Multi Agent Architecture for Automated Health Coaching

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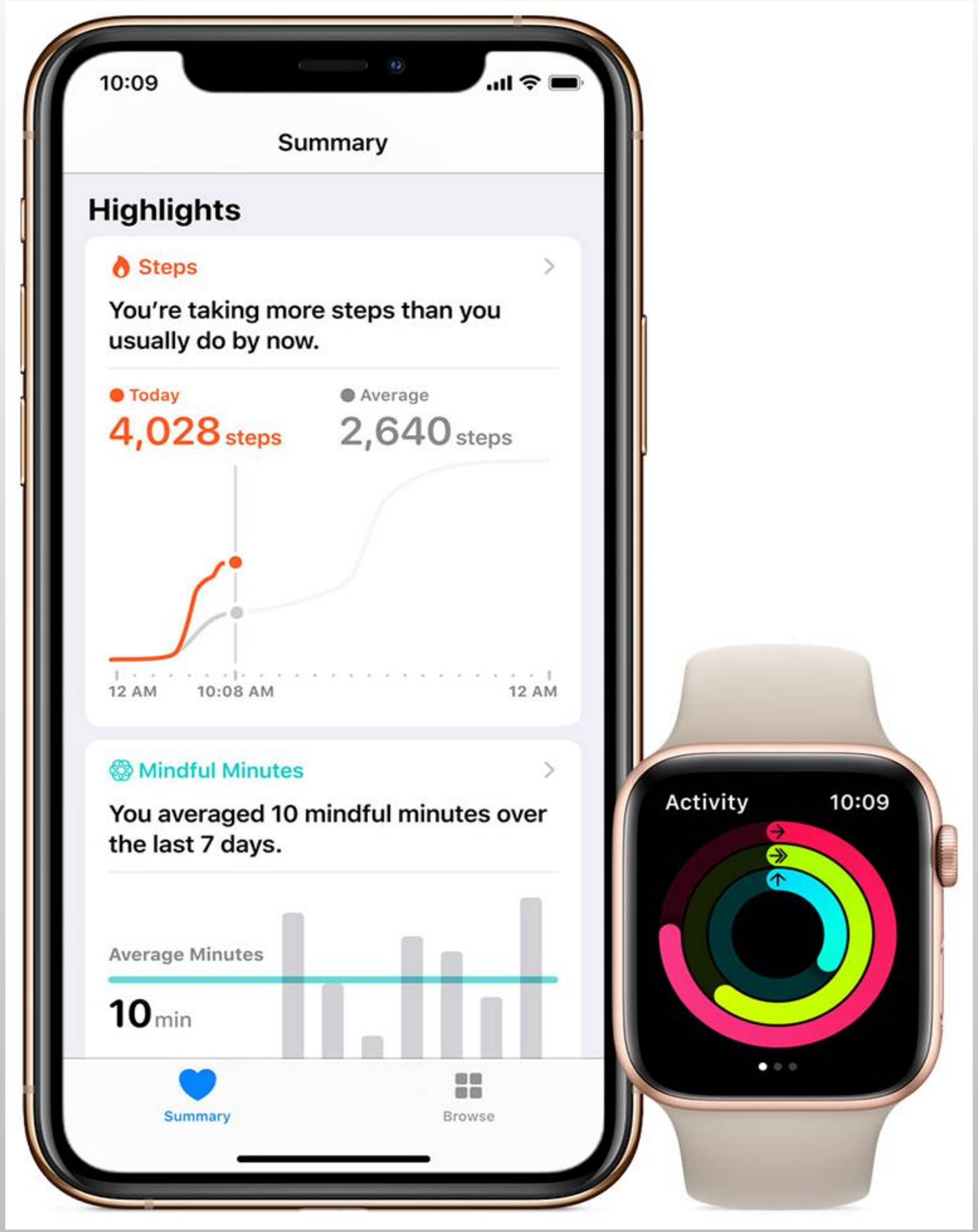
Increasing physical activity among adults
Doctors and other health professionals can use these steps to recommend aerobic physical activity options that match each person's specific abilities and connect him or her to resources that can help each person be physically active.
START
1. Know the Physical Activity Guidelines
The Physical Activity Guidelines are for everybody. www.health.gov/paguidelines/guidelines/
Review the patient's charts before each visit.
Explain that adults of all shapes, sizes and abilities can benefit from being physically active.
2½ HOURS
Encourage at least 2½ hours a week of moderate-intensity physical activity.
2. Ask about physical activity
Remember to look beyond the disability and put the person first. Use terms such as "person with a disability" instead of "disabled" or "handicapped person".
How can you add more physical activity in your life?
What types of physical activity do you enjoy?
How much physical activity are you currently doing each week?
3. Discuss barriers to physical activity
Physical Barriers
Emotional Barriers
4. Recommend physical activity options
Describe physical activity options based on patient's abilities.
Brisk walking
Wheeling oneself in wheelchair
Swimming laps
Water aerobics
Hand-crank bicycle
Wheelchair basketball, tennis, football, or softball
5. Refer patient to resources and programs
Check-in with patient about his or her activity level at every visit.
Refer patient to resources and programs to help them begin or maintain their physical activity.
Remember to use the "teach-back" method to make sure patient understands the recommendations.
SOURCE: 2008 Physical Activity Guidelines for Americans 2008; Exercise is Medicine, 2014, http://exerciseismedicine.org/.



Source: developer.apple.com

- Kamphorst [1] definition of an e-coach: “A set of computerized components that constitutes an artificial entity that can ***observe***, ***reason about***, ***learn*** from and ***predict*** a user’s behaviors, in ***context*** and over time, and that engages ***proactively*** in an ongoing ***collaborative conversation*** with the user in order to aid ***planning*** and promote ***effective goal striving*** through the use of persuasive techniques”.

Source : Photo: Getty Images/Illustration: Sarah Garcea

Overview:

Introduction

Related Work

Transferability

Formal definition of automated coaching problem

SMART-ALEC Architecture

Case studies

Conclusion

Introduction

- *Privacy*: Privacy of health data is of utmost importance and automated coaches should provide secure platform
- *Individualization*: Just-in-time adaptive interventions (JITAI) design requires delivering support at the moment it is needed requiring both individualization and customization of interventions
- *Transferability*: Inherit data limitation problem, health coaches should allow transferability of selective data from other, similar individuals (while preserving privacy)
- *Integration*: Extensive recognition of user's current context (state), which requires the integration of information from many sources

- *Scalability*: Automated coaches should be able to accommodate vast numbers of users and should be able to scale well, as opposed to systems that only augment human coaching
- *Flexibility and Modularity*: Modular design help to loosely couple system components allowing systems to adapt different applications (physical activity, reducing sedentary behavior, smoking cessation, etc.
- *Coordination*: In behavior change, especially physical activity, people who work in pairs have higher success towards goal achievement

Related Work

- iCardia [2] – mHealth platform to support remote monitoring and health coaching of cardiac rehabilitation patients. Uses Fitbits, smartphones and personalized SMS
- MobiCardio [3] – Integrates multi-sensors, machine-learning based sleep analytics and electronic health records to manage patients for clinical scenarios

Lack flexibility to serve as platforms for other health coaching problems

Related Work - Flexibility

- Blok et al [4] and Ochoa et al [5] developed flexible loosely coupled architectures
- Even though these architectures are built such that system structure is decoupled from its behavior they lack on scalability, transferability and coordination

Related Work - Scalable

- Ibrahim et al [6] – multi-agent platform to automate user-provided clinical outcome measures, not a health coaching application
- Azim et al [7] – hierarchical fog-assisted computing architecture (HiCH), remote IoT-based patient monitoring system, edge processing
- Scalable and flexible but lack of transferability and coordination
- Current architectures posses only a subset of features automated health coaching problem

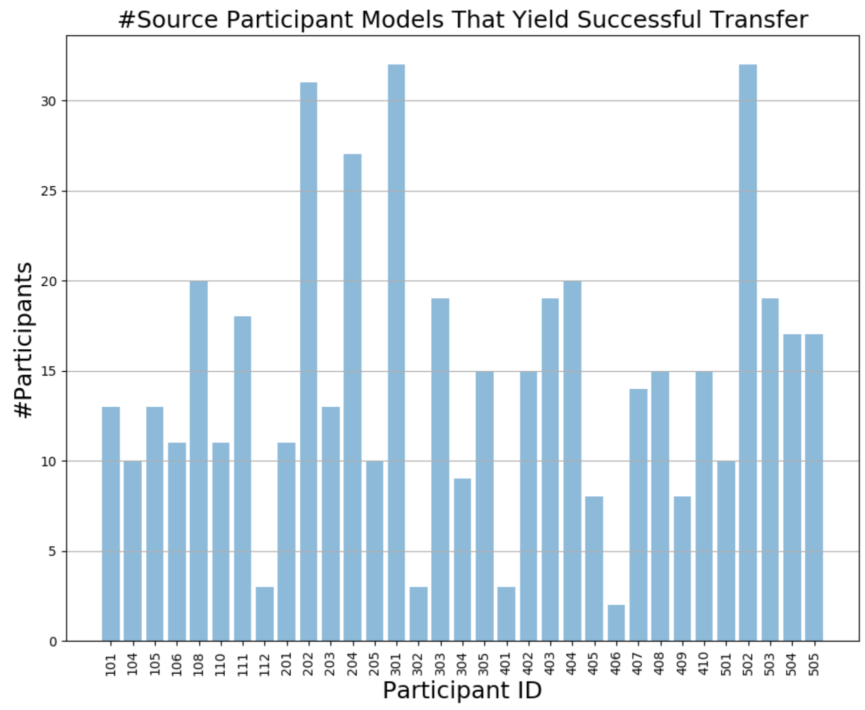
Transferability

Is transfer of intervention policies useful?

Experiment design:

- 2-week study with 33 random participants (20 males, 13 females, 20 students, 5 faculty, 8 staff)
- Healthy adults, age 18 – 55, 2-week study
- Installed study-developed mobile application which collected time, location, outdoors or not, driving or not
- Wore Fitbits
- Participants were nudged every 50th minute from 8:00 am to 9:00 pm (13 nudges a day)

- For each nudge, participants were requested to provide whether the nudge prompted activity (receptiveness)
- Examining accuracy of receptiveness when using transferred model against individual’s own trained model
- Random forest models for each participant (training – 1^{st} week, 2^{nd} week evaluation)
- Model features: location, outdoors or nor, driving or not, time, 250 steps by 50^{th} minute, 500 steps by 50^{th} minute
- Model classification: Whether the participant stated they acted based on the provided nudge



Number of source participants which yield acceptable (under 10 percent loss) transfers for each participant

Most participants can reasonably transfer from more than 30 percent of the population

Formal definition of automated coaching problem

H_i – automated health coach corresponding to participant P_i

H_i can be described as <G, A, S, T, R>

G – health coach goal (e.g., 10,000 steps a day, 5 days a week)

A = $\{a_1, a_2, \ldots, a_n\}$ (e.g., interventions, dialogue with user)

S = $\{s_1, s_2, \ldots., s_n\}$ (e.g., current context of user, data from sensors, goal progression)

T - S x A x S → [0,1]

R - S x A x S → **R** (e.g., positive reward for successful interventions)

G′ = $\{a_1, a_2, \ldots, a_n\}$ where each a_i is derived from $\Pi(s_k) = a_i$, $k \in [1, n]$

Given such set of automated coaches, automated coaching problem **AHC** can be written as:

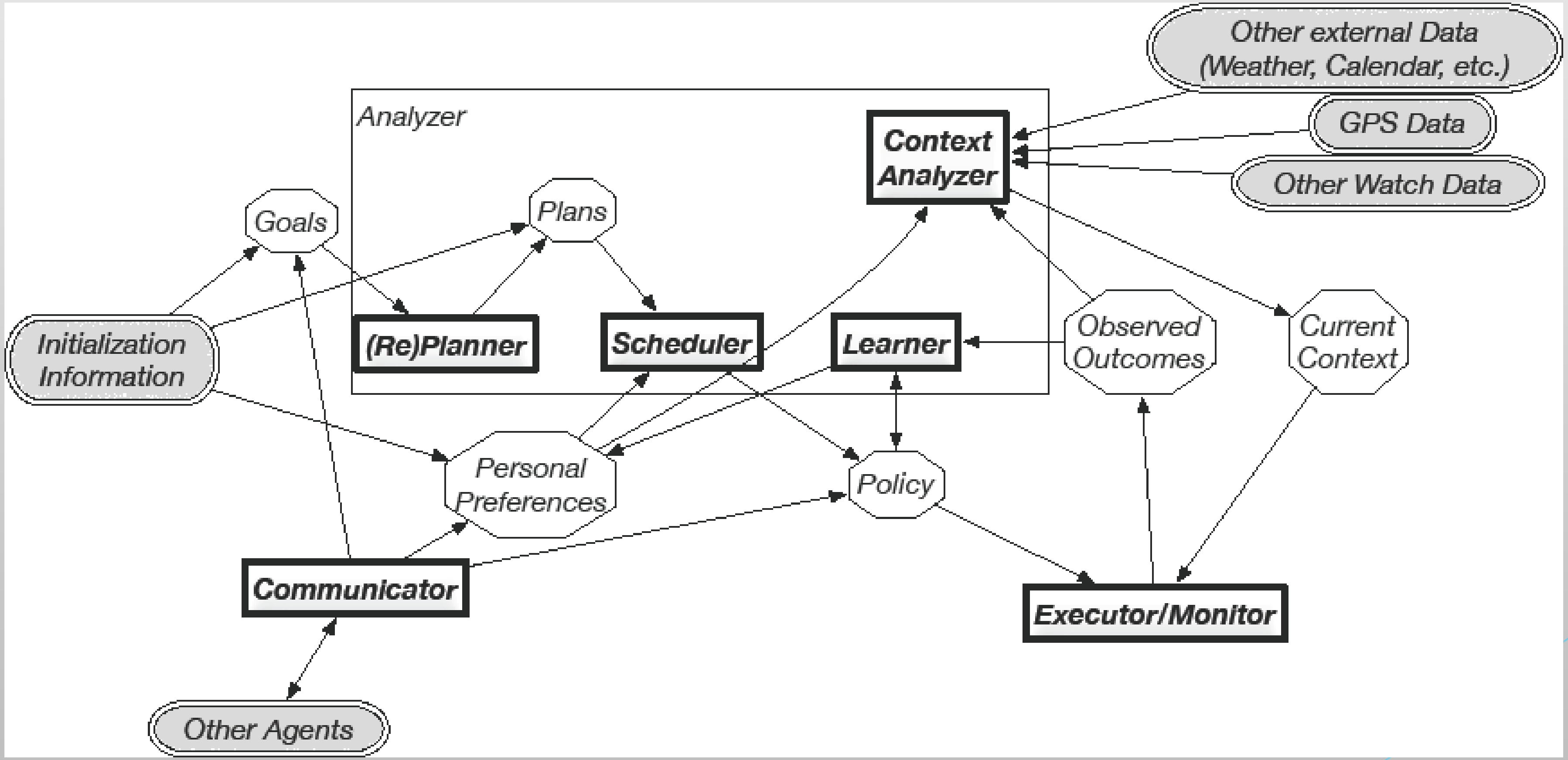
$$\mathbf{AHC} = \langle \mathbf{H}, \mathbf{G} \rangle$$

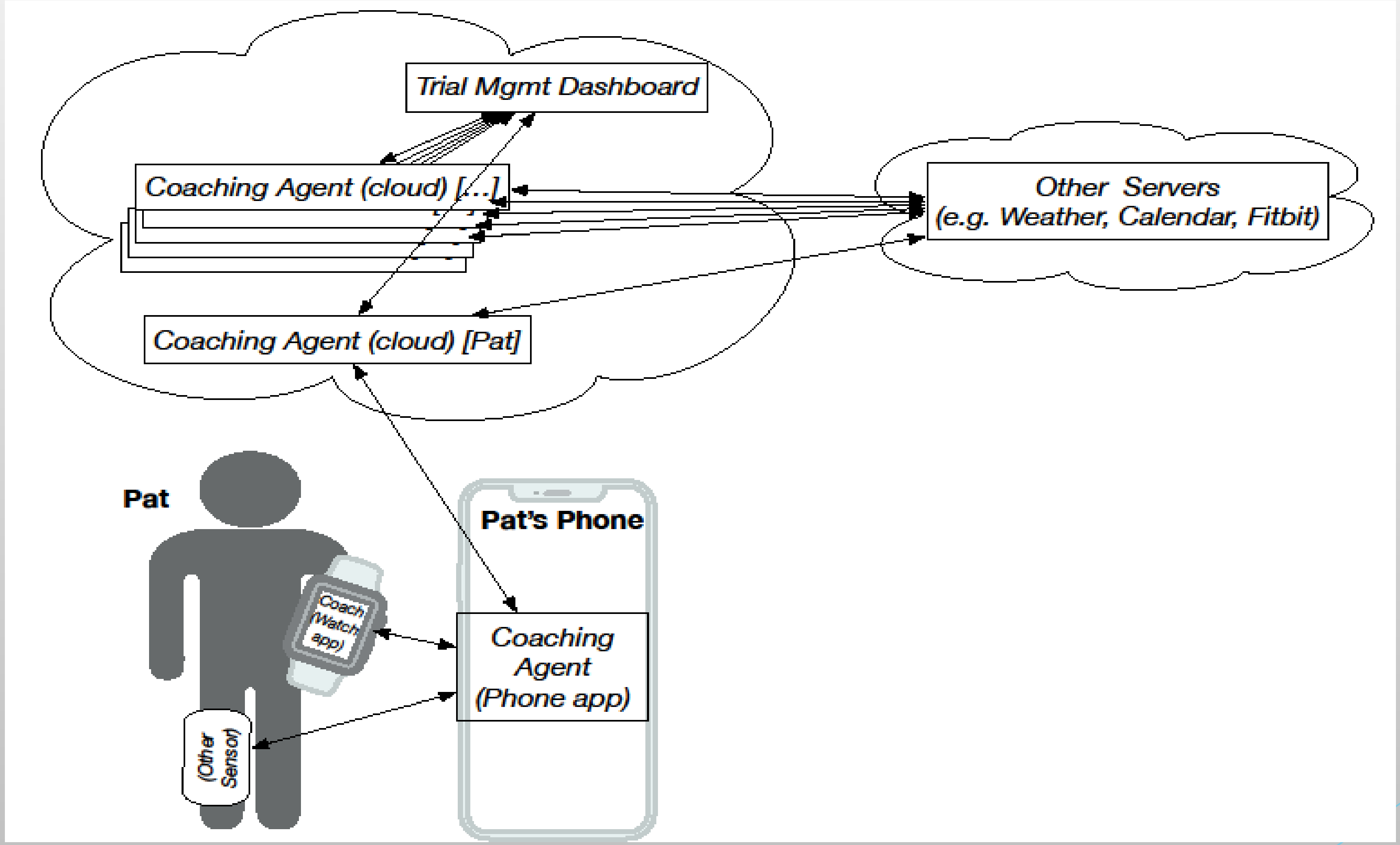
where $\mathbf{H} = \{H_1, H_2, \ldots\ldots, H_n\}$ and

$$\mathbf{G} = \{G_1 \wedge G_2 \wedge \ldots \wedge G_n\}$$

The inherent distributed nature of **AHC** problem along with features like privacy, transferability, individualization and coordination all point to a multi-agent system

SMART-ALEC (System to Monitor, Adapt, and Refine Target goals by Agent-based Learning in Everyday Contexts) Architecture





Trial Mgmt Dashboard
Coaching Agent (cloud) [...]
Other Servers
(e.g. Weather, Calendar, Fitbit)
Coaching Agent (cloud) [Pat]
Pat
Pat's Phone
Coach (Watch app)
Coaching Agent (Phone app)
(Other Sensor)

Case studies

BeSmart (Bio-behavioral Systems to Motivate and Reinforce Heart Health Trail)

Aim: To build an automated coach which leverages short messages service (SMS) and Fitbit within a could-based, bi-directional feedback system that provides **individually tailored behavior change messages** to increase MVPA and improve sleep metrics

The impact of changes in MVPA and sleep metrics on blood pressure were measured

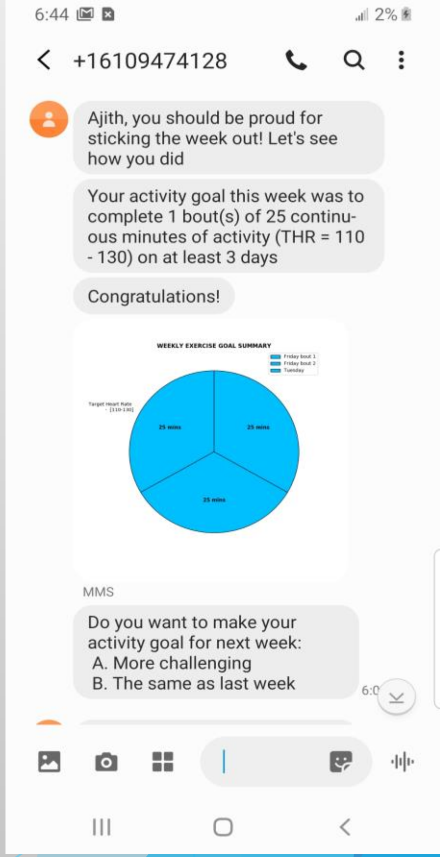
Experiment details:

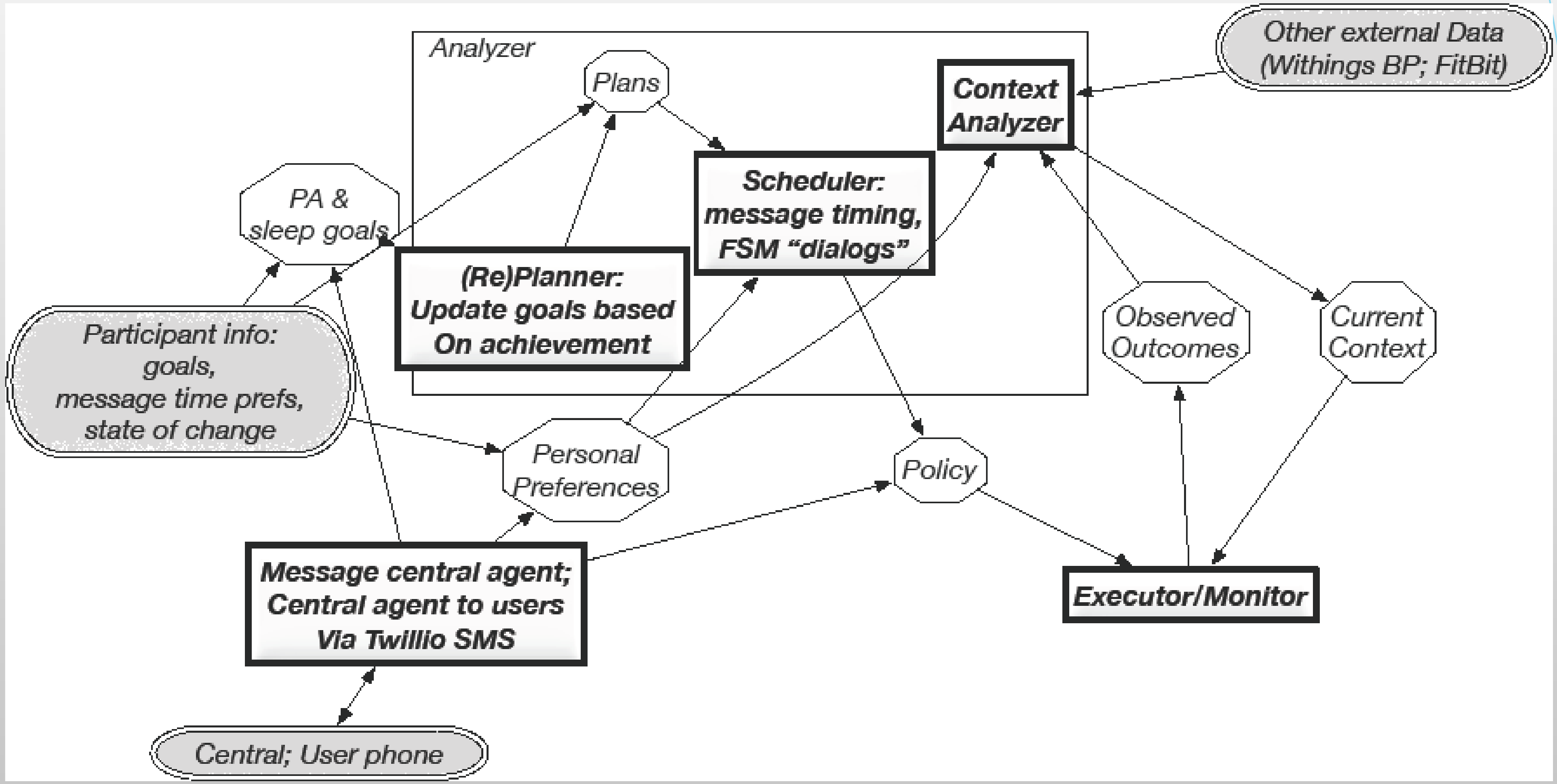
- Participants were made to consult human health coaches for assignment of PA and sleep goals
- The job of BeSmart is to

1. Help participants reach their goals
2. Modify goals for the upcoming week, making goals harder/easier

- BeSmart interacted with participants 3 times a week:

1. Mondays: SMS messages to remind their weekly goals
2. Thursdays: Goal progression messages (mms, pie and bar charts to depict PA and sleep progressions) and reinforcing messages
3. Sundays: A full dialogue with participants to inform weekly progress, modifying goals and recommending strategies to overcome barriers




Analyzer
Plans
Context Analyzer
Other external Data (Withings BP; FitBit)
PA & sleep goals
Scheduler: message timing, FSM “dialogs”
(Re)Planner: Update goals based On achievement
Participant info: goals, message time prefs, state of change
Observed Outcomes
Current Context
Personal Preferences
Policy
Message central agent; Central agent to users Via Twillio SMS
Executor/Monitor
Central; User phone

Beta testing results:

1. Percentage of messages successfully sent and received (98 %). 2% loss of messages happened when central agent interacted with Twillio. Central agent resent messages whenever a message loss was detected
2. Time delay of messages: No delay detected when the number of agents were scaled up to 250

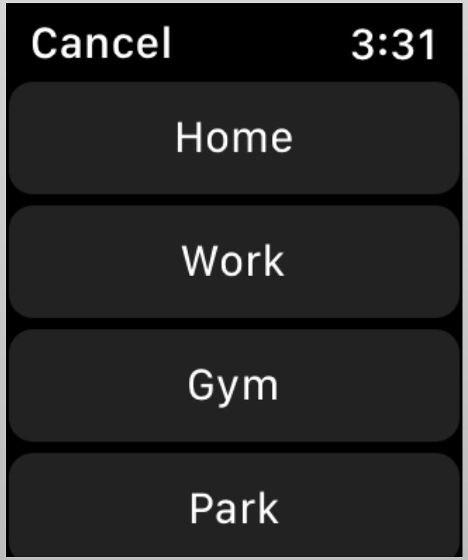
Walking with JITAIs (Just In Time Adaptive Interventions)

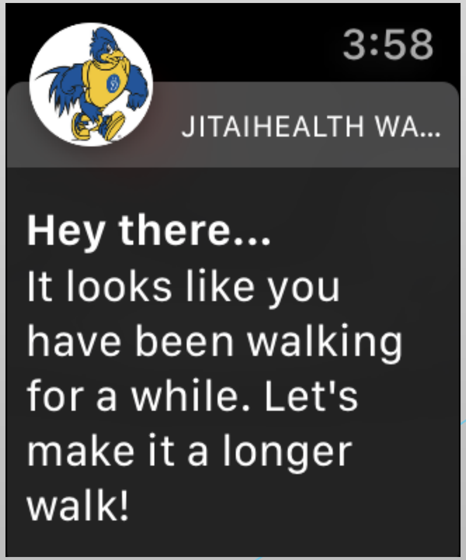
Aim: To build a remote-delivered and personally tailored JITAI system using Apple watches and Iphones to improve MVPA and reduce sedentary behavior.

The objective of the system is to learn whether/when to intervene to increase physical activity and reduce sedentary behavior

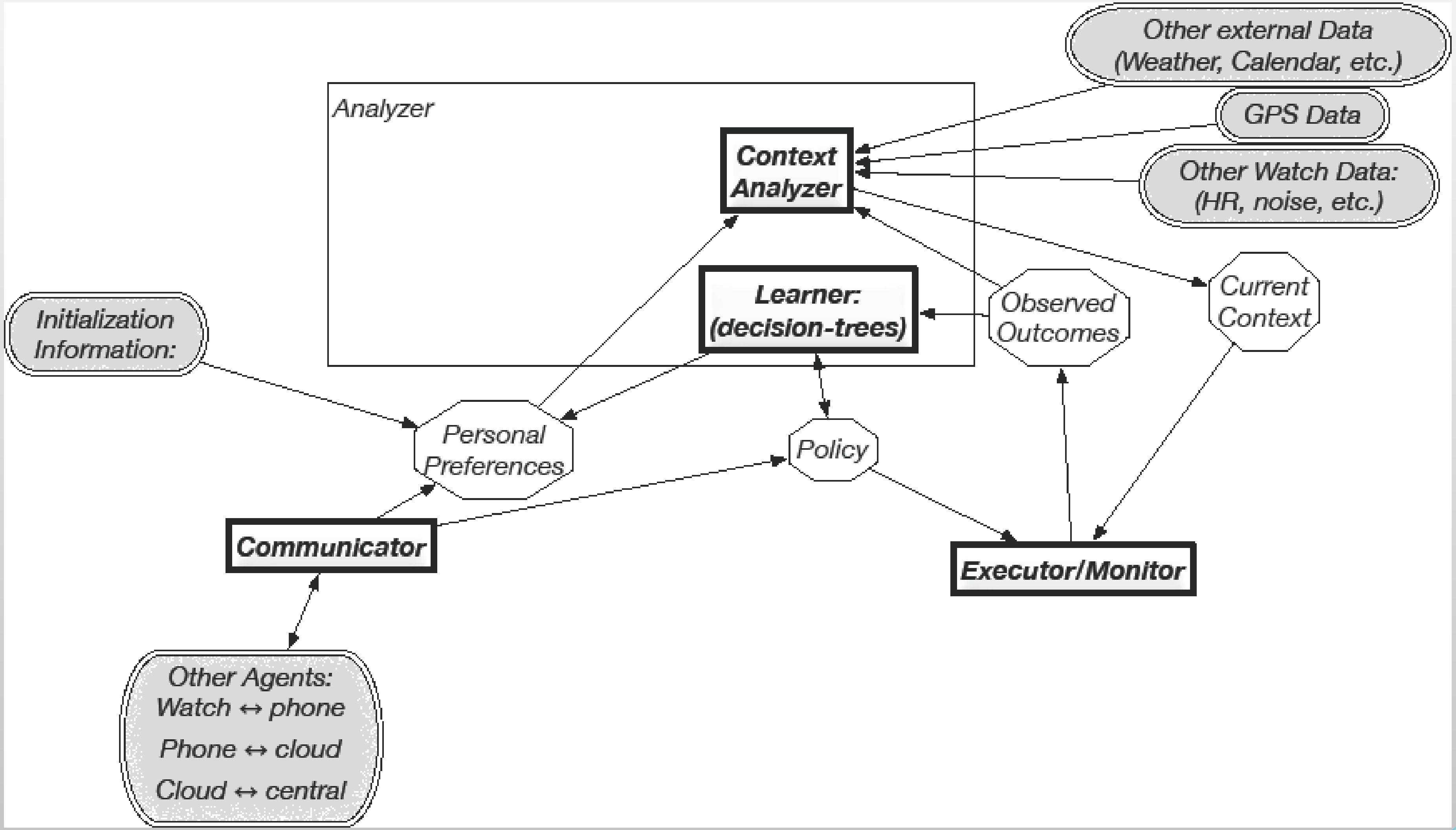
Experiment details:

- Context: Time, location, weather, events from calendar, heart rate, step activity
- 2-week observation period followed by a 2-week trial





- Data point features for physical activity: time, location, current activity, weather, threshold, response to previous interventions. Decision trees classify whether to intervene or not
- Sedentary data point: time, location, activity, response to previous interventions. Classification: yes or no
- Sedentary data and PA data is collected through out the day, learners run on server which are updated every night and sent to watches


Other external Data
(Weather, Calendar, etc.)
Analyzer
Context
Analyzer
GPS Data
Other Watch Data:
(HR, noise, etc.)
Learner:
(decision-trees)
Observed
Outcomes
Current
Context
Initialization
Information:
Personal
Preferences
Policy
Communicator
Executor/Monitor
Other Agents:
Watch ↔ phone
Phone ↔ cloud
Cloud ↔ central

Beta testing results:

- **Data loss**
- **Scalability**
- No data loss was detected whatsoever in our testing when scaled up to 250 agents

Conclusion

- Proposed a novel generic multi-agent architecture for automated health coaching
- Flexibility of the architecture was demonstrated by building two applications, a static system using Fitbits and a dynamic system using Apple watches
- Our future work focuses on building systems which can accommodate action and coping plans with preferences over activities, NLP systems for generating dialogues and extending this architecture to include other wearable sensors

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