EAGER: Detecting and Addressing Adverse Dependencies Across Human-in-the-Loop In-Home Medical Apps

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Goals of Project

- To make the simultaneous use of multiple medical and wellness apps, and health websites safe
- To reduce the effort for medical and wellness app developers
- To improve the design and implementation process for apps to make them more robust and aware of inter-app dependencies
- To generalize conflict detection and resolution to smart city services
- To interact in the Global Cities Challenge

Innovative Contributions

- A totally new approach to detecting primary and secondary dependencies across multiple in-situ, wellness, and medical apps
- Initially focused on human physiological parameters
- Using a personalized physiological simulator as part of a model predictive control loop
- Solutions consider personalized information and time dependent interventions
- New solutions for finding conflicting advice in textual outputs of apps
- A new watchdog architecture, CityGuard, for detecting and resolving conflicts in smart city services.

Research Challenges

- Development of a platform that supports construction of wireless and mobile medical apps that are conductive to dependency analysis
- Implementation of a set of apps with interventions
- Development of runtime platforms to support obtaining experience with running, detecting, and resolving dependencies to keep patients and people in smart cities safe
- Develop solutions that can understand when advice (a major type of intervention) given by different apps is conflicting
- Develop solutions for addressing secondary dependencies in both humans-in-the-loop apps and smart city services

Human-in-the-Loop Apps

Smartphone Paradigm

- Medical apps are booming
- US FDA expects 500M smart phone users downloading healthcare apps by 2015
- By 2020, 157 million Americans predicted to have more than one chronic disorder

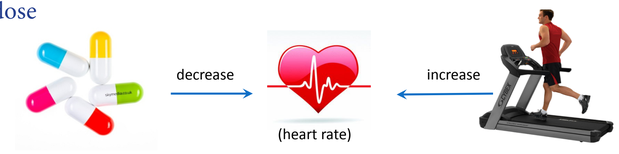
Conflicts in HiL CPSs

Very challenging!
Independently developed!

- Each app/system has its own assumption and strategy to control human physiological parameters

Multiple apps, multiple interventions : CONFLICTS

- Increase, decrease each others effects unwillingly
- Drug overdose



- Need to address a spectrum of (complex) dependencies

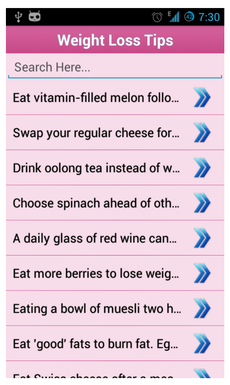
Conflicts in Textual Intervention

Majority of health apps and websites provide interventions as free text

- Advice/recommendations

Detecting conflicts from pieces of text involve

- *Understanding* the action
- *Understanding* / inferring the implications of the action: effect
- Detecting conceptual overlap
- Detecting *type* of conflict
  - Opposite action/effect
  - Quantitative mismatch
  - Temporal
  - Conditional, etc.



Parameter Classification

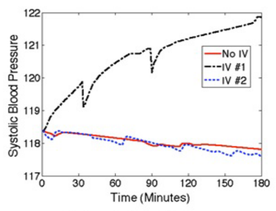
High Level Parameters (vital signs)

- Body temperature, heart rate, blood pressure, respiratory rate, glucose (normal range known) ✓ Extensible

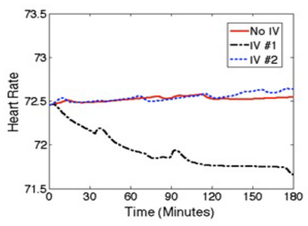
Low Level Parameters (secondary effects)

- Kidney-ArcuateArtery. BloodFlow, LeftHeart-Flow. BloodFlow, Liver-Fuel. GlucoseDelivered(Cals/Min)

Why do we need to worry about secondary effects (variables affected)?



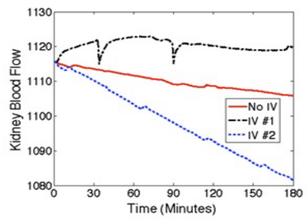
(a) Systolic Blood Pressure



(b) Heart Rate

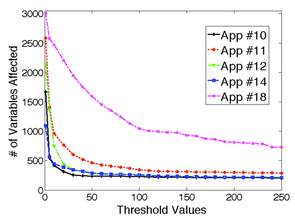
IV #1 = Administer Digoxin,
IV #2 = Administer Spironolactone

Conflict!



(c) Kidney Blood Flow

# of Variables Affected



X = 250%

App ID	# Variables
#10	208
#11	289
#12	219
#14	211
#18	727

Finding: App developers can not specify all the effects!

Use App Meta Data

```
<intervention> MidodrineSingleDose.Dose </intervention>
<dosage> 10 </dosage>
<param> Heart-Rate.Rate </param>
<effect> increase </effect>
```

App Developers Specify

- Only the high level parameters (just 5 parameters)
- Allowed to specify low level parameters, if known
  - Specify effect: *increase, decrease, null*

Types of Conflicts in Text Advice

	Advice 1	Advice 2
Opposite polarity (actions)	Eat citrus fruits and green leafy vegetables.	Be careful about green leafy vegetables if you are on Coumadin or ACE Inhibitors.
Temporal	Do stretching exercises when you wake up.	Avoid stretching or similar exercises after the end of week 12 of your pregnancy.
Conditional	Avoid alcohol if pregnant or trying to conceive.	Small amounts of alcohol increase the body's metabolic rate.
Sub-typical	Eat calcium-rich foods like milk and cheese.	Use skimmed milk instead of whole milk as dairy products often cause bloating and gas.
Quantitative	Limit your caffeine intake to less than 200 mg per day during pregnancy.	Up to 400 mg of caffeine a day appears to be safe for most healthy adults.
Cumulative	Run for at least 30 minutes a day.	Take Salmeterol 1 inhalation (50 mcg) twice daily.

Advice Dataset

Topic Name	Health Site	Mobile App	App Name
Anemia	39	6	Anemia Help
Diabetes	81	18	Health & Nutrition Guide
Digestive health	30	35	Food Shopping Essential
Diet	85	256	Healthy Nutrition Guide Health & Nutrition Guide Effective Weight Loss Guide
Exercise	51	60	Effective Weight Loss Guide Health & Nutrition Guide
Pregnancy	48	92	Pregnancy Pregnancy Foods to Avoid
Weight loss	32	323	QuickWeight Effective Weight Loss Guide
Total	366	790	1156

Solution Approach

- Semantic Rule Based Conflict Detection
- Polarity Assignment: *positive, negative*
- Finding Conceptual Overlap — Using *MetaMap, ConceptNet*
- Semantic Tokenization of Text — *object, quantity, action, subject*
- Sematic Clause Extraction — *action, effect, conditional, temporal*
- Personalization data
- Health Advice from apps
- Health advice from websites
- App metadata

Results: Textual Conflict Detection

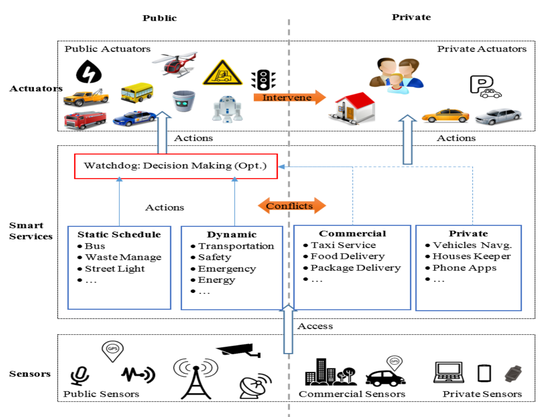
	Accuracy	Precision	Recall	F1
Baseline	60%	0.63	0.21	0.31
PreCluDe	90%	0.85	0.93	0.89

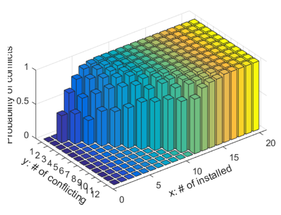
Table 1: Comparing our proposed solution with baseline methods wrt detecting direct conflict: PreCluDe increase accuracy and F1 by about 1.5 times

	Accuracy
Direct Conflict	90%
Conditional Conflict	95%
Temporal Conflict	80%
Quantitative Conflict	75%
Subtypical Conflict	94%
Numerical Conflict	84%

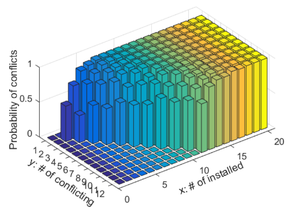
Table 2: Accuracy of detecting different types of conflicts

Conflicts in Smart Cities

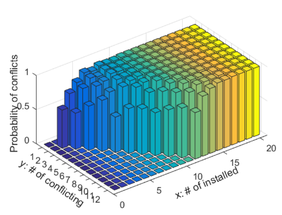




Device Conflicts



Environment Conflicts



Human Conflicts

Probability of conflicts of services related to device, environment, and human conflicts.

x and y axes represent the numbers of installed and conflicting services, respectively.

Smart Cities: Action Cluster Being Created

Title: Support for Safety of the Elderly Population
Participants

- Academia
  - University of Virginia
  - Stonybrook
  - University of Pennsylvania
  - DGIST, S. Korea
  - William and Mary
  - University of Minnesota
  - University of North Carolina
  - Virginia Tech
  - Texas A & M
- Industry - in progress
- Municipalities - in progress