

Chapter 11: The Art of Machine Learning

MATH2319

1 Different Perspectives on Prediction Models

2 Choosing a Machine Learning Approach

- Matching Machine Learning Approaches to Projects
- Matching Machine Learning Approaches to Data

3 Your Next Steps

- Predictive data analytics projects use machine learning to build models that capture the relationships in large datasets between descriptive features and a target feature.
- Machine Learning \approx inductive learning
 - ① a model learned by induction is not guaranteed to be correct.
 - ② learning cannot occur unless the learning process is biased in some way.

- *En masse* all of the questions that must be answered to successfully complete a predictive data analytics project can seem overwhelming.
- This is why we recommend using the **CRISP-DM (Cross-Industry Standard Process for Data Mining)** process to manage a project through its lifecycle.

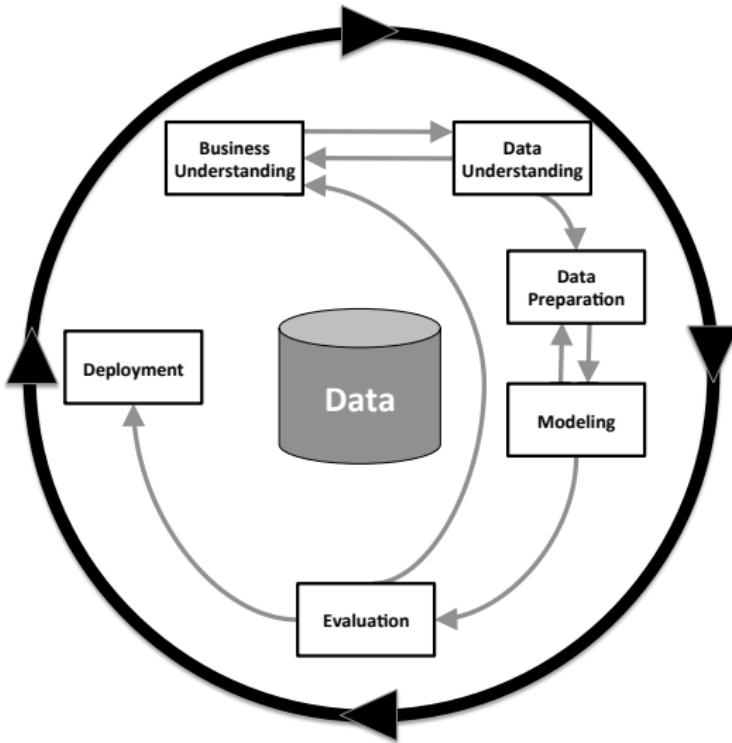


Figure: A diagram of the **CRISP-DM** process which shows the six key phases and indicates the important relationships between them.

CRISP-DM	Open Questions	Chapter
Business Understanding	<i>What is the organizational problem being addressed? In what ways could a prediction model address the organizational problem? Do we have situational fluency? What is the capacity of the organization to utilize the output of a prediction model? What data is available?</i>	Chapter 2
Data Understanding	<i>What is the prediction subject? What are the domain concepts? What is the target feature? What descriptive features will be used?</i>	Chapter 2

CRISP-DM	Open Questions	Chapter
Data Preparation	<i>Are there data quality issues? How will we handle missing values? How will we normalize our features? What features will we include?</i>	Chapter 3
Modelling	<i>What types of models will we use? How will we set the parameters of the machine learning algorithms? Have underfitting or overfitting occurred?</i>	Chapters 4, 5, 6 and 7

CRISP-DM	Open Questions	Chapter
Evaluation	<i>What evaluation process will we follow? What performance measures will we use? Is the model fit for purpose?</i>	Chapter 8
Deployment	<i>How will we continue to evaluate the model after deployment? How will the model be integrated into the organization?</i>	Section 8.4.6 and Chapters 9 and 10

Different Perspectives on Prediction Models

$$H(t, \mathcal{D}) = - \sum_{l \in levels(t)} (P(t = l) \times \log_2(P(t = l))) \quad (1)$$

$$dist(\mathbf{q}, \mathbf{d}) = \sqrt{\sum_{i=1}^m (\mathbf{q}[i] - \mathbf{d}[i])^2} \quad (2)$$

$$P(t = l | \mathbf{q}) = \frac{P(\mathbf{q} | t = l) P(t = l)}{P(\mathbf{q})} \quad (3)$$

$$L_2(\mathbb{M}_{\mathbf{w}}, \mathcal{D}) = \frac{1}{2} \sum_{i=1}^n (t_i - \mathbb{M}_{\mathbf{w}}(\mathbf{d}_i))^2 \quad (4)$$

Parametric versus Non-parametric

- Generally describes whether the size of the **domain representation** used to define a model is solely determined by the number of features in the domain or if it is affected by the number of instances in the dataset.
- Parametric model: the size of the domain representation is independent of the number of instances in the dataset (e.g., naive Bayes', regression models)
- Non-parametric model: the number of parameters used by the model increases as the number of instances increases (e.g., decision trees)

Generative versus Discriminative

- A model is generative if it can be used to generate data that will have the same characteristics as the dataset from which the model was produced.
- A discriminative model learns the boundary between classes rather than the characteristics of the distributions of the different classes.
- Generative and discriminative models attempt to learn different things!

A generative model works by:

- ① learning $P(\mathbf{d}|t_i)$ (class conditional densities) and $P(t_i)$;
- ② then using Bayes' theorem to compute $P(t_i|\mathbf{d})$;
- ③ applying a decision rule over the class posteriors to return a target level.

A discriminative model works by:

- ① learning the class posterior probability $P(t_i|\mathbf{d})$ directly from the data
- ② and then applying a decision rule over the class posteriors to return a target level.

Table: A taxonomy of models based on the parametric versus non-parametric and generative versus discriminative distinctions.

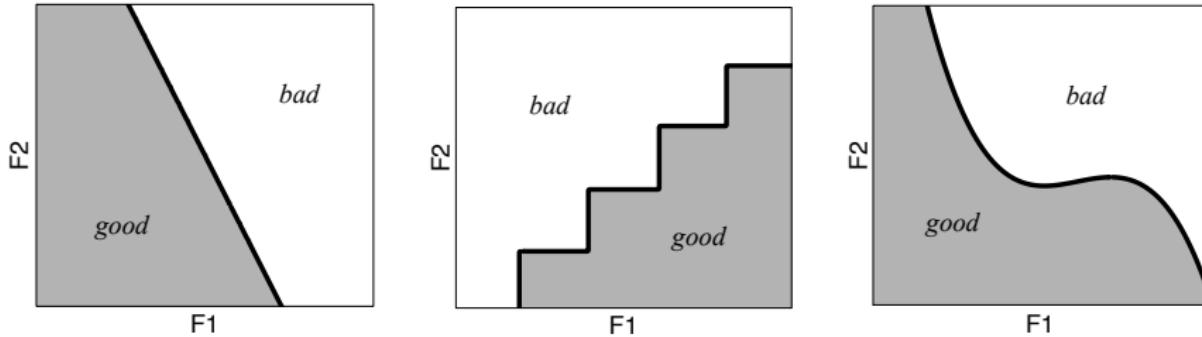
Model	Parametric/ Non-Parametric	Generative/ Discriminative
k nearest neighbor	Non-Parametric	Generative
Decision Trees	Non-Parametric	Discriminative
Bagging/Boosting	Parametric ¹	Discriminative
Naive Bayes	Parametric	Generative
Bayesian Network	Parametric	Generative
Linear Regression	Parametric	Discriminative
Logistic Regression	Parametric	Discriminative
SVM	Non-Parametric	Discriminative

¹While the individual models in an ensemble could be non-parametric (for example when decision trees are used) the ensemble model itself is considered parametric.

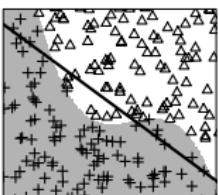
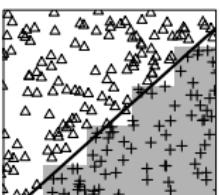
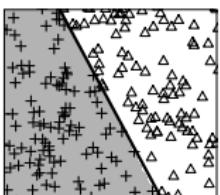
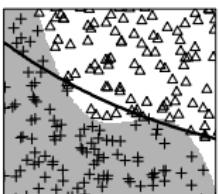
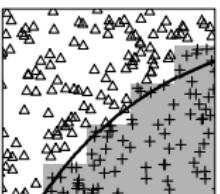
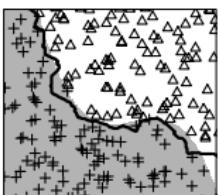
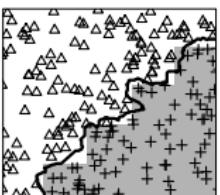
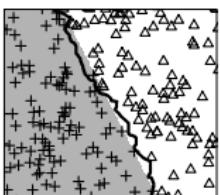
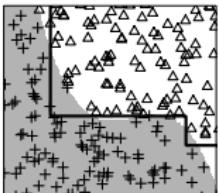
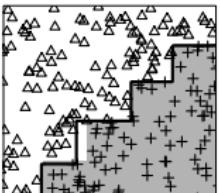
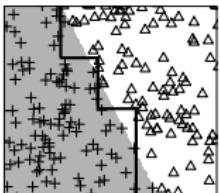
Choosing a Machine Learning Approach

- There is not one best approach that always outperforms the others; **no free lunch theorem**.
- We can see the assumptions encoded in each algorithm reflected in the distinctive characteristics of the decision boundaries that they learn for categorical prediction tasks.

Data Sets



- On the next slide, you will see the decision boundaries given by 4 different classifiers:
 - Decision Tree
 - 3- Nearest Neighbour
 - Naive Bayes
 - Logistic Regression
- Can you guess which one is which? (HINT: Same order as above)



- Typically choose a number of different approaches and to run experiments to evaluate which is the best the particular project.
- There are two questions to consider in the selection of a set of initial approaches:
 - ① Does a machine learning approach match the requirements of the project?
 - ② Is the approach suitable for the type of prediction we want to make and the types of descriptive features we are using?

Project Requirements

- Accuracy
- Prediction speed
- Capacity for retraining
- Interpretability

Data Considerations

- lots of descriptive features (curse of dimensionality) → feature selection
- continuous target → error based models
- categorical target → information and probability models
- continuous descriptive features → (+cat. target) similarity based models / (+cont. target) error based models
- categorical descriptive features → information and probability models

Your Next Steps

- The easy part of a predictive data analytics project is building the models.
- What makes predictive data analytics difficult, but also fascinating, is figuring out how to answer all the questions that surround the modelling phase of a project.
- Intuition, experience, and experimentation!

Key tasks for an analyst

- become situationally fluent so that we can converse with experts in the application domain;
- explore the data to understand it correctly;
- spend time cleaning the data;
- think hard about the best ways to represent features;
- spend time designing the evaluation process correctly.

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