Mobile and Ubiquitous Computing: A Large Scale Study on Mobile Application Usage

Brett Levasseur

Computer Science Dept.

Worcester Polytechnic Institute (WPI)

Introduction

- Characterize how apps are used
- Little data exists so far
- Results can inform
    - Research
    - App design

Related Work

- Location and time important to mobile web search [6]

- Web sessions brief unless using WiFi [7]

- Context directs types of mobile service used [18]

- Collecting data on phones [10]

- Data on usage/interaction to inform design [8]

- App store deployment research [12,16]

- Aggregate installs of apps [11]

Methodology

- Collect data on app usage (AppSensor)
- Deploy AppSensor through appazaar, an app recommendation app through Android market
- Categorized apps
- Collected data from 4,125 users from Aug 16th 2010 to Jan 25th 2011

AppSensor

- Detect currently used app

- Monitors app lifecycle

- For any time t detect which if any app is in use
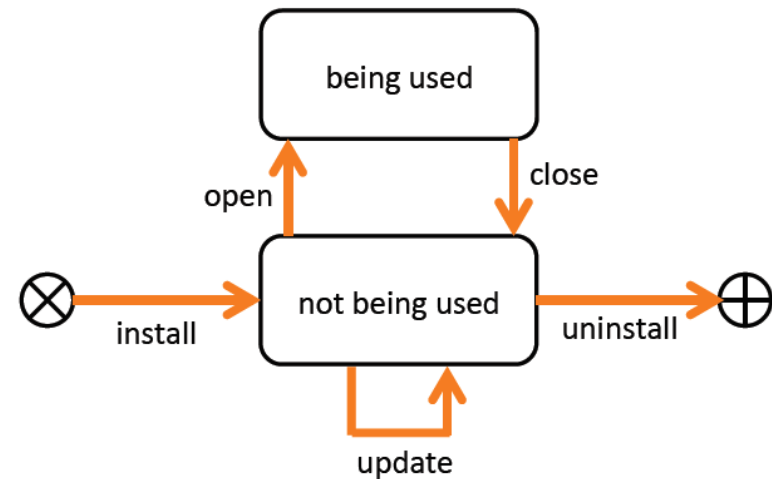
- Collects every 500 ms when screen is on

Figure 1. The lifecycle of a mobile app on a user's device according to different states and events.

Sample Size

- 4,125 users

- Aug 16th 2010 – Jan 25th 2011

- 22,626 different apps
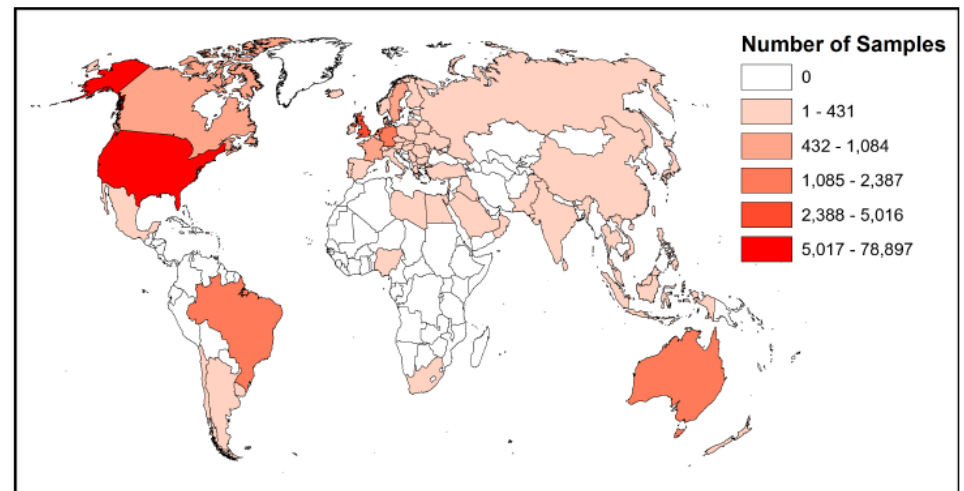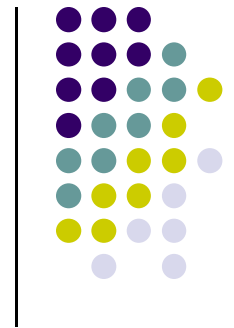
- 4.92 million values for app usage

Figure 2. The geographic distribution of our users. Data classes determined via ESRI ArcMap's 'natural breaks' algorithm, a well-known standard in cartography and geovisualization that is helpful in accurately displaying the underlying distribution of the data.

Average App Usage Time

Category	Apps	Avg. usage	Examplary Apps
unknown	4,823	36.37 sec	-
Finance	307	37.01 sec	Mint.com Personal Finance, Bank of America, Google Finance, iStockManager
Travel	782	44.72 sec	Google Maps, Yelp, Waze
Communication	881	46.92 sec	Google Mail, Handcent SMS, K-9 Mail
Productivity	1,062	61.49 sec	Calendar, Evernote, GTasks
Shopping	326	61.71 sec	Market, Barcode Scanner, Craigslist
Social	538	62.69 sec	Facebook for Android, Twitter, TweetDeck
Sports	385	65.98 sec	Yahoo! Fantasy Football '10, ESPN ScoreCenter, NFL Mobile
News	784	68.11 sec	NewsRob, reddit is fun, BBC News
Settings	1	68.71 sec	Default Settings App
Browser	10	74.01 sec	Default Browser, Skyfire Browser, Dolphin Browser
Entertainment	84	76.90 sec	IMDb Movies & TV, TV Guide Mobile, PhotoFunia
Multimedia	130	82.79 sec	Pandora Radio, Music, Camera
Comics	3,242	91.33 sec	DailyStrip, XkcdViewer, Dilbert Mobile
Games	2,822	114.25 sec	Angry Birds, Wordfeud FREE, Solitaire
Health	424	153.80 sec	CardioTrainer, Sleep Bot Tracker Log, Baby ESP
Lifestyle	956	167.77 sec	DailyHoroscope, Gentle Alarm, Epicurious Recipe
Reference	764	176.28 sec	Kindle for Android, Aldiko Book Reader, Audible
Tools	3,004	206.26 sec	AppBrain App Market, Apps Organizer, Google Goggles
Themes	1,061	258.28 sec	Zune Home, Fingerprint Screensaver, HomeChange
Libraries & Demos	240	274.23 sec	Google Services Framework, default Updater, Motorola Updater, Bubbles Demo, Ride Logger Demo, ES Task Manager

Table 2. Number of apps investigated in our study and average usage time of every categories' apps from opening to closing.
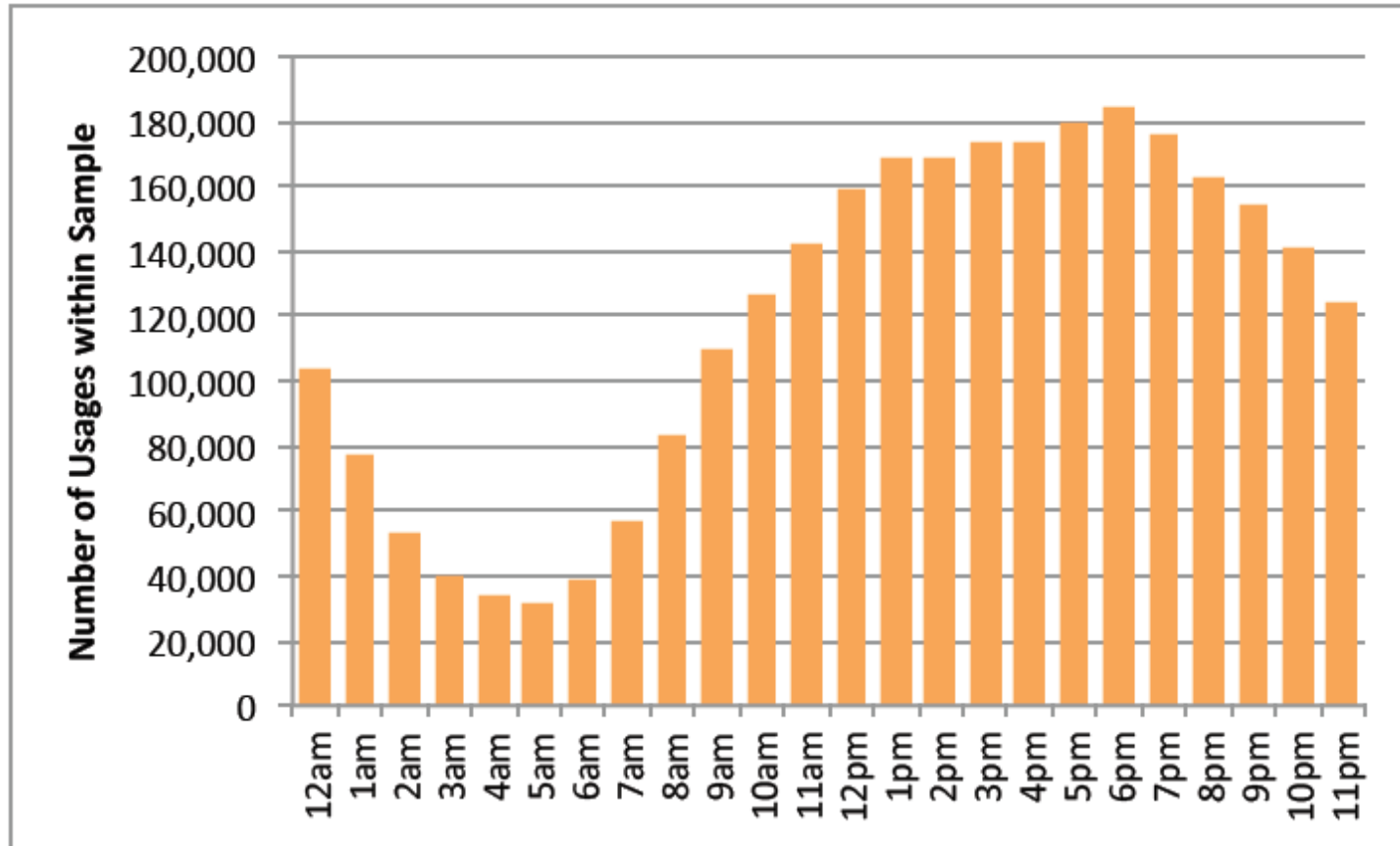
Usage Over Time

Figure 3. Total number of recorded app utilizations during a day.
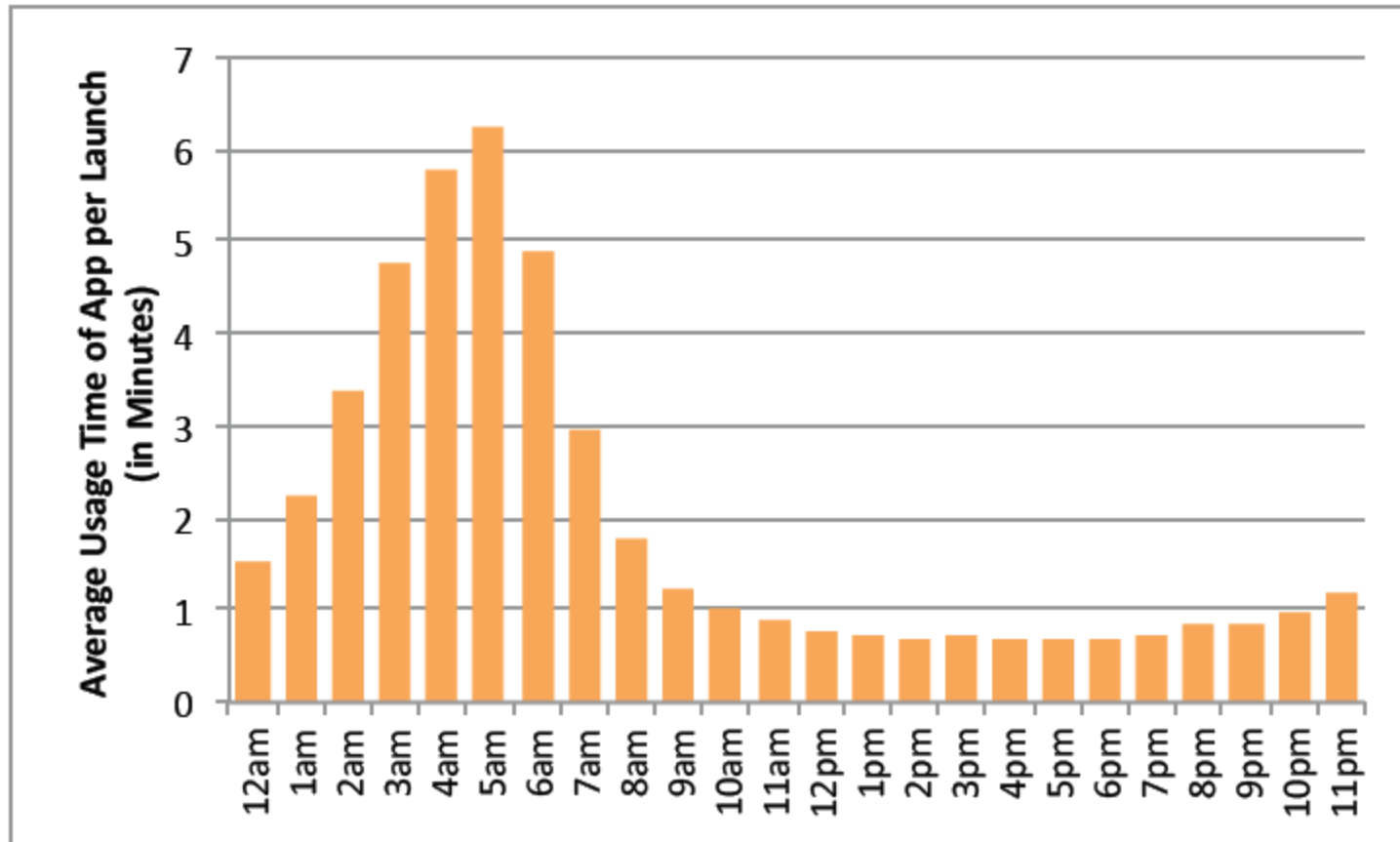
Usage Duration

Figure 4. Daily average usage duration of opened apps per launch in minutes.

Hourly Relative App Usage

	12am	1am	2am	3am	4am	5am	6am	7am	8am	9am	10am	11am	12pm	1pm	2pm	3pm	4pm	5pm	6pm	7pm	8pm	9pm	10pm	11pm	% of Total Launches	Users	Apps
Browser	7.9%	7.7%	7.8%	7.6%	7.3%	7.4%	7.0%	7.9%	8.1%	8.0%	7.7%	7.3%	7.0%	6.9%	6.8%	6.4%	6.6%	6.6%	6.4%	6.6%	7.0%	7.4%	7.5%	7.4%	6.83%	2,398	9
Comics	4.5%	5.2%	5.4%	5.8%	5.8%	5.6%	5.5%	5.2%	5.4%	5.1%	4.7%	4.3%	4.3%	4.2%	4.2%	4.3%	4.4%	4.0%	4.4%	4.2%	4.1%	4.1%	4.1%	4.4%	4.31%	2,151	1,810
Communication	44.9%	41.1%	38.3%	35.4%	31.6%	31.8%	32.7%	34.7%	39.4%	44.8%	49.0%	52.6%	54.8%	55.2%	55.2%	56.1%	55.7%	56.8%	57.1%	56.1%	54.8%	53.3%	52.0%	49.0%	49.50%	2,769	550
Entertainment	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.02%	126	43
Finance	0.2%	0.3%	0.3%	0.2%	0.1%	0.1%	0.1%	0.2%	0.3%	0.3%	0.4%	0.5%	0.3%	0.3%	0.4%	0.3%	0.3%	0.2%	0.2%	0.2%	0.2%	0.2%	0.2%	0.2%	0.25%	604	164
Games	3.2%	3.0%	3.0%	2.7%	2.5%	2.3%	2.2%	1.7%	1.9%	1.9%	2.0%	2.1%	2.2%	2.2%	2.2%	2.3%	2.3%	2.2%	2.2%	2.4%	2.7%	3.0%	3.0%	3.2%	2.30%	1,716	1,702
Health	0.3%	0.4%	0.4%	0.4%	0.6%	0.6%	0.7%	0.6%	0.4%	0.3%	0.3%	0.2%	0.2%	0.2%	0.2%	0.2%	0.2%	0.2%	0.3%	0.2%	0.3%	0.2%	0.3%	0.3%	0.26%	540	227
Libraries & Demo	0.4%	0.5%	0.6%	0.7%	0.9%	0.8%	0.7%	0.6%	0.5%	0.4%	0.3%	0.3%	0.2%	0.2%	0.2%	0.2%	0.2%	0.2%	0.2%	0.3%	0.3%	0.3%	0.3%	0.3%	0.30%	1,267	117
Lifestyle	0.8%	0.9%	1.0%	1.4%	1.3%	1.5%	1.4%	1.4%	1.1%	0.9%	0.6%	0.6%	0.5%	0.5%	0.5%	0.5%	0.6%	0.5%	0.3%	0.4%	0.4%	0.5%	0.5%	0.5%	0.60%	2,132	451
Multimedia	2.1%	2.1%	2.4%	2.4%	2.7%	2.4%	1.8%	1.8%	1.9%	1.7%	1.8%	2.0%	2.0%	2.0%	2.2%	2.1%	2.2%	2.4%	2.3%	2.3%	2.2%	2.1%	1.9%	2.0%	2.03%	1,713	76
News	2.6%	2.5%	2.6%	2.5%	2.5%	2.7%	3.3%	3.7%	4.1%	3.6%	3.0%	2.6%	2.5%	2.7%	2.5%	2.4%	2.2%	2.1%	2.3%	2.2%	2.3%	2.2%	2.3%	2.3%	2.46%	1,777	440
Productivity	3.6%	5.0%	5.0%	5.8%	6.3%	6.5%	6.0%	5.4%	4.8%	5.1%	4.9%	4.3%	4.2%	4.0%	4.0%	3.7%	3.4%	3.4%	3.0%	3.1%	3.1%	3.0%	2.9%	3.2%	3.76%	2,190	648
Reference	0.7%	0.7%	0.7%	0.7%	0.7%	0.7%	0.6%	0.6%	0.7%	0.5%	0.5%	0.5%	0.4%	0.4%	0.4%	0.3%	0.4%	0.4%	0.4%	0.5%	0.5%	0.5%	0.5%	0.6%	0.47%	903	346
Settings	1.3%	1.6%	1.5%	1.3%	1.6%	1.2%	1.2%	1.1%	1.3%	1.4%	1.4%	1.4%	1.2%	1.3%	1.2%	1.2%	1.3%	1.1%	1.1%	1.2%	1.2%	1.3%	1.3%	1.4%	1.23%	2,178	1
Shopping	3.9%	4.5%	3.7%	3.4%	3.2%	3.2%	3.1%	3.0%	3.1%	3.3%	3.2%	3.2%	3.2%	2.8%	2.9%	2.9%	2.7%	2.7%	2.7%	2.7%	2.8%	3.1%	3.6%	3.5%	2.96%	2,556	198
Social	5.7%	5.0%	4.9%	4.3%	4.2%	4.0%	4.4%	5.1%	5.3%	5.4%	5.2%	5.0%	4.7%	4.8%	4.9%	4.5%	4.5%	4.6%	4.6%	4.9%	5.2%	5.4%	5.8%	5.7%	4.77%	1,902	342
Sports	0.5%	0.3%	0.3%	0.2%	0.3%	0.3%	0.2%	0.3%	0.3%	0.3%	0.3%	0.4%	0.4%	0.6%	0.7%	0.8%	0.9%	0.8%	0.6%	0.6%	0.7%	0.8%	0.7%	0.7%	0.56%	571	215
Themes	0.2%	0.1%	0.2%	0.3%	0.4%	0.4%	0.4%	0.2%	0.2%	0.2%	0.1%	0.1%	0.1%	0.2%	0.1%	0.1%	0.1%	0.2%	0.1%	0.1%	0.2%	0.1%	0.1%	0.1%	0.14%	249	231
Tools	10.9%	12.2%	14.6%	17.6%	20.3%	21.5%	21.4%	18.6%	14.7%	10.4%	8.4%	6.8%	6.1%	5.9%	5.9%	6.0%	6.1%	5.8%	6.0%	6.3%	6.8%	7.4%	9.1%		7.89%	2,512	1,688
Travel	1.4%	1.6%	2.1%	2.2%	2.4%	2.6%	2.2%	1.9%	2.0%	2.1%	2.0%	1.8%	1.9%	1.9%	1.9%	1.8%	2.0%	1.9%	2.2%	2.2%	1.9%	1.7%	1.6%	1.4%	1.86%	1,752	407
Unknown	4.7%	5.3%	5.1%	5.0%	5.3%	4.4%	5.0%	5.9%	4.6%	4.4%	4.1%	3.8%	3.5%	3.8%	3.7%	3.7%	4.0%	3.6%	3.7%	3.7%	3.7%	3.9%	4.1%	4.5%	3.88%	2,284	1,796
Total Launches per Hour	103,604	77,053	53,633	40,332	33,438	30,949	38,161	56,895	83,488	109,550	127,069	142,642	158,876	168,082	169,018	172,935	173,963	179,801	184,012	176,050	163,080	153,835	141,303	123,639			

Figure 5. Hourly relative app usage by category in terms of launches. Each cell value refers to the percentage of app launches done by our users within each hour for each category. Colors are normalized by row, with green indicating each category's maximum percentage of application time, and white indicating each category's minimum. For example, games reach their peak in the evening (green) and trough in the morning (white).
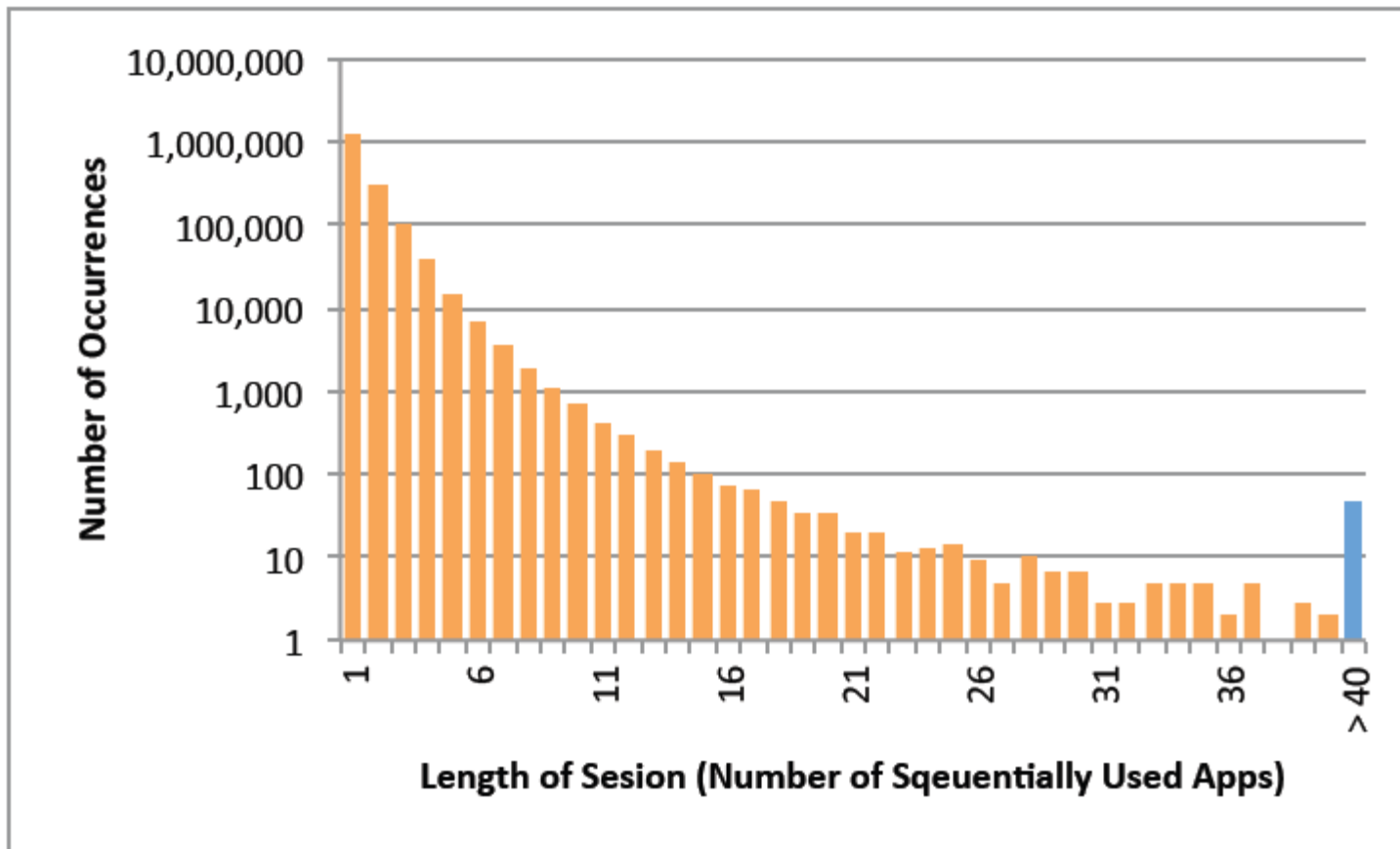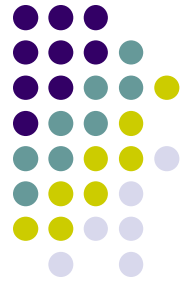
App Chains

Figure 6. Number of apps used in a session. We aggregated sessions longer than 40 apps since the graph flattens out and scarcity increases. Maximum length is 237.
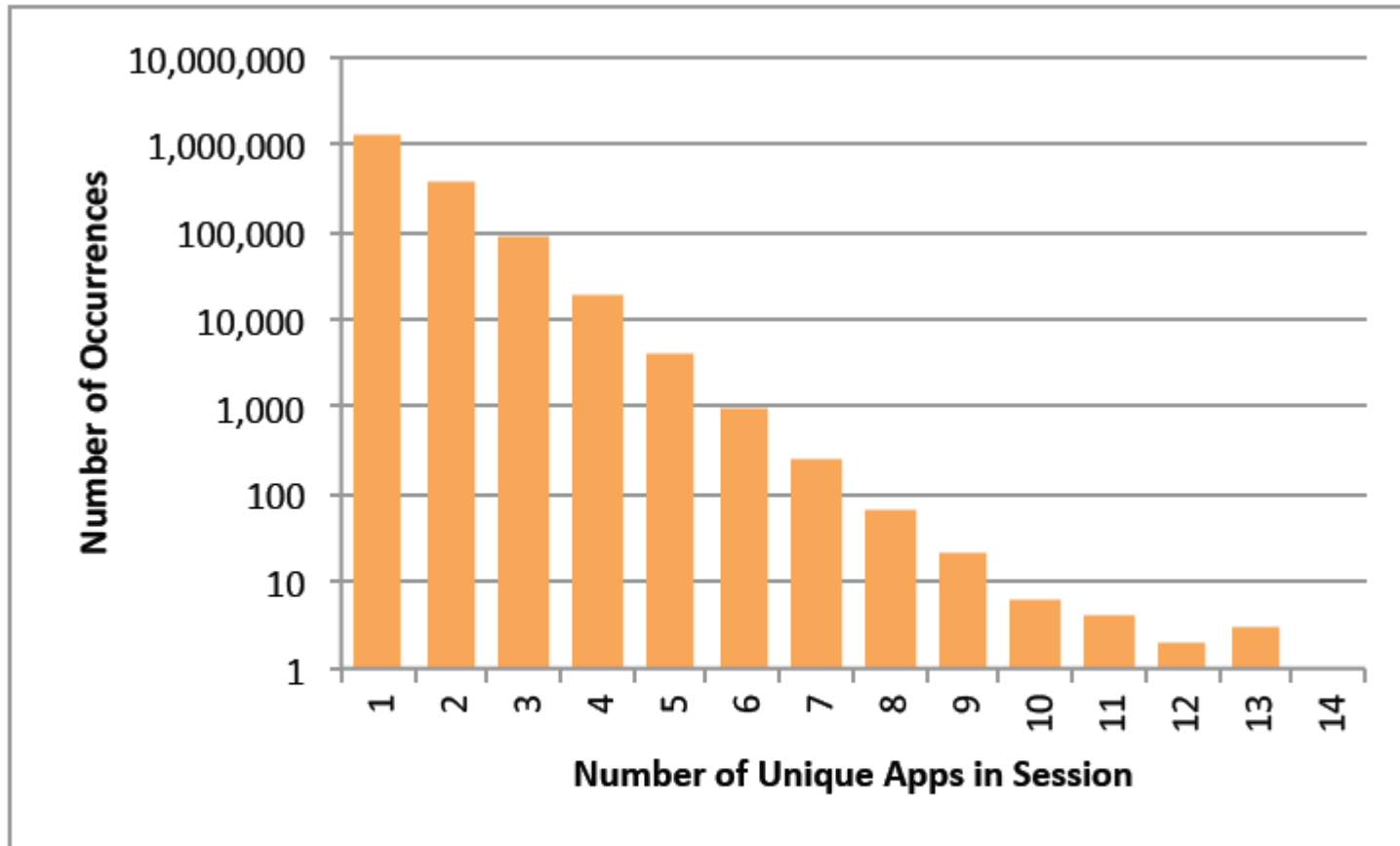
Unique Apps per Chain

Figure 7. Occurrences of sessions according to number of unique apps used within a session.
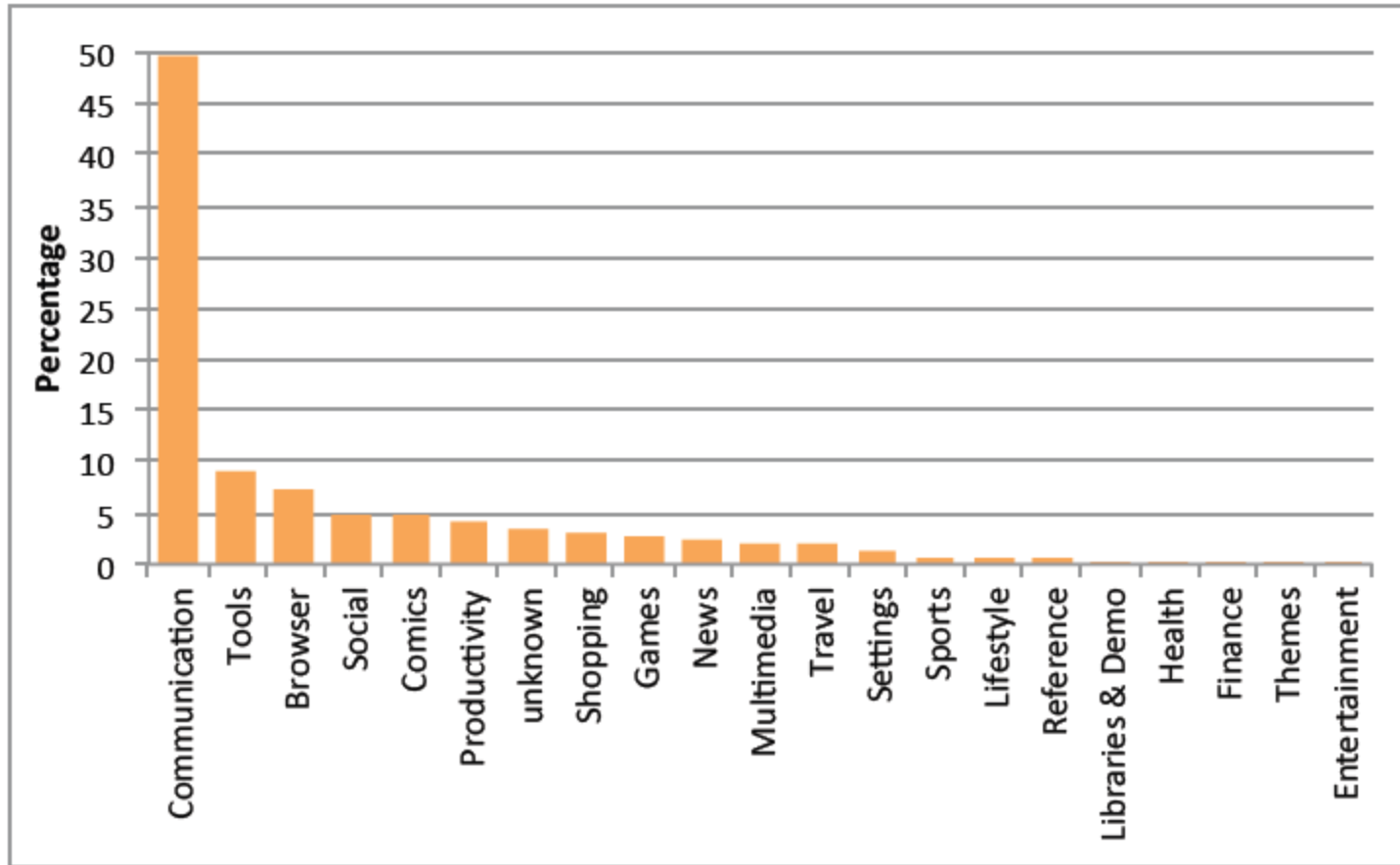
First App Used in Session

Figure 8. Categories of first used app within a session.

Transition Probabilities

	Browser	Comics	Communication	Entertainment	Finance	Games	Health	Libraries & Demo	Lifestyle	Multimedia	News	Productivity	Reference	Settings	Shopping	Social	Sports	Themes	Tools	Travel	Unknown	Samples	Users	Apps
Browser	2.4%	3.6%	33.8%	0.0%	0.3%	3.5%	0.2%	0.2%	0.4%	1.5%	11.8%	3.8%	0.6%	1.7%	3.6%	15.6%	0.5%	0.3%	8.1%	2.2%	6.1%	48,379	2,193	9
Comics	6.5%	9.4%	36.1%	0.0%	0.2%	4.8%	0.6%	0.2%	0.6%	5.2%	2.7%	4.1%	0.6%	2.2%	5.2%	4.3%	0.6%	0.4%	8.4%	2.7%	5.0%	31,258	1,754	1,220
Communication	5.7%	2.7%	65.5%	0.0%	0.2%	1.5%	0.1%	0.1%	0.2%	1.3%	2.1%	2.5%	0.3%	1.0%	1.7%	4.8%	0.4%	0.1%	5.0%	1.4%	3.2%	434,974	2,839	449
Entertainment	6.7%	6.1%	26.1%	0.0%	0.0%	3.3%	0.6%	0.0%	0.6%	5.6%	0.6%	2.8%	0.0%	3.3%	7.2%	3.3%	3.3%	0.0%	8.3%	5.6%	16.7%	180	65	28
Finance	10.3%	3.7%	37.3%	0.0%	1.8%	2.9%	0.2%	0.3%	0.2%	1.5%	8.6%	3.5%	0.1%	1.5%	5.5%	6.1%	0.7%	0.1%	10.6%	1.9%	3.1%	1,496	347	117
Games	11.8%	5.9%	30.4%	0.0%	0.3%	15.1%	0.3%	0.4%	0.7%	1.0%	2.1%	4.2%	0.7%	1.5%	6.5%	4.0%	0.8%	0.1%	8.3%	1.7%	4.2%	8,620	1,077	995
Health	3.8%	4.8%	34.3%	0.0%	0.3%	2.5%	6.1%	0.6%	1.2%	6.1%	2.9%	3.1%	1.6%	2.3%	6.0%	4.9%	0.8%	0.0%	12.4%	2.3%	3.9%	1,466	328	130
Libraries & Demo	6.0%	3.7%	23.3%	0.0%	0.2%	2.3%	0.3%	2.6%	0.8%	1.3%	1.7%	3.2%	0.3%	16.2%	11.9%	3.7%	0.3%	0.1%	13.4%	3.2%	5.5%	3,936	1,082	90
Lifestyle	8.2%	5.3%	17.3%	0.0%	0.1%	4.0%	0.5%	0.6%	3.0%	0.9%	2.3%	4.3%	0.7%	2.3%	28.7%	3.1%	0.2%	0.4%	10.2%	2.2%	5.5%	4,673	1,383	303
Multimedia		10.5%	38.2%	0.0%		1.4%	0.6%	0.2%	0.4%	2.5%	2.5%	6.2%	0.3%	2.0%		4.4%	0.3%	0.4%	9.5%	3.2%	9.1%	12,451	1,376	53
News	33.6%	3.3%	33.3%	0.0%	0.5%	1.6%	0.2%	0.1%	0.2%	1.4%	3.9%	2.9%	0.4%	1.4%	3.0%	3.7%	0.4%	0.0%	6.5%	1.0%	2.4%	25,131	1,440	312
Productivity	7.4%	5.0%	38.5%	0.0%	0.4%	2.6%	0.4%	0.2%	0.6%	2.8%	2.8%	7.2%	1.1%	3.8%	4.8%	5.1%	0.6%	0.3%	9.7%	2.4%	4.4%	31,113	1,954	498
Reference	13.1%	4.5%	34.3%	0.0%	0.2%	7.5%	0.6%	0.3%	1.0%	1.0%	2.5%	4.6%	2.9%	1.7%	5.2%	4.1%	0.4%	0.2%	9.8%	1.7%	4.4%	2,611	552	199
Settings	8.9%	5.6%	26.3%	0.1%	0.2%	1.8%	0.4%	5.2%	0.7%	2.0%	2.6%	6.9%	0.5%	0.0%	5.6%	4.7%	0.6%	0.5%	11.6%	4.8%	11.1%	13,576	1,863	1
Shopping	8.5%	7.8%	23.2%	0.0%	0.4%	4.8%	0.4%	0.9%	9.6%	0.9%	2.8%	5.2%	0.7%	3.0%	4.7%	4.3%	0.5%	0.5%	16.6%	1.6%	3.8%	21,788	2,207	132
Social	24.1%	3.0%	35.3%	0.0%	0.3%	2.3%	0.2%	0.2%	0.3%	1.2%	2.9%	2.8%	0.3%	1.5%	2.7%	12.4%	0.7%	0.1%	5.3%	1.2%	3.3%	35,086	1,593	239
Sports	7.4%	4.3%	43.3%	0.1%	0.4%	2.5%	0.4%	0.2%	0.3%	1.3%	3.0%	4.8%	0.5%	2.4%	3.8%	5.4%	7.6%	0.0%	7.0%	1.5%	3.9%	2,793	387	135
Themes	8.5%	10.2%	37.2%	0.0%	0.2%	2.4%	0.1%	0.2%	1.4%	3.2%	0.4%	4.7%	0.4%	3.3%	6.5%	3.6%	0.1%	1.2%	8.6%	3.3%	4.6%	1,929	175	175
Tools	11.0%	5.1%	36.1%	0.0%	0.2%	2.7%	0.3%	0.4%	0.6%	2.1%	2.4%	4.2%	0.6%	2.1%	5.5%	4.1%	0.4%	0.2%	15.7%	2.8%	3.5%	88,911	2,384	1,310
Travel	6.7%	9.1%	36.2%	0.1%	0.4%	2.3%	0.3%	0.5%	0.7%	1.9%	1.6%	6.7%	0.4%	5.0%	2.9%	4.4%	0.3%	0.2%	10.2%	6.6%	3.6%	12,556	1,403	281
Unknown	10.7%	4.4%	40.8%	0.1%	0.2%	2.1%	0.2%	0.3%	0.6%	3.9%	1.8%	3.2%	0.3%	3.9%	2.9%	4.7%	0.3%	0.2%	6.4%	1.5%	11.6%	48,379	1,972	1,277

Figure 9. Transition probabilities in app chains. The transitions are from categories in a row to categories in a column. The diagonal indicates transitions between apps in the same category. The probability ranges from yellow (low) to green (high).

Usage by Location

- In US airports
  - 2.78 times more likely to use browser
  - Games, tools and reference apps less likely
- Traveling faster than 25kph
  - 2.26 times more likely to use multimedia app
  - 0.83 less likely to use travel apps
- Nationality usage
  - European users 1.21 times more likely to use browser
  - Americans use sports, health and reference more

Usage Throughout Day

	12am	1am	2am	3am	4am	5am	6am	7am	8am	9am	10am	11am	12pm	1pm	2pm	3pm	4pm	5pm	6pm	7pm	8pm	9pm	10pm	11pm	% of Total Usage Time	Users
Facebook	4.8%	3.9%	4.0%	3.4%	3.2%	3.3%	3.8%	4.1%	4.1%	4.1%	3.9%	4.7%	4.0%	4.2%	4.1%	3.5%	4.1%	4.0%	4.3%	4.5%	4.7%	4.8%	5.6%	4.8%	1.91%	1,467
Google Maps	2.9%	1.7%	2.0%	1.8%	1.8%	1.8%	1.9%	2.2%	3.2%	4.0%	4.0%	5.0%	5.7%	5.6%	5.7%	5.8%	6.8%	6.4%	7.3%	6.6%	5.0%	4.8%	4.6%	3.4%	0.81%	1,584
Alarmclock 1	6.6%	8.2%	8.8%	10.0%	10.4%	9.7%	8.7%	6.8%	4.8%	3.3%	2.2%	1.4%	1.0%	1.0%	1.0%	1.0%	0.9%	0.6%	1.0%	1.2%	1.4%	2.0%	3.0%	5.0%	4.55%	341
Alarmclock 2	3.9%	4.3%	7.5%	9.2%	10.8%	10.7%	9.7%	9.2%	8.2%	7.7%	5.3%	3.3%	1.8%	0.5%	0.4%	0.3%	0.5%	0.6%	0.7%	0.4%	1.0%	0.6%	1.1%	2.0%	0.32%	169
Weather App	2.1%	0.9%	0.6%	0.3%	0.5%	2.0%	3.8%	2.2%	4.0%	10.1%	11.2%	9.8%	8.1%	3.2%	2.9%	5.9%	6.5%	4.3%	2.0%	4.9%	3.3%	4.0%	4.7%	2.5%	0.06%	309
Twitter	3.6%	3.3%	3.6%	4.4%	3.3%	3.0%	3.8%	4.0%	4.3%	4.3%	4.8%	4.7%	4.3%	4.4%	4.7%	4.6%	4.0%	4.1%	4.0%	4.6%	4.9%	4.8%	4.3%	4.1%	0.56%	457
Phone	2.6%	2.2%	1.9%	1.9%	1.8%	1.9%	1.9%	1.7%	2.4%	3.3%	4.1%	4.8%	5.2%	5.8%	5.7%	6.5%	6.4%	7.4%	7.6%	6.8%	5.8%	4.8%	4.1%	3.5%	1.94%	2,409
Angry Birds	5.3%	4.3%	3.2%	2.4%	1.6%	1.8%	1.5%	2.0%	1.8%	2.8%	3.5%	3.5%	4.6%	5.6%	4.9%	6.5%	4.7%	6.2%	5.6%	6.0%	5.1%	6.0%	5.4%	5.7%	0.64%	727
Kindle	9.1%	7.7%	6.9%	5.5%	4.0%	3.2%	2.9%	2.3%	1.7%	2.0%	2.3%	1.9%	2.8%	3.6%	2.6%	4.3%	2.5%	3.8%	3.1%	2.5%	4.9%	5.3%	7.3%	7.7%	0.47%	209
Calculator	3.6%	3.3%	3.0%	0.8%	0.7%	0.8%	1.1%	1.7%	2.8%	1.6%	6.6%	6.8%	7.1%	6.3%	5.6%	7.6%	7.7%	6.0%	5.8%	5.3%	4.6%	3.3%	3.3%	1.8%	0.10%	550
Calendar	5.1%	3.6%	0.7%	0.4%	0.2%	0.4%	3.8%	2.2%	3.9%	6.1%	7.6%	7.8%	6.3%	5.3%	3.5%	5.5%	5.8%	5.3%	3.8%	4.4%	5.6%	4.3%	3.1%	5.1%	0.14%	615
Camera	4.3%	4.3%	3.7%	3.5%	3.7%	3.0%	3.0%	2.2%	1.3%	3.6%	3.3%	4.6%	5.7%	5.0%	5.1%	6.2%	5.7%	6.0%	4.7%	5.0%	5.8%	4.5%	5.7%	0.10%	781
Music	2.0%	3.6%	4.5%	5.1%	5.3%	5.4%	6.2%	6.1%	5.8%	4.5%	5.3%	3.7%	4.2%	3.8%	3.6%	3.6%	3.4%	3.6%	3.1%	4.1%	3.6%	3.8%	2.9%	2.8%	0.41%	483

Figure 10. Application usage time throughout the day. Within each row (i.e., for each app) low usage is indicated by white, increasing through yellow and reaching a peak at red. Percentages indicate the usage time of each app and are normalized within each row.

Discussion

- Improve app and OS design
  - Change app icon location based on time
  - Link apps
  - Design UI based on context (eg used mostly in car)
  - Support better inter-app navigation
- Use AppSensor in context-aware apps
  - App use focus context guess

Limitations

- General purpose apps
  - Browsers used for many contexts
- Can't detect background apps (music) or widgets
- Test group probably more app savvy than general
- App in use does not mean an active user
- Only active when using phone apps
- Sample frequency
- Current design only works on Android

Conclusions

- Deployment based research through app store combined with fine-grained data collection for app usage

- Developed virtual sensor for app activity

- Users spend 1 hour a day using apps

- Less than 72 seconds with app at a time (varies between categories)

- Phone used mostly for communication

- Some apps have spikes in usage

Conclusions continued

- Active users spend less time per app

- Short sessions with one app more frequent

- In multi app sessions communication is usually the first app

- Traveling users more likely to use multimedia

Future Work

- Make whole data set available to community
- Inform design of appazaar recommender system
- Develop models to predict next-to-be-used app
- Better understand location-based results with detailed spatial analysis

References

- Bohmer, M., Hecht, B., Schoning, J., Kruger, A., Bauer, G. Falling Asleep with Angry Birds, Facebook and Kindle A Large Scale Study on Mobile Application Usage. In Proc MobileHCI 2011

- Church, K., and Smyth, B. Understanding mobile information needs. In Proceedings of the 10th international conference on Human computer interaction with mobile devices and services, MobileHCI '08, ACM (New York, NY, USA, 2008), 493–494. [6]

- Cui, Y., and Roto, V. How people use the web on mobile devices. In Proceeding of the 17th international conference on World Wide Web, WWW '08, ACM (New York, NY, USA, 2008), 905–914. [7]

- Demumieux, R., and Losquin, P. Gather customer's real usage on mobile phones. In Proceedings of the 7th international conference on Human computer interaction with mobile devices and services, MobileHCI '05, ACM (New York, NY, USA, 2005), 267–270. [8]

References Continued

- Froehlich, J., Chen, M. Y., Consolvo, S., Harrison, B., and Landay, J. A. Myexperience: a system for in situ tracing and capturing of user feedback on mobile phones. In Proceedings of the 5th international conference on Mobile systems, applications and services, MobiSys '07, ACM (New York, NY, USA, 2007), 57–70. [10]

- Girardello, A., and Michahelles, F. Appaware: which mobile applications are hot? In Proceedings of the 12th international conference on Human computer interaction with mobile devices and services, MobileHCI '10, ACM (New York, NY, USA, 2010), 431–434. [11]

- Henze, N., Poppinga, B., and Boll, S. Experiments in the wild: public evaluation of off-screen visualizations in the android market. In Proceedings of the 6th Nordic Conference on Human-Computer Interaction: Extending Boundaries, NordiCHI '10, ACM (New York, NY, USA, 2010), 675–678. [12]

References Continued

- McMillan, D., Morrison, A., Brown, O., Hall, M., and Chalmers, M. Further into the wild: Running worldwide trials of mobile systems. In Pervasive Computing, P. Floréen, A. Krüger, and M. Spasojevic, Eds., vol. 6030 of Lecture Notes in Computer Science. Springer Berlin / Heidelberg, Berlin, Heidelberg, 2010, ch. 13, 210–227–227. [16]
- Verkasalo, H. Contextual patterns in mobile service usage. Personal and Ubiquitous Computing 13, 5 (2009).