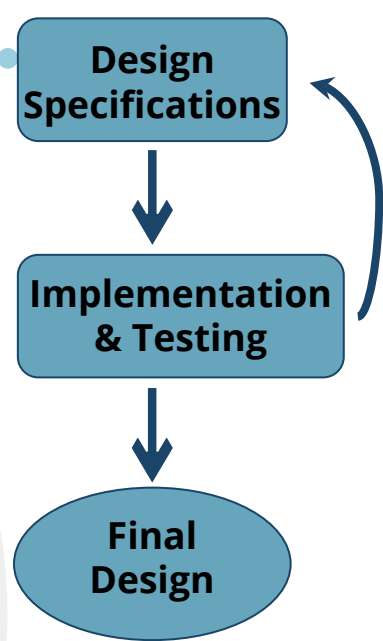


Inverse Design of Wave Energy Converter Using Artificial Intelligence

Christopher Snook

REU Mentor: Dr. Yufei Tang

Methods of Design



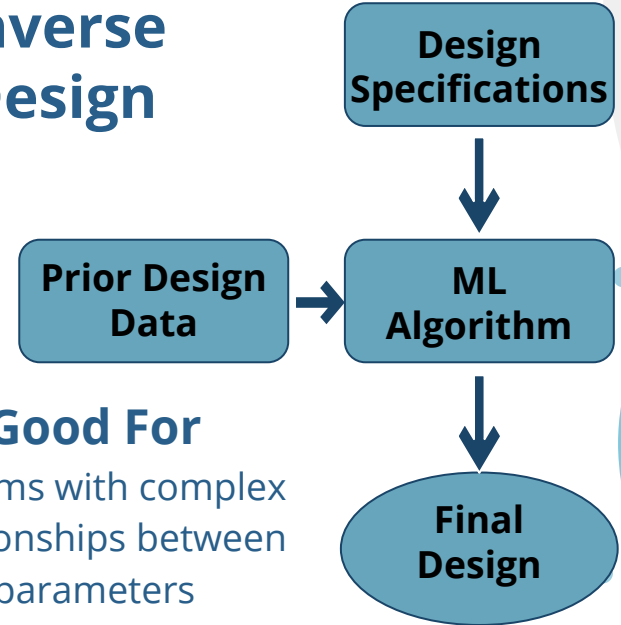
Traditional Design

Good For

Areas with few prior designs

Simple systems with describable relationships

Inverse Design

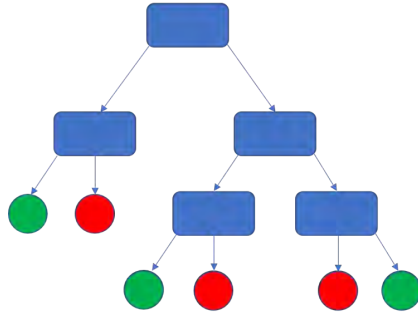


Good For

Systems with complex relationships between parameters

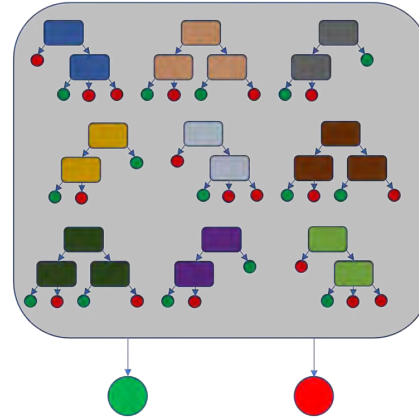
Efficient optimization

Machine Learning Algorithms



Decision Tree

- Path of decisions from input to output
- Good for inverse design



https://commons.wikimedia.org/wiki/File:Decision_Tree_vs._Random_Forest.png

Random Forest

- Combines multiple decision trees
- Generally more accurate than a decision tree

We need a decision tree to implement inverse design but want the accuracy of a random forest

Model Manipulation

Random Forest

High accuracy ML model

Decision Tree

Accurate and usable for inverse design



Initial Data Generation

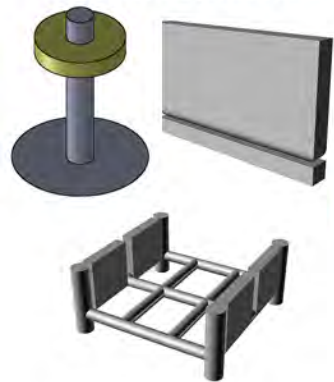
WEC-SIM

Software developed by
National Renewable Energy
Lab and Sandia National Lab

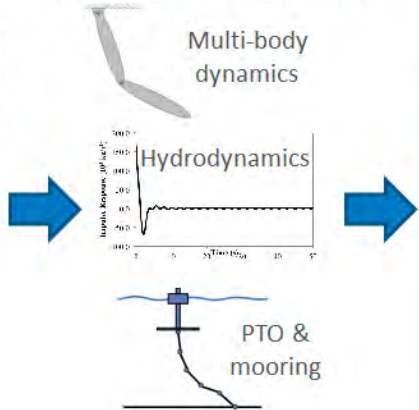
Data

- RM3 wave energy converter
- Design variables
 - Damping coefficient
 - Mass of float
 - Mass of base
- Power as output
- 10000 data points generated

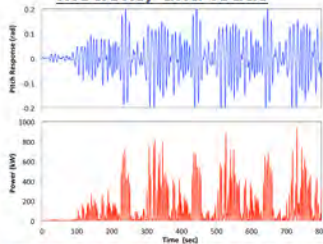
WEC device specification



Relevant numerical methods



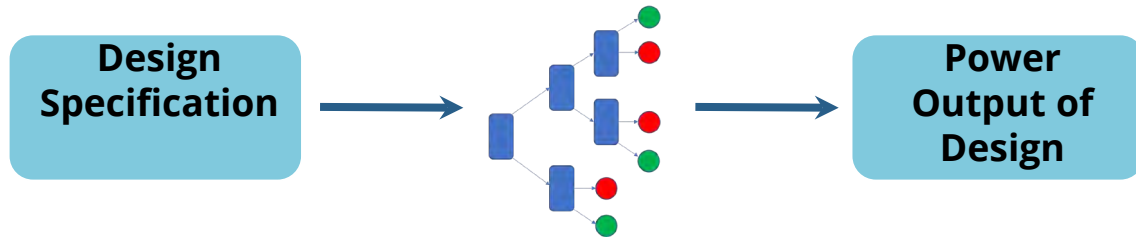
WEC performance, motions, and loads



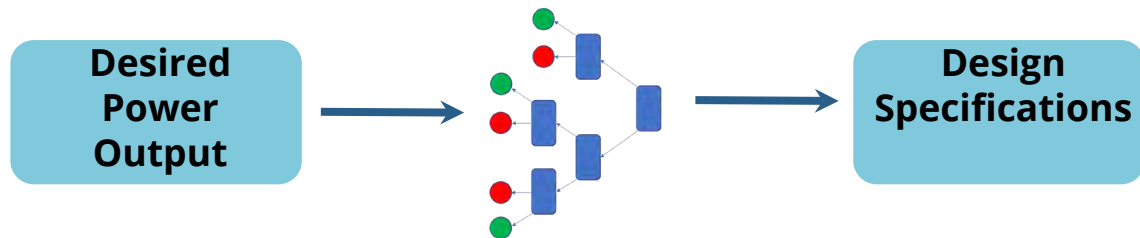
Time (s)	Power Matrix (kW) Cd_float=1.4; Cd_plate=4.25 (Based on CFD)									
	5.0	6.0	7.0	8.0	9.0	10.0	11.0	12.0	13.0	14.0
5.20	0.40	0.70	0.90	1.00	1.00	1.00	1.00	1.00	1.00	1.00
6.20	0.70	1.30	1.70	1.80	1.80	1.80	1.80	1.80	1.80	1.80
7.20	1.00	1.70	2.30	2.50	2.50	2.50	2.50	2.50	2.50	2.50
8.20	1.30	2.30	3.00	3.20	3.20	3.20	3.20	3.20	3.20	3.20
9.20	1.60	2.90	3.80	4.00	4.00	4.00	4.00	4.00	4.00	4.00
10.20	1.90	3.50	4.50	4.70	4.70	4.70	4.70	4.70	4.70	4.70
11.20	2.20	4.10	5.20	5.40	5.40	5.40	5.40	5.40	5.40	5.40
12.20	2.50	4.70	5.90	6.10	6.10	6.10	6.10	6.10	6.10	6.10
13.20	2.80	5.30	6.60	6.80	6.80	6.80	6.80	6.80	6.80	6.80
14.20	3.10	5.90	7.30	7.50	7.50	7.50	7.50	7.50	7.50	7.50
15.20	3.40	6.50	8.00	8.20	8.20	8.20	8.20	8.20	8.20	8.20
16.20	3.70	7.10	8.70	8.90	8.90	8.90	8.90	8.90	8.90	8.90
17.20	4.00	7.70	9.40	9.60	9.60	9.60	9.60	9.60	9.60	9.60
18.20	4.30	8.30	10.10	10.30	10.30	10.30	10.30	10.30	10.30	10.30
19.20	4.60	8.90	10.80	11.00	11.00	11.00	11.00	11.00	11.00	11.00
20.20	4.90	9.50	11.50	11.70	11.70	11.70	11.70	11.70	11.70	11.70
21.20	5.20	10.10	12.20	12.40	12.40	12.40	12.40	12.40	12.40	12.40
22.20	5.50	10.70	12.90	13.10	13.10	13.10	13.10	13.10	13.10	13.10
23.20	5.80	11.30	13.60	13.80	13.80	13.80	13.80	13.80	13.80	13.80
24.20	6.10	11.90	14.30	14.50	14.50	14.50	14.50	14.50	14.50	14.50
25.20	6.40	12.50	15.00	15.20	15.20	15.20	15.20	15.20	15.20	15.20
26.20	6.70	13.10	15.70	15.90	15.90	15.90	15.90	15.90	15.90	15.90
27.20	7.00	13.70	16.40	16.60	16.60	16.60	16.60	16.60	16.60	16.60
28.20	7.30	14.30	17.10	17.30	17.30	17.30	17.30	17.30	17.30	17.30
29.20	7.60	14.90	17.80	18.00	18.00	18.00	18.00	18.00	18.00	18.00
30.20	7.90	15.50	18.50	18.70	18.70	18.70	18.70	18.70	18.70	18.70
31.20	8.20	16.10	19.20	19.40	19.40	19.40	19.40	19.40	19.40	19.40
32.20	8.50	16.70	19.90	20.10	20.10	20.10	20.10	20.10	20.10	20.10
33.20	8.80	17.30	20.60	20.80	20.80	20.80	20.80	20.80	20.80	20.80
34.20	9.10	17.90	21.30	21.50	21.50	21.50	21.50	21.50	21.50	21.50
35.20	9.40	18.50	22.00	22.20	22.20	22.20	22.20	22.20	22.20	22.20
36.20	9.70	19.10	22.70	22.90	22.90	22.90	22.90	22.90	22.90	22.90
37.20	10.00	19.70	23.40	23.60	23.60	23.60	23.60	23.60	23.60	23.60
38.20	10.30	20.30	24.10	24.30	24.30	24.30	24.30	24.30	24.30	24.30
39.20	10.60	20.90	24.80	25.00	25.00	25.00	25.00	25.00	25.00	25.00
40.20	10.90	21.50	25.50	25.70	25.70	25.70	25.70	25.70	25.70	25.70
41.20	11.20	22.10	26.20	26.40	26.40	26.40	26.40	26.40	26.40	26.40
42.20	11.50	22.70	26.90	27.10	27.10	27.10	27.10	27.10	27.10	27.10
43.20	11.80	23.30	27.60	27.80	27.80	27.80	27.80	27.80	27.80	27.80
44.20	12.10	23.90	28.30	28.50	28.50	28.50	28.50	28.50	28.50	28.50
45.20	12.40	24.50	29.00	29.20	29.20	29.20	29.20	29.20	29.20	29.20
46.20	12.70	25.10	29.70	29.90	29.90	29.90	29.90	29.90	29.90	29.90
47.20	13.00	25.70	30.40	30.60	30.60	30.60	30.60	30.60	30.60	30.60
48.20	13.30	26.30	31.10	31.30	31.30	31.30	31.30	31.30	31.30	31.30
49.20	13.60	26.90	31.80	32.00	32.00	32.00	32.00	32.00	32.00	32.00
50.20	13.90	27.50	32.50	32.70	32.70	32.70	32.70	32.70	32.70	32.70
51.20	14.20	28.10	33.20	33.40	33.40	33.40	33.40	33.40	33.40	33.40
52.20	14.50	28.70	33.90	34.10	34.10	34.10	34.10	34.10	34.10	34.10
53.20	14.80	29.30	34.60	34.80	34.80	34.80	34.80	34.80	34.80	34.80
54.20	15.10	29.90	35.30	35.50	35.50	35.50	35.50	35.50	35.50	35.50
55.20	15.40	30.50	36.00	36.20	36.20	36.20	36.20	36.20	36.20	36.20
56.20	15.70	31.10	36.70	36.90	36.90	36.90	36.90	36.90	36.90	36.90
57.20	16.00	31.70	37.40	37.60	37.60	37.60	37.60	37.60	37.60	37.60
58.20	16.30	32.30	38.10	38.30	38.30	38.30	38.30	38.30	38.30	38.30
59.20	16.60	32.90	38.80	39.00	39.00	39.00	39.00	39.00	39.00	39.00
60.20	16.90	33.50	39.50	39.70	39.70	39.70	39.70	39.70	39.70	39.70
61.20	17.20	34.10	40.20	40.40	40.40	40.40	40.40	40.40	40.40	40.40
62.20	17.50	34.70	40.90	41.10	41.10	41.10	41.10	41.10	41.10	41.10
63.20	17.80	35.30	41.60	41.80	41.80	41.80	41.80	41.80	41.80	41.80
64.20	18.10	35.90	42.30	42.50	42.50	42.50	42.50	42.50	42.50	42.50
65.20	18.40	36.50	43.00	43.20	43.20	43.20	43.20	43.20	43.20	43.20
66.20	18.70	37.10	43.70	43.90	43.90	43.90	43.90	43.90	43.90	43.90
67.20	19.00	37.70	44.40	44.60	44.60	44.60	44.60	44.60	44.60	44.60
68.20	19.30	38.30	45.10	45.30	45.30	45.30	45.30	45.30	45.30	45.30
69.20	19.60	38.90	45.80	46.00	46.00	46.00	46.00	46.00	46.00	46.00
70.20	19.90	39.50	46.50	46.70	46.70	46.70	46.70	46.70	46.70	46.70
71.20	20.20	40.10	47.20	47.40	47.40	47.40	47.40	47.40	47.40	47.40
72.20	20.50	40.70	47.90	48.10	48.10	48.10	48.10	48.10	48.10	48.10
73.20	20.80	41.30	48.60	48.80	48.80	48.80	48.80	48.80	48.80	48.80
74.20	21.10	41.90	49.30	49.50	49.50	49.50	49.50	49.50	49.50	49.50
75.20	21.40	42.50	50.00	50.20	50.20	50.20	50.20	50.20	50.20	50.20

What the Model Does

Forward Design & Training



Inverse Design



Results

Accuracy

R² of DT trained on original data: 0.9999827285388839

R² of RF trained on original data: 0.9999785551484541

Efficiency

Initial data generation: ~7s/sample

Model training and analysis: 3s total

Conclusions

Was this practical?

- Inverse design worked
- Actual results were limited due to data

What next?

- More Data
- More complex systems
- Optimize ML algorithm