In [1]:
```
import pandas as pd
import numpy as np
from tqdm import tqdm
import sklearn
from sklearn.model_selection import train_test_split
```

In [2]:
```
df = pd.read_csv("tic-tac-toe.data.txt", sep=',', names = list(range(9))
+ ['target'])
df.head()
```

Out[2]:

	0	1	2	3	4	5	6	7	8	target
0	x	x	x	x	o	o	x	o	o	positive
1	x	x	x	x	o	o	o	x	o	positive
2	x	x	x	x	o	o	o	o	x	positive
3	x	x	x	x	o	o	o	b	b	positive
4	x	x	x	x	o	o	b	o	b	positive

In [3]:
```
import copy

def dummy_encode_categorical_columns(data):
    result_data = copy.deepcopy(data)
    for column in data.columns.values:
        result_data = pd.concat([result_data, pd.get_dummies(result_data
[column], prefix = column, prefix_sep = '_')], axis = 1)
        del result_data[column]

    return result_data
```

In [4]:
```
df = dummy_encode_categorical_columns(df)
df['target'] = df['target_positive']
df = df.drop(['target_positive', 'target_negative'], axis=1)
df.head()
```

Out[4]:

	0_b	0_o	0_x	1_b	1_o	1_x	2_b	2_o	2_x	3_b	...	6_b	6_o	6_x	7_b	7_o	7_x	8_b	8_o	8_
0	0	0	1	0	0	1	0	0	1	0	...	0	0	1	0	1	0	0	1	0
1	0	0	1	0	0	1	0	0	1	0	...	0	1	0	0	0	1	0	1	0
2	0	0	1	0	0	1	0	0	1	0	...	0	1	0	0	1	0	0	0	1
3	0	0	1	0	0	1	0	0	1	0	...	0	1	0	1	0	0	1	0	0
4	0	0	1	0	0	1	0	0	1	0	...	1	0	0	0	1	0	1	0	0

5 rows × 28 columns

In [23]:
```
X, y = df.drop(['target'], axis=1), df['target']
X_train, X_test, y_train, y_test = train_test_split(X, y, test_size=0.2)
```

In [24]:
```
positive_context = np.array(X_train[y_train == 1], dtype=int)
negative_context = np.array(X_train[y_train == 0], dtype=int)
```

In [25]:
```
def average_closure(x, context):
    closure_total = 0

    for x_train in context:
        intersection = (x == x_train)
        closure_total += np.sum(np.all(x[intersection] == context[:, int
ersection], axis=1))

    average_closure = closure_total / context.shape[0]

    return average_closure
```

In [26]:
```
def average_intersection(x, context):
    return np.mean([np.sum(x == x_train) for x_train in context])
```

In [27]:
```
def predict(x, params):
    positive_score = average_closure(x, positive_context)
    negative_score = average_closure(x, negative_context)

    if positive_score > params['coeff'] * negative_score:
        return 1
    else:
        return 0
```

In [28]:
```
predictions = [predict(np.array(x[1]), {'coeff': 1}) for x in X_test.ite
rrows()]
```

In [29]:
```
def get_scores(y_true, predictions):
    accuracy = sklearn.metrics.accuracy_score(y_true, predictions)
    precision = sklearn.metrics.precision_score(y_true, predictions)
    recall = sklearn.metrics.recall_score(y_true, predictions)
    f1 = sklearn.metrics.f1_score(y_true, predictions)

    return {
        'accuracy': accuracy,
        'precision': precision,
        'recall': recall,
        'F1': f1
    }
```

In [30]:
```
get_scores(y_test, predictions)
```

Out[30]:
```
{'accuracy': 0.6041666666666666,
 'precision': 0.6041666666666666,
 'recall': 1.0,
 'F1': 0.7532467532467533}
```

Cross val

In [31]:
```
from sklearn.model_selection import cross_val_score, KFold, StratifiedKF
old, ShuffleSplit
```

Зададим класс, действующий по алгоритму выше и оценим его качество с помощью кросс-валидации датасета на K фолдов.

In [43]:
```
class LazyFcaPredictor:
    def __init__(self, params):
        self.params = params


    def fit(self, X_train, y_train):
        self.positive_context = np.array(X_train[y_train == 1])
        self.negative_context = np.array(X_train[y_train == 0])


    def predict(self, X_test):
        return [self.__predict_impl(X_test[i]) for i in range(X_test.sha
pe[0])]


    def __predict_impl(self, x):
        positive_score = self.__average_closure(x, self.positive_context
)
        negative_score = self.__average_closure(x, self.negative_context
)

        if positive_score > self.params['coeff'] * negative_score:
            return 1
        else:
            return 0


    def __average_closure(self, x, X_train):
        closure_total = 0

        for x_train in X_train:
            intersection = (x == x_train)
            closure_total += np.sum(np.all(x[intersection] == X_train[:,
intersection], axis=1))

        average_closure = closure_total / X_train.shape[0]

        return average_closure
```

In [44]:
```
clf = LazyFcaPredictor({'coeff': 1})
```

In [45]:
```
X = np.array(df.drop(['target'], axis=1))
y = np.array(df['target'])
```

In [46]:
```
kfold = ShuffleSplit(n_splits=4)
```

In [47]:
```
def get_avg_scores(threshold):
    f1 = []
    acc = []
    prec = []
    rec = []

    for train_ix, test_ix in kfold.split(X, y):
        X_train, X_test = X[train_ix], X[test_ix]
        y_train, y_test = y[train_ix], y[test_ix]

        #print(X_train.shape)
        #print(y_train.shape)
        clf = LazyFcaPredictor({'coeff': threshold})
        clf.fit(X_train, y_train)
        predictions = clf.predict(X_test)
        scores = get_scores(y_test, predictions)

        f1.append(scores['F1'])
        acc.append(scores['accuracy'])
        prec.append(scores['precision'])
        rec.append(scores['recall'])

    return np.mean(f1), np.mean(acc), np.mean(prec), np.mean(rec)
```

In [48]:
```
threshold_grid = np.arange(0.2, 3, 0.2)

accs = []
precs = []
recs = []
f1s = []

for threshold in tqdm(threshold_grid):
    f1, acc, prec, rec = get_avg_scores(threshold)

    f1s.append(f1)
    accs.append(acc)
    precs.append(prec)
    recs.append(rec)
```

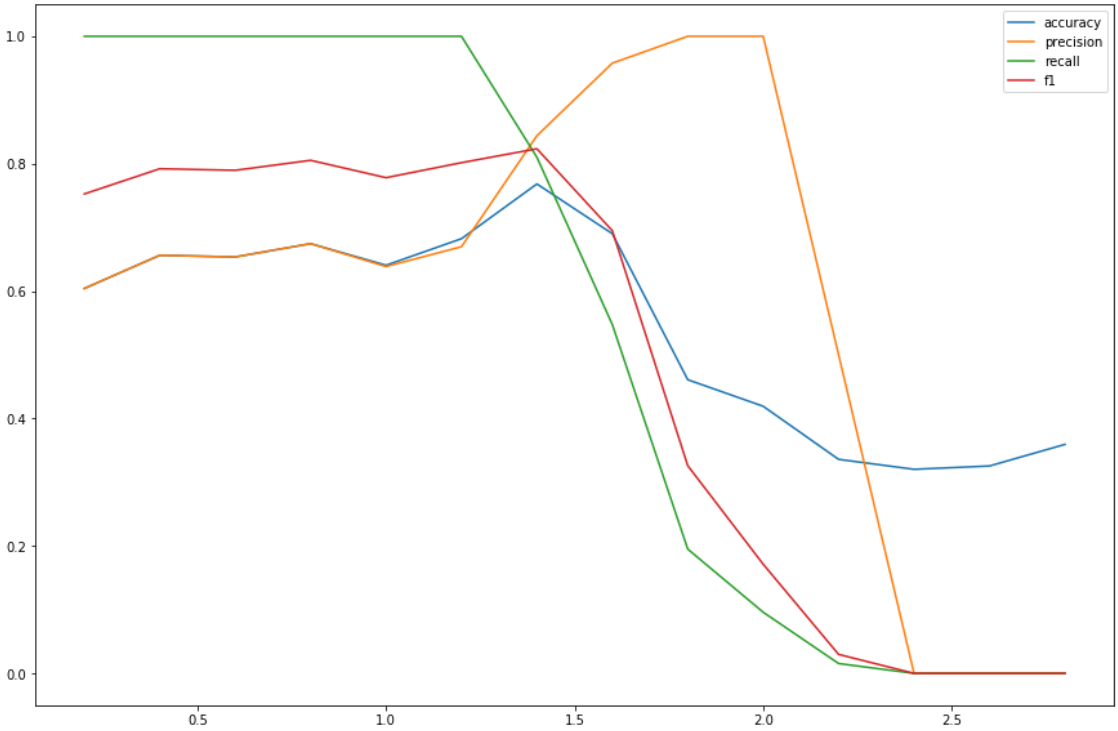
```
 71%|███████   | 10/14 [02:21<00:56, 14.22s/it]/Users/nkarpachev/py3_rl/l
ib/python3.6/site-packages/sklearn/metrics/classification.py:1143: Undefi
nedMetricWarning: Precision is ill-defined and being set to 0.0 due to no
predicted samples.
  'precision', 'predicted', average, warn_for)
/Users/nkarpachev/py3_rl/lib/python3.6/site-packages/sklearn/metrics/clas
sification.py:1143: UndefinedMetricWarning: F-score is ill-defined and be
ing set to 0.0 due to no predicted samples.
  'precision', 'predicted', average, warn_for)
100%|██████████| 14/14 [03:20<00:00, 14.37s/it]
```

In [49]:
```
from matplotlib import pyplot as plt
%matplotlib inline
```

In [50]:
```
plt.figure(figsize=(15, 10))

plt.plot(threshold_grid, accs, label='accuracy')
plt.plot(threshold_grid, precs, label='precision')
plt.plot(threshold_grid, recs, label='recall')
plt.plot(threshold_grid, f1s, label='f1')

plt.legend()
plt.show()
```



Зависимость качества от порога классификации. Можно наблюдать tradeoff между точностью и полнотой, при этом общее качество не слишком высоко (максимальное значение F1-score около 0.8).

Попробуем использовать более сложные модели (а именно решающие деревья и их ансамбли), используюя методы анализа формальных понятий для извлечения признаков.

Use better models

In [58]:
```
def extract_features(x, positive_context, negative_context):
    return [
        average_closure(x, positive_context),
        average_closure(x, negative_context),
        average_intersection(x, positive_context),
        average_intersection(x, negative_context)
    ]
```

In [63]:
```
X = df.drop(['target'], axis=1)
y = df['target']
```

In [64]:
```
X_train, X_test, y_train, y_test = train_test_split(X, y, test_size=0.2)
```

In [65]:
```
features_train = np.array([extract_features(np.array(elem[1]), positive_
context, negative_context) for
                 elem in X_train.iterrows()])
```

In [66]:
```
features_test = np.array([extract_features(np.array(elem[1]), positive_c
ontext, negative_context) for
                  elem in X_test.iterrows()])
```

In [67]:
```
from sklearn.linear_model import *
from sklearn.ensemble import RandomForestClassifier
```

Randpm Forest Classifier

In [68]:
```
clf = RandomForestClassifier()

clf.fit(features_train, np.array(y_train == 1))
pred = clf.predict(features_test)
get_scores(np.array(y_test == 1), pred)
```

```
/Users/nkarpachev/py3_rl/lib/python3.6/site-packages/sklearn/ensemble/for
est.py:248: FutureWarning: The default value of n_estimators will change
from 10 in version 0.20 to 100 in 0.22.
  "10 in version 0.20 to 100 in 0.22.", FutureWarning)
```

Out[68]:
```
{'accuracy': 0.9739583333333334,
 'precision': 0.9761904761904762,
 'recall': 0.984,
 'F1': 0.9800796812749003}
```

In [69]:
```
clf.feature_importances_
```

Out[69]:
```
array([0.345512  , 0.49791167, 0.11124115, 0.04533519])
```

Decision Tree Classifier

In [70]:
```
from sklearn.tree import DecisionTreeClassifier

clf = DecisionTreeClassifier()

clf.fit(features_train, np.array(y_train == 1))
pred = clf.predict(features_test)
get_scores(np.array(y_test == 1), pred)
```

Out[70]:
```
{'accuracy': 0.921875,
 'precision': 0.9583333333333334,
 'recall': 0.92,
 'F1': 0.9387755102040817}
```

In [ ]:
```

```