Estimating Jumping Heights of a Small Legged Robot based on Terrain Properties, Control Efforts, and Tactile Sensor Measurements

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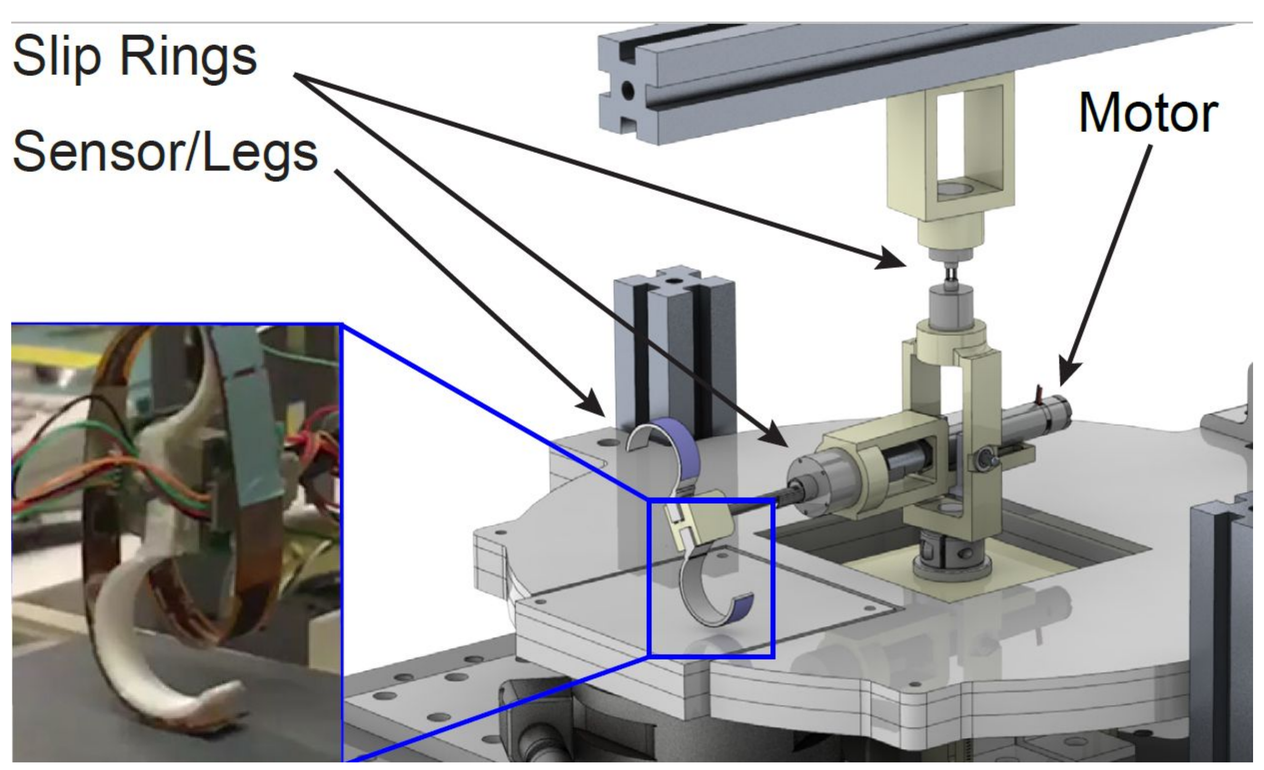
Abstract

Jumping of legged mobile robots has been a highly motivated research area. When a running robot encounters obstacles comparable to its body height, jumping is one of the most effective ways to overcome them. Also, if the robots can jump over gaps or crevices, the mobility of robots in a wild field would be enhanced drastically.The jumping performance is dependent on the terrain properties as well as its jumping mechanism. We focus on low and high friction surfaces that result in higher and lower jumping heights, respectively. In this project, we classify terrain type, high versus low friction surfaces, and estimate jumping heights. Training data include stride frequencies, sensor data, and jumping height.For both terrain classification and jumping height estimation, SMO regression with PUK kernel has the best performance with mean test error of 0.09 and 1.5 mm, respectively.Greedy stepwise algorithm is used for feature selection, and using the five most influential features, comparable accuracies are obtained. From the results, several interesting attributes of the jumping robot are found.

Experimental Setup

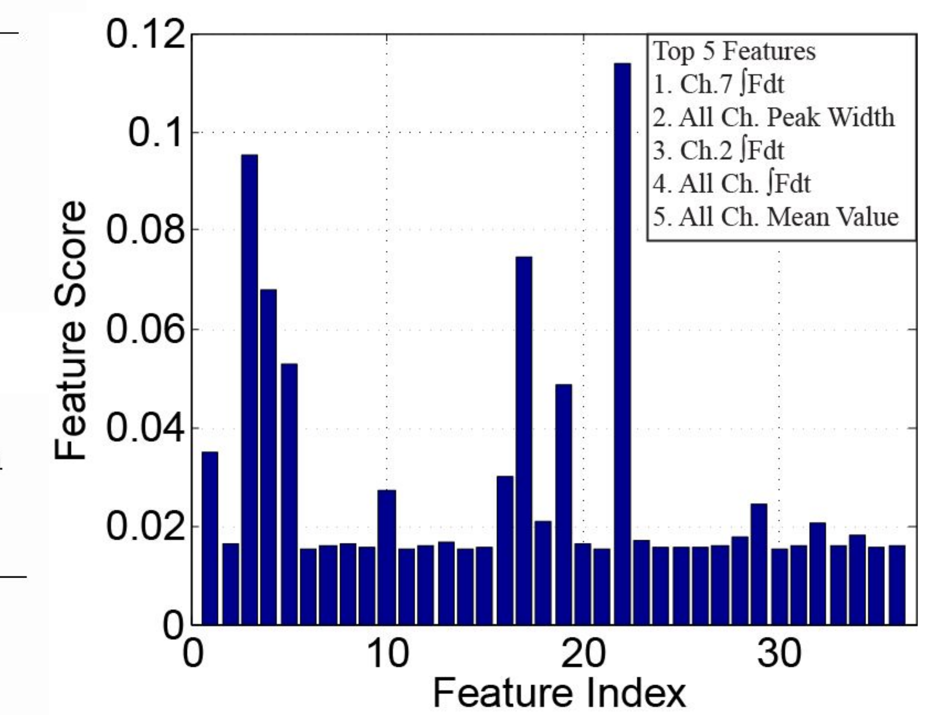


Machine Learning Feature Set

Index	Feature Name
1	Robot stride frequency
2	Sensor force (net) peak amplitude
3	Sensor force (net) duration
4	Sensor force (net) area under curve
5	Sensor force (net) average amplitude
6-15	Individual taxel (1-10) force peak amplitude
16-25	Individual taxel (1-10) area under curve
26-35	Individual taxel (1-10) average amplitude
36	Sensor force peak to average
37	Height

Terrain Classification

Classifiers	Kappa Statistics	Mean Absolute Error	Root Mean Squared Error	Computation Time [s]
SVM-SMO PUK Kernel	0.98	0.09	0.095	35.9
Gaussian	0.94	0.035	0.168	3.6
Logistic Regression	0.92	0.068	0.181	2.63
Multilayer Perceptron	0.97	0.020	0.118	166.7



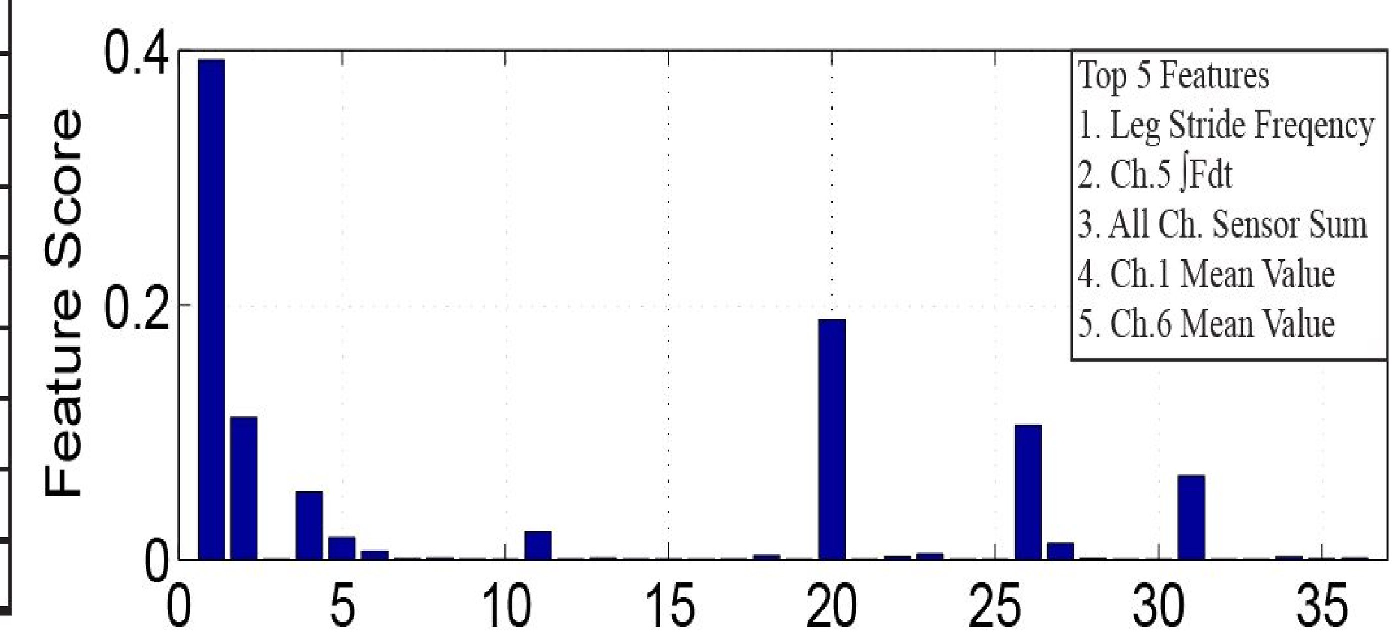
Confusion Matrix: Trained with All Features vs. Top 5 Features

	Low Friction Surface (Teflon)	High Friction Surface (Rubber)
Low Friction Surface	99.04	0.96
High Friction Surface	0.83	99.17

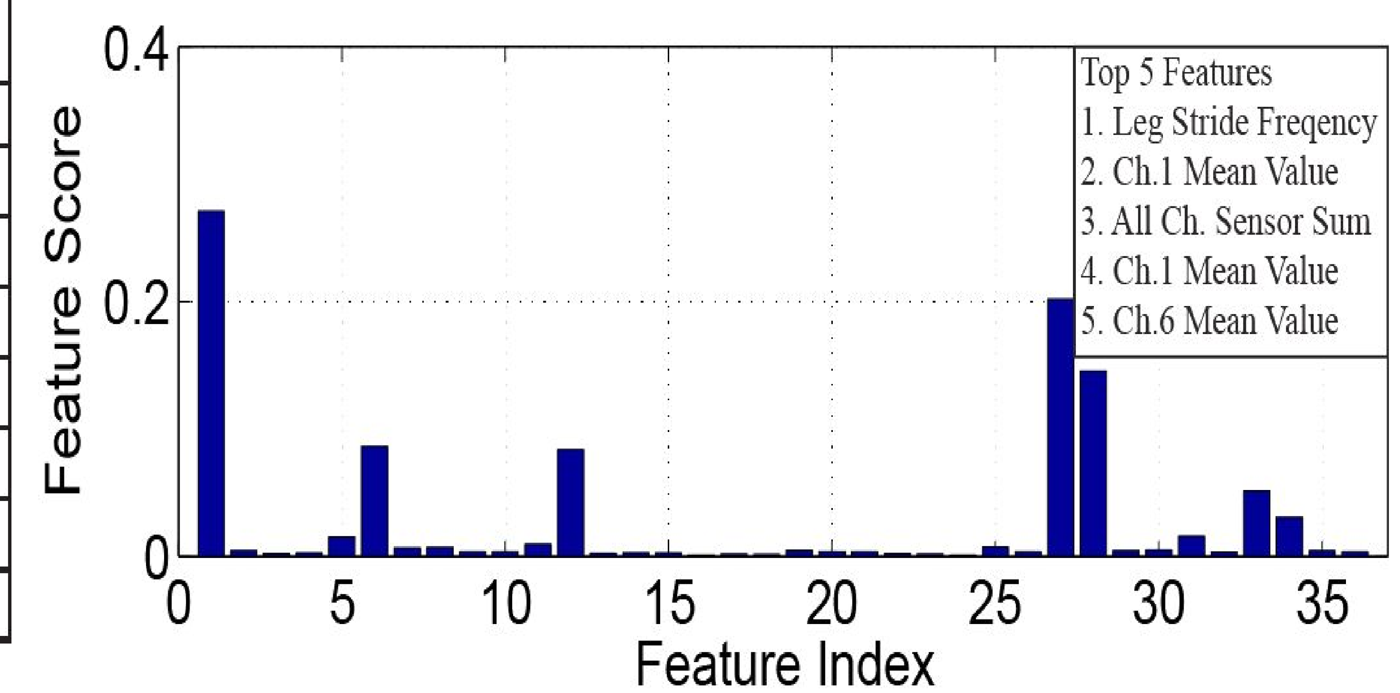
	Low Friction Surface (Teflon)	High Friction Surface (Rubber)
Low Friction Surface	91.73	8.27
High Friction Surface	12.70	87.30

Jumping Height Regression

High Friction Surface	Train Error Mean (mm)		Test Error Mean (mm)		Computing Time (sec)	
	All	Top 5	All	Top 5	All	Top 5
Linear Reg.	1.01	1.90	1.04	1.91	4.5	4.0
SMO (RBF)	0.93	1.83	0.95	1.84	25.2	20.6
SMO (PUK)	0.04	0.34	0.48	0.48	101.3	84.4
SMO (Poly)	0.40	1.31	0.54	1.34	988.1	29.1
Gaussian (RBF)	0.49	1.27	0.56	1.28	107.5	110.9
Gaussian (PUK)	0.00	0.17	0.49	0.68	101.1	95.7
Gaussian (Poly)	0.33	1.96	0.58	1.97	104.7	95.0



Low Friction Surface	Train Error Mean (mm)		Test Error Mean (mm)		Computing Time (sec)	
	All	Top 5	All	Top 5	All	Top 5
Linear Reg.	2.53	3.33	2.63	3.36	4.3	4.0
SMO (RBF)	2.65	3.53	2.72	3.56	23.9	21.8
SMO (PUK)	0.24	1.34	1.33	1.50	147.1	35.8
SMO (Poly)	1.22	3.32	1.51	3.38	403.5	19.9
Gaussian (RBF)	1.58	2.66	1.76	2.69	107.8	104.1
Gaussian (PUK)	0.01	1.04	1.42	1.74	100.6	94.8
Gaussian (Poly)	1.04	5.18	1.97	5.30	102.0	95.4



Conclusion

- Terrain Classification
  - SMO regression with PUK Kernel performs terrain classification with mean test error of 0.09.
  - Greedy stepwise algorithm is used for feature selection.
  - When trained with only the top 5 features, the model has classification accuracy comparable to that when trained with all features. (99%, 90%)
- Jumping Height Regression
  - SMO regression with PUK kernel estimate jumping height with test error mean of 1.33 mm.
  - Same greedy stepwise algorithm is used for feature selection and the results show that test error means when trained with all feature vs. top 5 feature are comparable.
- Future Work
  - Attributes of the jumping robot acquired from this machine learning will be used to build a robot that can control its jumping height.