AI For Highway Maintenance

Takeaways

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- B.S. CS from RHIT, 2006
- PhD in AI from UNH, 2012
- 5 years in Defense Research
- 3 years in Static Analysis
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How did we get here?

@DrBass

How did we get here?

The Road Ahead

- The Problem Domain
- Using AI for Planning
- Some Initial Roadblocks
  - Understanding the domain
  - Problematic Models
  - Performance Hurdles
- Meeting the users where they are
  - Understanding needs
  - Adapting the solver

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gettyimages

Asphalt concrete layer (30.5)
Asphalt concrete layer (58.5)
Asphalt concrete layer (38.1)
Unbound (granular) base (144.8)
Unbound subbase (406.7)

INDOT
PASER
Year
10
9
8
7
6
5
4
3
0
5
10
15
20
25
30
35
40
45

RATING
10
RATING
7
RATING
4
RATING
1
Transportation
Information Center
University of Wisconsin–Madison

Some Terminology

- Segment - A section of road with a stop and end point
- Road Network - A collection of segments
- Agency - Some group charged with taking care of a road network
- PASER - the visual inspection scale for grading roads in Indiana
    - PAvement Surface Evaluation and Rating

Harker Simmentals
Little Haw Creek
W & W Auto Parts & Services
Hope
Jackson St
Community Center of Hope
Hope First Wesleyan Church
Mill St
High St
Hope Moravian Church
Price Motorsport Engineering
Action Filtration
Fourman Enterprises
Joe's Automotive Repair
Floline
Premier Ag
South St
650 N
Walters Engineering and Performance
Powertrain Diagnostics | Walte...
Hauser Jr./Sr. High School
Hauser Dr
E County Rd 600 N
Meadow Pl
Hitchcock Dr
Blind Bee Honey Farm
Majors True Value Hardware
First Financial Bank & ATM
E Lake Shore Dr N
Hawpatch Hawcreek Conservation Club
E 550 N
N County Rd 900 E
800 E

The Maintenance Process

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The Maintenance Process

Where’s Software?

Where’s Software?

Where’s Software?

Today's Talk

There’s a Problem Though

How Is It Done Today?

Roadway	From	To	Rating	2020 Treatment
1ST ST	Park Avenue	Cross Street	8	Mill and Overlay - 1.5"
1ST ST	Cross Street	Dead End	8	Mill and Overlay - 1.5"
2ND ST	Park Avenue	Cross Street	8	
2ND ST	Cross Street	Dead End	8	
A ST	North Main Street	Graham Road	6	
ACORN RD	Galaxy Drive	Fairlane Court	8	
ACORN RD	Fairlane Court	Cobra Drive	4	
ACORN RD	Cobra Drive	Torino Lane	5	
ACORN RD	Torino Lane	Taurus Lane	5	

Asphalt Full Depth Repairs
Cape Seal
Chip Seal
Chip Seal - Double
Chip Seal - Double and Fog
Chip Seal - Triple
Chip Seal and Fog
Chip Seal and Microsurfacing

Instructions | Road Asset Inventory | Surface Types | Rating System | Functional Classifications | Treatr ...

Ready Page: 1 of 19 Display Settings

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Let’s Do That

1ST ST
2ND ST
3RD ST
4TH ST

Let’s Do That

10M

1ST ST

2ND ST
3RD ST
4TH ST

Let’s Do That

1ST ST

2ND ST
3RD ST
4TH ST

Let’s Do That

1ST ST

2ND ST
3RD ST
4TH ST

Let’s Do That

1ST ST

2ND ST
3RD ST
4TH ST

Let’s Do That

1ST ST

2ND ST
3RD ST
4TH ST

Let’s Do That

1ST ST

2ND ST

3RD ST
4TH ST

Let’s Do That

1ST ST
2ND ST
3RD ST
10M
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NR
5M
… etc
10M
~
NR
10M
5M
… etc
~
NR
10M
0M
… etc
… etc

Let's Do ***Tree Search***

Let’s Do Tree Search

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Why Is This So Hard?

- Programmers Are Not Civil Engineers
- Our Input Data Wasn’t Pristine
- Tree Search at These Scales is Inherently Difficult

Building Tree Search with SMEs

Building Tree Search with SMEs

Our Plans Underperformed Expert Expectations

Real World Data and Official Model Don’t Align

These Curves Were Made Using Other AI Techniques

Product
Software
AI Technique 1
AI Technique 2
AI Technique 3

Zionsville
2018 Data

...

Adams County
2019 Data

...

Marion County
2022 Data

Surface Trajectory Calculator

Machine Learning

Surface Degradation Predictor

Zionsville
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...
Adams County
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Surface Trajectory Calculator
PASER
Year
Machine Learning
Surface Degradation Predictor
asphalt
concrete
INDOT
PASER
Year

10 9 8 7 6 5 4 3 2 1

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1

Why Is Tree Search Hard?

"Space is big. Really big. You just won't believe how vastly hugely mind-bogglingly big it is. I mean, you may think it's a long way down the road to the chemist, but that's just peanuts to space.”

Hitchhiker’s Guide to the Galaxy

So, Why Is Finding Good Goals Hard?

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Atoms in the Observable Universe = 10^82

Work Smarter, Not Harder

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Also, Work Faster

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~ 1,000,000 nodes a second

Use a Profiler

Function Name	Total CPU [unit, 9
Microsoft.FSharp.Collections.FSharpMap<T, double>.System.Collections.IStructuralEquatable.Equals(object, System.Collections.IEqualityComparer)	4103 (24.12%)
TreatmentGrounder+walk@94.Invoke(Microsoft.FSharp.Collections.FSharpList<RawTreatment>)	3593 (21.12%)
Microsoft.FSharp.Collections.FSharpList<T>.Cons(T, Microsoft.FSharp.Collections.FSharpList<T>)	823 (4.84%)
PlanModel+numChildren@105.Invoke(PlanningState)	7566 (44.48%)
TreatmentModel.degradeRawSegment(DegradationModel, RawRoadSegment)	520 (3.06%)

Hot Path

Function Name

console (PID: 25552)

Console.main(System.String[])

Program.runOneThing(Instance, string, string, string, SolverStrategy, Microsoft.FSharp.Core.FSharpOption<float64>, float64[], Microsoft.FSharp.Core.FSharpOp

LimitedDiscrepancySearch+startSearch@88-2[System.__Canon,System.__Canon].Invoke(Microsoft.FSharp.Core.Unit)

LimitedDiscrepancySearch+expandNode@65-1[System.__Canon,System.__Canon].Invoke(Microsoft.FSharp.Core.Unit)

Kernel : 98.7% (16795)
Other : 1.3% (216)

Also, Work Faster

Write Down Expensive Computations in Tables

Trick 2: Gotta Go Fast
Avoid Conditionals Where Possible

Trick 2: Gotta Go Fast

Trick 2: Gotta Go Fast

7.5

7500

Trick 2: Gotta Go Fast

7.500

7 500

Trick 2: Gotta Go Fast
Integer Math is Often Faster Than Floating Point

7.500

7 500

How Much Did Tuning Matter?

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How Were The Solutions Over All?

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How Do You Win Hearts and Minds?

The Maintenance Process
Is Iterative, Not Comparative

The Users Iterated in Two Major Ways

- Don’t do this part, and use the money on something else
- Do this, and find budget for it

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The Development Process Is Iterative Too!

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If I Knew Then What I Know Now

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