Learning Trigger-Action Programs for the Smart Home

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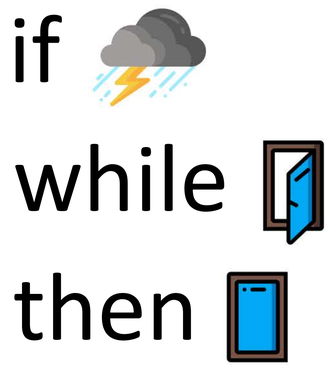
Background

Many smart devices allow users to control their behavior using **trigger-action programming (TAP)** or "if this then that" rules. However, recent work has shown that writing more expressive and complex rules within the TAP framework can lead to bugs and unexpected outcomes [1][2].



A TAP rule for closing the window if it begins to rain. TAP rules consist of a single trigger event, zero or more conditions, and an action.

Objective

We design a system that infers TAP rules from the history of a user's interactions with their devices — a **trace**. The user is no longer required to write TAP rules and there is less risk of human-introduced bugs. The learned TAP rules are also easily interpretable. They can be presented to the user for verification before they are implemented.

Given examples of actions performed by the user in certain states, the system must learn to label new states with the appropriate action. We use decision trees to perform the classification since decision trees lend themselves to straightforward conversion into TAP rules.

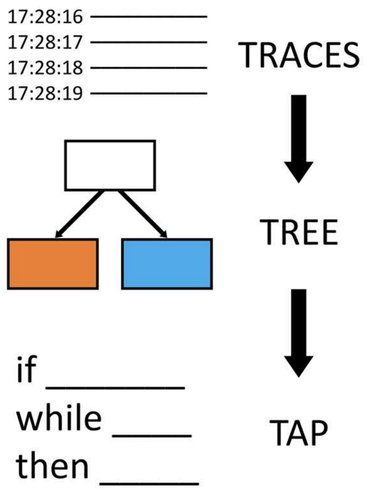
Learning a Decision Tree

Trace data was collected over the course of 1 week in the office of a university professor. The office included 8 separate lights, a motion sensor, and a temperature sensor.

We created a training example for each second in the data. The examples were vectors consisting of the following features:

- The status of the lights (off/on)
- The time since the lights were turned off or on (seconds)
- The time since motion was detected (seconds)
- The temperature

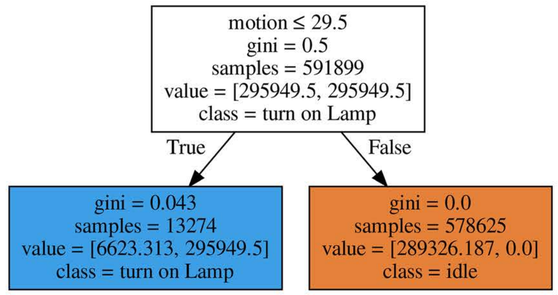
Each example was labeled with the action that occurred in that second or "idle" if no action occurred. Then, for each action we used the CART algorithm to generate a decision tree that classified the examples.



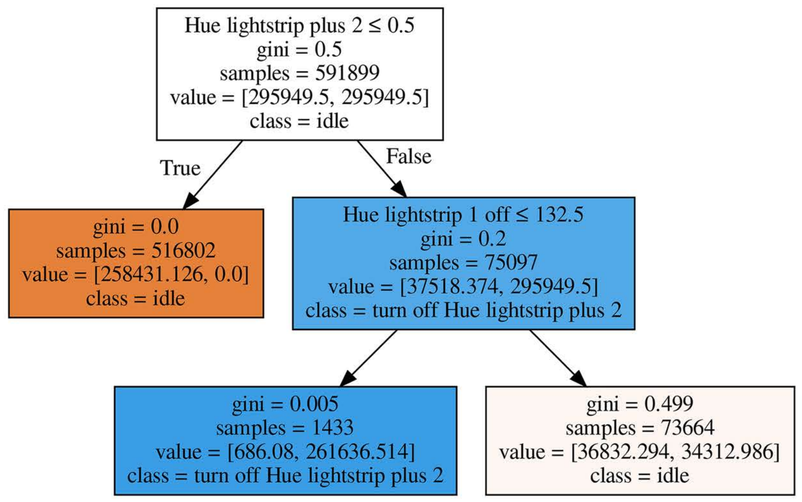
Converting to TAP Rules

Each path from the root to an "action" leaf represents a conjunction of conditions that must be true for an action to occur. We select one condition in the path to convert into the triggering event. Then, the rest of the conditions in the path become the conditions of the TAP rule. For a *k*-length path from root to leaf, we generate *k* unique TAP rules, one where each condition is selected as the trigger.

Results



IF motion occurred less than 29.5s ago **THEN** turn on the lamp



IF hue lightstrip 2 is on **WHILE** hue lightstrip 1 was turned off less than 132.5s ago **THEN** turn off hue lightstrip 2

IF hue lightstrip 1 was turned off less than 132.5s ago **WHILE** hue lightstrip 2 is on **THEN** turn off hue lightstrip 2

[1] J. Huang and M. Cakmak. Supporting mental model accuracy in trigger-action programming. *In Proc. UbiComp*, 2015.
[2] B. Ur, E. McManus, M. Pak Yong Ho, and M. L. Littman. Practical trigger-action programming in the smart home. In *Proc. CHI*, 2014.