dtControl 2.0
Explainable Strategy Representation via Decision Tree Learning
Steered by Experts

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Talk in one slide

https://breezecomputer.com/wp-content/uploads/2018/12/1.-Huele-GameCube-Controller-2-Pack.jpg
Talk in one slide
Talk in one slide

Why?

.dtControl 2.0

Small

Explainable

What?
Controller by example

\[ C : S \rightarrow A \]
Controller by example

\[ C : S \rightarrow A \]
Controller by example

C : S → A
Controller by example

C : S → A
Controller by example

$C : S \rightarrow A$

Diagram showing a network of nodes and connections with labels $H_1$ and $H_2$.
Controller by example

C : S → A
Controller by example

C : S → A

Memory efficient

Executable

Lowers deployment cost

Helps debugging & modeling

Explainable
How?
How?

dtControl 2.0
Inner workings
Inner workings

HSCC video: https://www.youtube.com/watch?v=K6d3pS6Ege0 (slide 23-31)
Inner workings

- **Axis-aligned**
  \[ T2 \leq 20.625 \]

- **Linear**
  \[ 0.5 \times T2 + 1.3 \times T5 \leq 20.625 \]

- **Algebraic**
  \[ T2^4 \times \log(T5) - \sqrt{T7} \leq 20.625 \]
Algebraic predicates

Safe controller

- Lookup Table: 295,695 rows
- BDD: 2,400 nodes
- dtControl 1.0: 374 nodes
Algebraic predicates

Domain knowledge
\[ d = \frac{1}{2} at^2 + ut + d_0 \]
\[ v = u + at \]
Algebraic predicates

\[ d = \frac{1}{2} at^2 + ut + d_0 \]
\[ v = u + at \]

Domain knowledge

\[ d - 2 + \left( \frac{-4 - v_e - 2t_f}{-2} \right)^2 + (-6 - v_e) \left( \frac{-6 - v_e - 2t_f}{-2} \right) \leq 5 \]
Algebraic predicates

**Domain knowledge**

\[ d = \frac{1}{2} at^2 + ut + d_0 \]

\[ v = u + at \]

Worst-case distance (accelerate) \( \leq 5 \)
Algebraic predicates

Domain knowledge
\[ d = \frac{1}{2} at^2 + ut + d_0 \]
\[ v = u + at \]
Algebraic predicates

Worst-case distance (accelerate) ≤ 5
Worst-case distance (neutral) ≤ 5

Domain knowledge
\[ d = \frac{1}{2} at^2 + ut + d_0 \]
\[ v = u + at \]
Distilling a Neural Network Into a Soft Decision Tree

Nicholas Frosst, Geoffrey Hinton

Google Brain Team

Abstract. Deep neural networks have proved to be a very effective way to perform classification tasks. They excel when the input data is high dimensional, the relationship between the input and the output is complicated, and the number of labeled training examples is large [Szegedy et al., 2015, Wu et al. 2016, Jozefowicz et al. 2016, Graves et al., 2013]. But it is hard to explain why a learned network makes a particular classification decision on a particular test case. This is due to their reliance on distributed hierarchical representations. If we could take the knowledge acquired by the neural net and express the same knowledge in a model that relies on hierarchical decisions instead...
Algebraic predicates

Worst-case distance (accelerate) ≤ 5

Worst-case distance (neutral) ≤ 5

Domain knowledge
\[ d = \frac{1}{2} at^2 + ut + d_0 \]
\[ v = u + at \]
Demo

- This is how the tree looks in our awesome new GUI
- We can scroll, collapse etc. to explore the tree
- This is how we made the tree:
  Choose controller file - Note we support Storm, PRISM, Scots, Uppaal and csv
  Choose preset (lots of automatic, we now want user-defined)
  Enter your cool predicates (first an axis-aligned, then the rest with a good mix of explanation and Ctrl+V)
  If this was scary: Documentation
- Add, play; while playing, explain benchmarking
- View -> Result we showed earlier.
- Ok, how did we get these fancy predicates? 1. Domain knowledge, understanding 2. Trial and error.
  Show interactive tree building.
- Much more to help us understand controller and DT, like running simulations and more ways to affect predicate construction or changing trees on the fly. -> Delegate to Docs, papers and QEST video
Determinization

...
Determinization

... x >= 6...

false true

{a,b} {b,c}

Permissive

... {b}...

Determinized
## Experimental results

| Case study       | States | BDD  | dtControl 1.0 | dtControl 2.0 |
|------------------|--------|------|---------------|---------------|
| cartpole         | 271    | 127  | 11            | 7             |
| 10rooms          | 26,244 | 128  | 7             | 7             |
| helicopter       | 280,539| 870  | 221           | 123           |
| cruise-latest    | 295,615| 1,448| 3             | 3             |
| dc1dc            | 593,089| 381  | 9             | 5             |
| truck_trailer    | 1,386,211| 18,186| 42,561        | 31,499        |
| traffic_30m      | 16,639,662| TO   | 127           | 97            |
Conclusion

dtControl 2.0

- Algebraic predicates
- GUI
- Better determinization

dtcontrol.model.in.tum.de
Conclusion

dtControl 2.0

+ Algebraic predicates
+ GUI
+ Better determinization

dtcontrol.model.in.tum.de

Small

Explainable

Thank you!
More information
Algebraic predicates

\[ d = \frac{1}{2} at^2 + vt + d_0 \]
\[ v = at \]

Domain knowledge