Machine Learning
Blatt 2

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Nr.1

Code

```
1  import org.kramerlab.teaching.ml.datasets.*;

3  import java.io.File;
4  import java.util.*;

6  //TODO exceptions
7  /**
8   * Created by David Klopp, Christian Stricker, Markus Vieth on 21.04.2016.
9   */
10 public class DecisionTree {

12     /**
13      * Inner Node class
14      */
15     private class Node {
16         Node parent;
17         Attribute attribute = null;
18         List<Edge> edges = new ArrayList<>();
19         List<Integer> indices;
20         List<Attribute> notVisited;
21         boolean isSingleNode = false;
22         Value value;

24         /**
25          * Constructor
26          * @param indices
27          */
28         public Node(List<Integer> indices, Node parent) {
29             this.indices = indices;
30             this.parent = parent;
31             if (parent == null) {
32                 notVisited = dataset.getAttributes();
33             } else {
34                 notVisited = parent.notVisited;
35             }
36         }

38         public void addEdge(Edge edge) {
39             this.edges.add(edge);
40         }

42         public Value getValue() {
43             if (isSingleNode)
44                 return value;
45             return null;
46         }

48         public void print(String prefix) {
49             if (isSingleNode) {
50                 System.out.println(prefix + " " + value);
51             } else {
52                 System.out.println(prefix + " " + attribute);
53             }
54             for(Edge edge : edges) {
55                 edge.end.print(prefix+'-');
56             }
```

```
57          }
58
59          public void setAttribute(Attribute attribute) {
60              this.attribute = attribute;
61              this.notVisited.remove(attribute);
62          }
63      }
64
65
66      /**
67       * Edge class
68       */
69      private class Edge {
70          Value value = null;
71          Node start;
72          Node end;
73
74          /**
75           * Constructor
76           * @param value
77           */
78          public Edge(Value value, Node start) {
79              this.value = value;
80              this.start = start;
81              this.start.addEdge(this);
82          }
83      }
84
85
86
87
88      private Node root = null;
89
90      private Instance[] data;
91      private Dataset dataset;
92      private Attribute classAttribute;
93
94      /**
95       * default constructor
96       */
97      public DecisionTree() {
98
99      }
100
101
102
103
104     //--------------------------------------------------------------------------
105     //-------------------------Train tree---------------------------------------
106     //--------------------------------------------------------------------------
107
108     /**
109      *
110      * @param node
111      * @return
112      */
113     public Attribute selectAttribute(Node node) {
114         Attribute select = null;
115         double maxGain = Double.NEGATIVE_INFINITY;
116         for (Attribute attribute : node.notVisited) {
117             if (attribute.equals(classAttribute)) {
```

```
118                 continue;
119             }
120             double gain = this.informationGain(attribute, node.indices);
121             if (gain > maxGain) {
122                 select = attribute;
123                 maxGain = gain;
124             }
125         }
126         return select;
127     }


130     /**
131      *
132      */
133     public void train(List<Integer> trainset) {
134         // create root Node
135         this.root = new Node(trainset, null);
136         this.train_recursive(this.root);
137     }

139     /**
140      * Internal method
141      * @param n
142      */
143     public void train_recursive(Node n) {
144         // todo remove attributes to prevet duplicates

146         // exit function
147         if (this.isSingleNode(n)) {
148             return;
149         }
150         //select attribute with biggest informationGain
151         n.setAttribute(this.selectAttribute(n));

153         // create edges for each value of the attribute
154         NominalAttribute attr = (NominalAttribute)n.attribute;
155         for (int i = 0; i < attr.getNumberOfValues(); i++) {
156             Value v = attr.getValue(i);
157             Edge edge = new Edge(v, n);
158             edge.end = new Node(new ArrayList<>(), n);
159         }



163         for (Integer idx : n.indices) {
164             Instance i = this.data[idx];
165             Value v = i.getValue(n.attribute);



169             // add index to right edge
170             for (Edge edge : n.edges) {
171                 if (edge.value.equals(v)) {
172                     edge.end.indices.add(idx);
173                     break;
174                 }
175             }

177         }
```

```
179         // create tree
180         for (Edge e : n.edges) {
181             this.train_recursive(e.end);
182         }
183     }

185     /**
186      *
187      * @param node
188      * @return
189      */
190     private boolean isSingleNode(Node node) {

192         if (node.indices.size() == 0 || node.notVisited.size() == 0 || (node
193                 .notVisited.size() == 1 && node.notVisited.contains(classAttribute))) {
194             node.value = mostCommonValue(node.parent, this.classAttribute);
195             node.isSingleNode = true;
196             return true;
197         }

199         Value value = data[node.indices.get(0)].getValue(classAttribute);

201         for (int i = 1; i < node.indices.size(); i++) {
202             Instance instance = data[node.indices.get(i)];
203             if (! instance.getValue(classAttribute).equals(value)) {
204                 return false;
205             }
206         }

208         node.isSingleNode = true;
209         node.value = value;
210         return true;
211     }


214     //-------------------------------------------------------------------------
215     //-------------------------classify tree-----------------------------------
216     //-------------------------------------------------------------------------


219     public double classify(List<Integer> data) {
220         int correctlyClassified = 0;
221         // repeat for each instance
222         for (Integer i : data) {
223             Instance instance = this.data[i];

225             // iterate over tre
226             Node currentNode = this.root;
227             while (!currentNode.isSingleNode) {
228                 Attribute attr = currentNode.attribute;
229                 Value value = instance.getValue(attr);

231                 // find right edge
232                 for (Edge edge : currentNode.edges) {
233                     if (edge.value.equals(value)) {
234                         currentNode = edge.end;
235                         break;
236                     }
237                 }
238             }
```

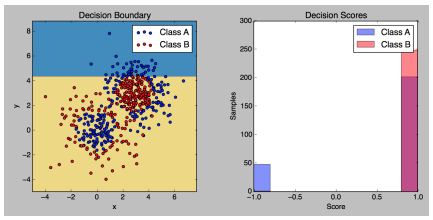
```
240             // check if class attr is correct
241             if ( currentNode.getValue().equals(instance.getValue(classAttribute)) ) {
242                 correctlyClassified ++;
243             }

245         }

247         return (double)correctlyClassified/(double)data.size();
248     }




253     //-------------------------------------------------------------------------
254     //-------------------------Constructor-------------------------------------
255     //-------------------------------------------------------------------------

257     private Value mostCommonValue(Node node, Attribute attribute) {
258         Map<Value, Integer> numValues = new HashMap<Value, Integer>();
259         Value max = null;
260         int maxInt = -1;

262         for (Integer i : node.indices) {
263             Instance instance = data[i];
264             Value value = instance.getValue(attribute);
265             Integer integer = 1;
266             if(numValues.containsKey(value)) {
267                 integer = numValues.get(value);
268                 integer++;
269                 numValues.replace(value, integer);
270             } else {
271                 numValues.put(value, integer);
272             }

274             if (integer > maxInt) {
275                 max = value;
276             }
277         }

279         return max;
280     }

282     /**
283      * loads arff
284      * @param path path to arff
285      */
286     public DecisionTree(String path) {
287         try {
288             this.loadArff(path);
289         } catch (Exception e) {
290             e.printStackTrace();
291         }
292     }

294     /**
295      * loads arff
296      * @param file arff file
297      */
298     public DecisionTree(File file) {
299         try {
300             this.loadArff(file);
```

```
301         } catch (Exception e) {
302             e.printStackTrace();
303         }
304     }

306     /**
307      * loads arff
308      * @param path path to arff
309      * @throws Exception see kramerlabs dataset
310      */
311     public void loadArff(String path) throws Exception {
312         File file = new File(path);
313         this.loadArff(file);
314     }

316     /**
317      * loads arff
318      * @param file arff file
319      * @throws Exception see kramerlabs dataset
320      */
321     public void loadArff(File file) throws Exception {
322         this.dataset = new Dataset();
323         dataset.load(file);
324         this.data = new Instance[dataset.getNumberOfInstances()];

326         for (int i = 0; i < data.length; i++) {
327             this.data[i] = dataset.getInstance(i);
328         }
329         this.classAttribute = this.dataset.getAttributes().get(this.dataset
330                 .getClassIndex());
331     }


334     // Implement a method informationGain that takes two arguments: attribute A
335     // and a list of indices i 1 , i 2 , i m .
336     /**
337      * calculates information gain for given attribute and instances
338      * @param attribute given attribute
339      * @param indices given indices of instances
340      * @return information gain
341      */
342     public double informationGain(Attribute attribute, List<Integer> indices) {
343         Attribute classAttr = classAttribute;

345         //TODO throw Exception
346         // Check if nominal
347         if (!attribute.isNominal()) {
348             System.err.println(attribute.getName() + "is not nominal");
349             return Double.NaN;
350         } else if (!classAttr.isNominal()) {
351             System.err.println(classAttr.getName() + "is not nominal");
352             return Double.NaN;
353         }

355         NominalAttribute attr = (NominalAttribute) attribute;
356         // Init gain
357         double gain = calculateEntropy((NominalAttribute)classAttr,
358                 indices);
359         // sum over all values in attribute
360         for (int v = 0; v < attr.getNumberOfValues(); v++) {
361             List<Integer> subIndices = new ArrayList<>();
```

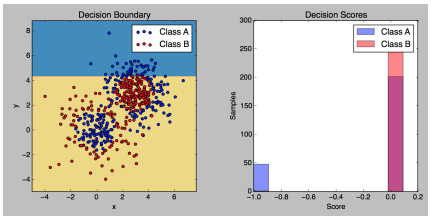
```
362             // Alternative we could copy data in a list and remove already
363             // picked instances to improve runtime
364             // creates subset with indices of instances with value v
365             for (int i : indices) {
366                 Instance instance = data[i];
367                 NominalValue value = (NominalValue)instance.getValue(attr);
368                 if (attr.getValue(v).equals(value)) {
369                     subIndices.add(i);
370                 }
371             }

373             // calculates entropy
374             double entropy = 0.0;
375             if (subIndices.size() != 0) {
376                 entropy = calculateEntropy((NominalAttribute)classAttr,
377                         subIndices);
378             }

380             // see formula
381             gain -= entropy * ((double)subIndices.size())
382                     /((double)indices.size());
383         }

385         return gain;
386     }


389     /**
390      * calculates entropy
391      * @param classAttr given class attribute
392      * @param indices indices of instances
393      * @return entropy
394      */
395     private double calculateEntropy(NominalAttribute classAttr, List<Integer>
396             indices
397     ) {
398         int[] values = new int[classAttr.getNumberOfValues()];
399         // calculates number of instances with value v in class attribute
400         for (int v = 0; v < classAttr.getNumberOfValues(); v++) {
401             values[v] = 0;
402             for(int i : indices) {
403                 Instance instance = data[i];
404                 NominalValue value = (NominalValue)instance.getValue(classAttr);
405                 NominalValue classValue = classAttr.getValue(v);
406                 if (classValue.equals(value)) {
407                     values[v]++;
408                 }
409             }
410         }
411         return calculateEntropy(values);
412     }

414     /**
415      * calculates entropy
416      * @param values given values
417      * @return entropy
418      */
419     private double calculateEntropy(int[] values) {
420         double sum = 0;
421         for (int i : values) {
422             sum += i;
```

```
423         }
424         double entropy = 0.0;
425         for (int value : values) {
426             double p = value/sum;
427             entropy -= p * log2(p);
428         }
429
430         return entropy;
431     }
432
433
434     /**
435      * calculates log to base 2
436      * @param a given parameter
437      * @return log2(a) or 0 if a == 0
438      */
439     private double log2(double a) {
440         if ( Double.compare(0.0, Math.abs(a)) == 0 )
441             return 0;
442         return Math.log(a) / Math.log(2);
443     }
444
445
446
447     //-------------------------------------------------------------------------
448     //-------------------------Train and Testset-------------------------------
449     //-------------------------------------------------------------------------
450
451
452     /**
453      * @return 2/3 trainset
454      */
455     public List<Integer> getTrainset() {
456         // get List with all indices
457         List<Integer> indices = new ArrayList<>();
458         for (int i = 0; i < this.data.length; i++) {
459             indices.add(i);
460         }
461
462         // get random indices
463         int size = indices.size() * 2/3;
464         while (indices.size() ≥size) {
465             Random random = new Random();
466             Integer randomIdx = random.nextInt(indices.size());
467             indices.remove(randomIdx);
468         }
469
470
471         return indices;
472     }
473
474
475     public List<Integer> getInverseSet(List<Integer> originalSet) {
476         List<Integer> inverseSet = new ArrayList<>();
477         for (int i=0; i<this.data.length; i++) {
478             if (!originalSet.contains(i))
479                 inverseSet.add(i);
480         }
481         return inverseSet;
482     }
```

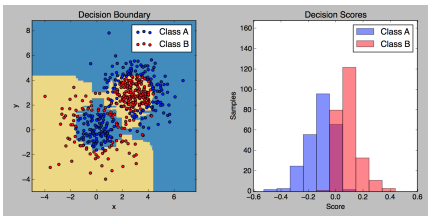
```
488     //-------------------------------------------------------------------------
489     //-------------------------test--------------------------------------------
490     //-------------------------------------------------------------------------



494     /**
495      * prints some test data
496      */
497     private void testPrint() {
498         List<Integer> indices = new ArrayList<>();
499         for (int i = 0; i < data.length; i++) {
500             indices.add(i);
501         }

503         /*for (Attribute attr : this.dataset.getAttributes()) {
504             System.out.print("Attribute " + attr.getName());
505             System.out.print(" has an InformationGain of " + informationGain
506                     (attr, indices));
507             System.out.println();
508         }*/

510         List<Integer> trainset = this.getTrainset();
511         this.train(trainset);
512         System.out.println(this.classify(this.getInverseSet(trainset)));
513     }

515     private void printTree() {
516         root.print("");
517     }

519     /**
520      * a test
521      * @param args none
522      */
523     public static void main(String[] args) {
524         DecisionTree dt = new DecisionTree("res/car.arff");
525         dt.testPrint();
526         dt.printTree();
527     }
528 }
```



(a) Abbildung 1: 1 Lerner



(b) Abbildung 2: 2 Lerner



(c) Abbildung 3: 500 Lerner

Plots bei verschieden vielen Lernern

Nr.2

Anmerkung

Aufgabe

AdaBoost nutzt mehrere weak learner (in diesem Beispiel Bäume der Tiefe 1), um zusammen einen strong learner zu bilden. In Abbildung 1 ist zu sehen, dass die Decision Borders bei einem learner aus einer geraden Linie besteht, welche die Instanzen in 2 Gruppen aufteilt. Im Histogramm ist zu sehen, dass dies zwar dazu führt, dass mehr als die Hälfte der Instanzen richtig klassifiziert werden, aber auch, dass die Fehlerquote sehr hoch ist. Bei 2 Lernern, wie in Abbildung 2 können mehr Instanzen richtig klassifiziert werden. Mit hunderten, wie in Abbildung 3, werden die Decision Borders komplexer und die Klassifizierung noch genauer. Im Histogramm wird deutlich, dass die „Sicherheit“ (Score) der Aussagen mit zunehmender Anzahl an Lernern, abnimmt.

Nr.3

0.632 Bootstrap meint die Bootstrap-Evaluierung mit einem Testset der Größe n, wobei n die Größe des genutzten Datensatzes ist. Für das Bootstrapverfahren werden zufällig gleichverteilt Instanzen aus dem Datensatz dem Trainingssatz hinzugefügt, bis dieser voll ist. Dabei wird in jeder Iteration der komplette Datensatz betrachtet, inklusive der bereits gewählten Instanzen. Die nicht gewählten Instanzen bilden den Testsatz. Die Wahrscheinlichkeit, dass eine Instanz in einer Iteration nicht gewählt wird beträgt

$$1 - \frac{1}{n}$$

Die prozentuale Größe des Testsatzes beträgt somit

$$(1 - \frac{1}{n})^m$$

wobei n die Größe des Datensatzes und m die Größe des Trainingssatzes ist. Für $n = m$ gilt:

$$1 - (1 - \frac{1}{n})^n \approx 1 - \frac{1}{e} \approx 0,632$$

Für einen Testsatz der Größe $2n$ folgt somit:

$$1 - (1 - \frac{1}{n})^2 n = 1 - \left((1 - \frac{1}{n})^n\right)^2 \approx 1 - \frac{1}{e^2} \approx 0,865$$