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Using SVM and Deep Learning to facilitate orthognathic surgery planning

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INTRODUCTION

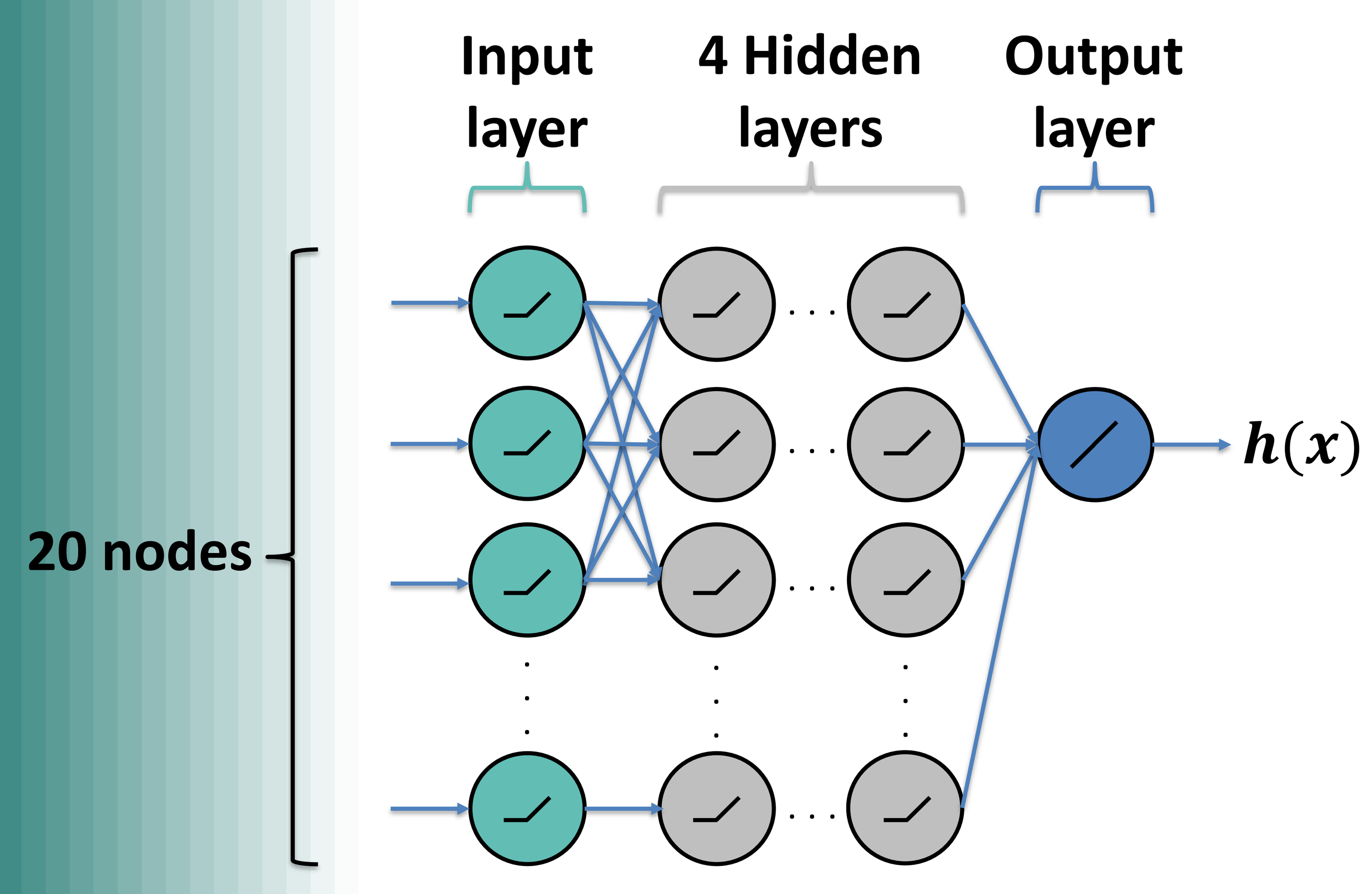
Clinical studies provide a significant amount of data to surgeons. For orthognathic patients, the final outcome is important for functional and aesthetical reasons. Therefore, it is important to make a proper pre-operative surgical planning. The experience of the surgeon plays an important role. For inexperienced surgeons, the extensive amount of data may result in suboptimal decision-making. This research proposes the use of machine learning to aid surgeons in this process.

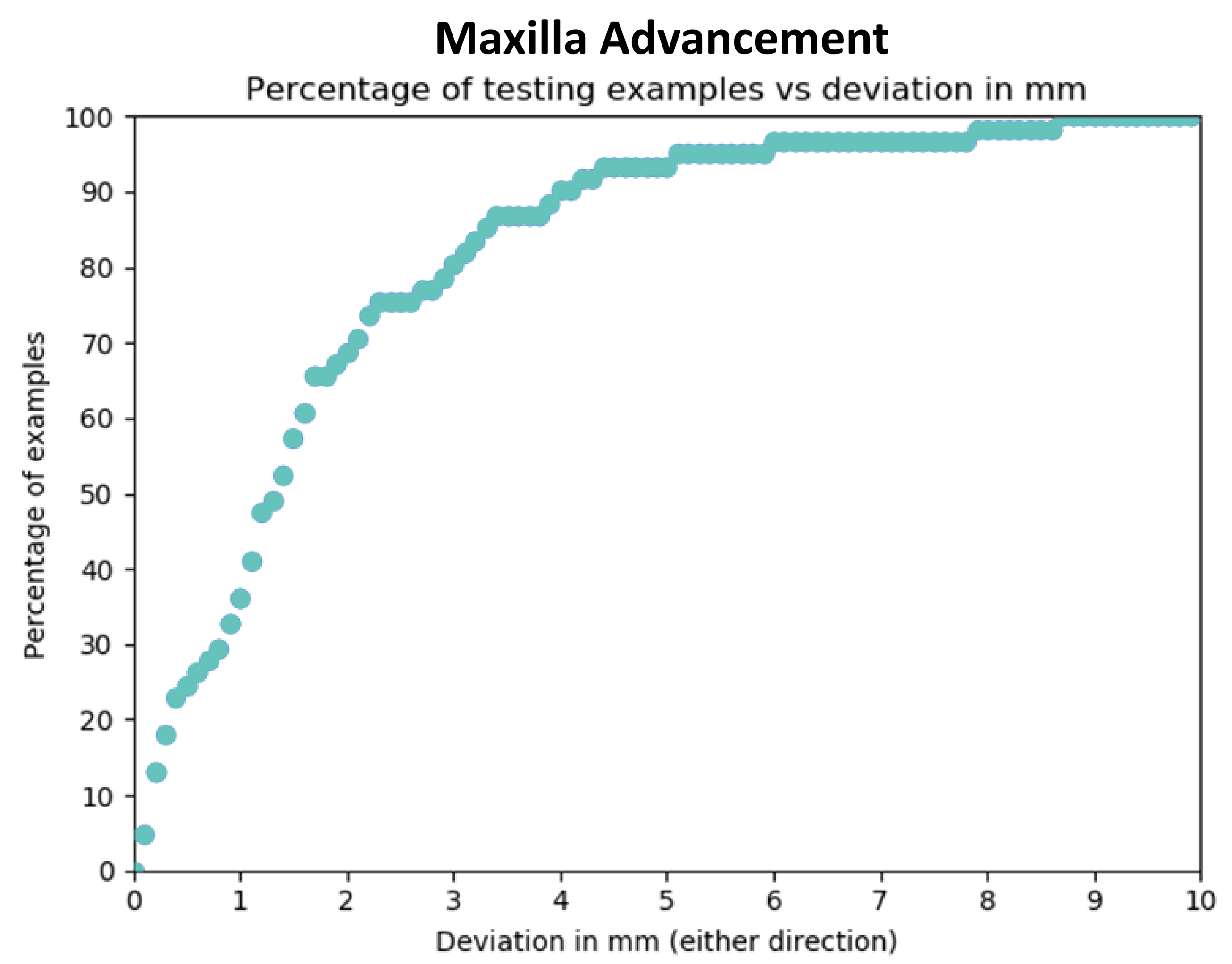
METHOD

Multiple algorithms were tested in MATLAB and implemented in Python. The final algorithms consist of 2 SVM implementations for discrete values (surgery type) and 6 neural networks with linear output activation for analog values (surgical movement). The input features consist of the 20 best correlated features from the clinical studies. The dataset included 320 patients, of which 64% were used for training, 20% for testing and 16% for cross-validation. These 320 patients include patients undergoing every type of surgery. The Python script was later integrated to be used in conjunction with a web interface.

RESULTS

Neural Networks





	Maxilla Advancement (margin)	Maxilla Anterior	Maxilla Posterior	Maxilla Midline Rotation	Chin Advancement	Chin Intrusion/Extrusion
# neurons	6	14	4	1	9	1
R^2_{train}	0.580	0.745	0.168	-0.006	0.524	-0.050
R^2_{test}	0.438	0.499	0.100	-0.066	0.045	-0.050
MSE	4.009	4.381	2.897	0.658	4.987	0.065
MAE	1.615	1.501	1.197	0.241	1.408	0.068

Due to the low amount of training examples and the complexity of the dataset, the models do not accurately reflect the training or testing set. It should be noted though that for maxilla advancement, around 70% of the testing examples are located within an acceptable range of deviation (±2mm).

Support Vector Machines

Maxilla

Class	Precision	Recall	F1-score	RCCE	# Testing examples
Nothing	0.78	1.00	0.88		28
One piece	0.96	0.80	0.87		30
More pieces	1.00	0.50	0.67		6
average / total	0.88	0.86	0.85	0.86	64

Mandible

Class	Precision	Recall	F1-score	RCCE	# Testing examples
Nothing	-	-	-		6
Setback	0.68	0.93	0.79		14
Advancement	0.89	0.91	0.90		44
average / total	0.76	0.83	0.79	0.83	64

	Maxilla one/more pieces	Mandible advancement/setback
Kernel	Linear	RBF
C	1.000	2.184
γ	-	1.207×10^{-3}

The classification algorithms show promising results for both F1-score and Ratio of Correctly Classified Examples (RCCE). Results could be improved by increasing the amount of training examples for each category.

CONCLUSION

Multiple algorithms were constructed to predict pre-surgical decisions. Surgery types are predicted quite accurately, but surgical movement predictions seem to inaccurately reflect the dataset. This is most likely solved by increasing the amount of training examples.

FURTHER RESEARCH

Due to the low regression values and relatively high tolerance, it might be interesting to transform the regression problem into a classification problem. This is done by predefining certain ranges as classes (eg. 0mm = class 0, $]0mm, 1mm]$ = class 1 etc.).

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