Рабочая программа дисциплины «Методы машинного обучения и майнинга данных»
(на английском языке)
«Machine Learning and Data Mining»

для образовательной программы «Науки о данных»
направления подготовки 01.04.02. Прикладная математика и информатика
уровень - магистр

Разработчик программы
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Руководитель департамента анализа данных и искусственного интеллекта Школы
С.О. Кузнецов ________

Утверждена Акademическим советом образовательной программы
«___»____________ 2016 г., № протокола__________________

Академический руководитель образовательной программы
С.О. Кузнецов ________________

Москва, 2016

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1. Teachers

Author, lecturer: Dmitry Ignatov, National Research University Higher School of Economics, Department of Data Analysis and Artificial Intelligence, associate professor

2. Scope of Use

The present program establishes minimum demands of students’ knowledge and skills, and determines content of the course.

The present syllabus is aimed at department teaching the course, their teaching assistants, and students of the Master of Science program 010402.68 «Data Sciences».

This syllabus meets the standards required by:

• Educational standards of National Research University Higher School of Economics;
• Educational program «Data Sciences» of Federal Master’s Degree Program 010402.68 «Applied Mathematics and Informatics», 2014;
• University curriculum of the Master’s program in «Data Sciences» for 2014.

3. Summary

The course “Machine Learning and Data Mining” introduces students to new and actively evolving interdisciplinary field of modern data analysis. Started as a branch of Artificial Intelligence, it attracted attention of physicists, computer scientists, economists, computational biologists, linguists and others and become a truly interdisciplinary field of study. In spite of the variety of data sources that could be analyzed, objects and attributes that from a particular dataset poses common statistical and structural properties. The interplay between known data and unknown ones give rise to complex pattern structures and machine learning methods that are the focus of the study. In the course we will consider methods of Machine Learning and Data Mining. Special attention will be given to the hands-on practical analysis of the real world datasets using available software tools and modern programming languages and libraries.

4. Learning Objectives

Learning objectives of the course “Machine Learning and Data Mining” (MLDM) are to familiarize students with a new rapidly evolving filed of machine learning and mining, and provide practical knowledge experience in analysis of real world data.

5. Learning outcomes

After completing the study of the discipline “Machine Learning and Data Mining”, the student should:

• Know basic notions and terminology used in MLDM
• Understand fundamental principles of modern data analysis
• Learn to develop mathematical models of MLDM
• Be capable of analyzing real world data

After completing the study of the discipline “Machine Learning and Data Mining” the student should have the following competences:
<table>
<thead>
<tr>
<th>Competence</th>
<th>Code</th>
<th>Code (UC)</th>
<th>Descriptors (indicators of achievement of the result)</th>
<th>Educatove forms and methods aimed at generation and development of the competence</th>
</tr>
</thead>
<tbody>
<tr>
<td>The ability to reflect developed methods of activity.</td>
<td>SC-1</td>
<td>SC-M1</td>
<td>The student is able to reflect developed mathematical methods for machine learning and data mining (data sciences)</td>
<td>Lectures and tutorials, group discussions, presentations, paper reviews.</td>
</tr>
<tr>
<td>The ability to propose a model to invent and test methods and tools of professional activity</td>
<td>SC-2</td>
<td>SC-M2</td>
<td>The student is able to improve and develop research methods as applicable to machine learning and data mining (data sciences)</td>
<td>Classes, home works.</td>
</tr>
<tr>
<td>Capability of development of new research methods, change of scientific and industrial profile of self-activities</td>
<td>SC-3</td>
<td>SC-M3</td>
<td>The student obtains necessary knowledge in machine learning and data mining, which is sufficient to develop new methods</td>
<td>Home tasks, paper reviews</td>
</tr>
<tr>
<td>The ability to describe problems and situations of professional activity in terms of humanitarian, economic and social sciences to solve problems which occur across sciences, in allied professional fields.</td>
<td>PC-5</td>
<td>IC-M5.3_5.4_5.6_2.4.1</td>
<td>The student is able to describe data analysis problems in terms of computational mathematics.</td>
<td>Lectures and tutorials, group discussions, presentations, paper reviews.</td>
</tr>
<tr>
<td>The ability to detect, transmit common goals in the professional and social activities</td>
<td>PC-8</td>
<td>SPC-M3</td>
<td>The student is able to identify mathematical aspects in machine learning and data mining tasks, evaluate correctness of the used methods, and their applicability in each current situation</td>
<td>Discussion of paper reviews; cross discipline lectures</td>
</tr>
</tbody>
</table>
6. Place of the discipline in the Master’s program structure

The course “Machine Learning and Data Mining” is a course taught in the first year of the Master’s program 010402.68 “Data Sciences” and is a base course for specialization “Intelligent Systems and Structural Analysis”

**Prerequisites**

The course is based on knowledge and understanding of

- Discrete mathematics
- Algorithms and data structures
- Linear algebra
- Theory of probability and statistical analysis

It also requires some programming experience in one of the languages:

- Python
- Matlab

7. Schedule

One pair consists of 1 academic hour for lecture and 1 academic hour for classes after lecture.

<table>
<thead>
<tr>
<th>№</th>
<th>Topic</th>
<th>Total hours</th>
<th>Contact hours</th>
<th>Self-study</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td></td>
<td></td>
<td>Lectures</td>
<td>Seminars</td>
</tr>
<tr>
<td>1</td>
<td>Introduction to Machine Learning and Data Mining</td>
<td>16</td>
<td>2</td>
<td>4</td>
</tr>
<tr>
<td>2</td>
<td>Clustering and basic techniques.</td>
<td>22</td>
<td>4</td>
<td>4</td>
</tr>
<tr>
<td>3</td>
<td>Classification and basic techniques.</td>
<td>23</td>
<td>5</td>
<td>4</td>
</tr>
<tr>
<td>4</td>
<td>Frequent Itemset Mining and Association Rules.</td>
<td>23</td>
<td>4</td>
<td>4</td>
</tr>
<tr>
<td>5</td>
<td>Feature Selection and Dimensionality Reduction. Outlier detection.</td>
<td>14</td>
<td>2</td>
<td>2</td>
</tr>
<tr>
<td>6</td>
<td>Recommender Systems and Algorithms.</td>
<td>16</td>
<td>3</td>
<td>3</td>
</tr>
<tr>
<td>7</td>
<td>Ensemble Clustering and Classification.</td>
<td>14</td>
<td>2</td>
<td>2</td>
</tr>
<tr>
<td>8</td>
<td>Multimodal relational clustering.</td>
<td>15</td>
<td>2</td>
<td>3</td>
</tr>
<tr>
<td>9</td>
<td>Artificial Neural Methods and Stochastic Optimization. Elements of Statistical Learning.</td>
<td>22</td>
<td>4</td>
<td>4</td>
</tr>
<tr>
<td>10</td>
<td>Machine Learning Tools and Big Data.</td>
<td>26</td>
<td>2</td>
<td>4</td>
</tr>
<tr>
<td></td>
<td><strong>Total</strong></td>
<td><strong>191</strong></td>
<td><strong>30</strong></td>
<td><strong>34</strong></td>
</tr>
</tbody>
</table>
8. Requirements and Grading

<table>
<thead>
<tr>
<th>Type of grading</th>
<th>Type of work</th>
<th>Characteristics</th>
</tr>
</thead>
<tbody>
<tr>
<td>Homework</td>
<td>5</td>
<td>Solving homework tasks and examples.</td>
</tr>
<tr>
<td>Special homework</td>
<td>2</td>
<td>Independent modelling and verification of research papers results</td>
</tr>
<tr>
<td>– research projects</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Exam</td>
<td>1</td>
<td>Written exam</td>
</tr>
</tbody>
</table>

9. Assessment

*The assessment* consists of classwork and homework, assigned after each lecture. Students have to demonstrate their knowledge in each lecture topic concerning both theoretical facts, and practical tasks’ solving. All tasks are connected through the discipline and have increasing complexity.

*Final assessment* is the final exam. Students have to demonstrate knowledge of theory facts, but the most of tasks would evaluate their ability to solve practical examples, present straight operation, and recognition skills to solve them.

The grade formula:

*The exam* will consist of 10 problems, giving 10 points each, total 100 points for the exam

*Final course mark* is obtained from the following formula:

\[
O_{\text{final}} = 0.6 \times O_{\text{cumulative}} + 0.4 \times O_{\text{exam}}
\]

The grades are rounded in favour of examiner/lecturer with respect to regularity of class and home works. All grades, having a fractional part greater than 0.5, are rounded up.

**Table of Grade Accordance**

<table>
<thead>
<tr>
<th>Ten-point Grading Scale</th>
<th>Five-point Grading Scale</th>
</tr>
</thead>
<tbody>
<tr>
<td>1 - very bad</td>
<td>Unsatisfactory - 2</td>
</tr>
<tr>
<td>2 – bad</td>
<td></td>
</tr>
<tr>
<td>3 – no pass</td>
<td></td>
</tr>
<tr>
<td>4 – pass</td>
<td>Satisfactory – 3</td>
</tr>
<tr>
<td>5 – highly pass</td>
<td></td>
</tr>
<tr>
<td>6 – good</td>
<td>Good – 4</td>
</tr>
<tr>
<td>7 – very good</td>
<td></td>
</tr>
<tr>
<td>8 – almost excellent</td>
<td>Excellent – 5</td>
</tr>
<tr>
<td>9 – excellent</td>
<td></td>
</tr>
<tr>
<td>10 – perfect</td>
<td></td>
</tr>
</tbody>
</table>
10. Course Description

The following list describes main topics covered by the course with lecture order.

**Topic 1. Introduction to Machine Learning and Data Mining**

**Content:** Introduction to modern data analysis. Machine Learning. Data Mining and Knowledge Discovery in Data Bases. Basic tasks and examples.

**Topic 2. Clustering and basic techniques.**


**Topic 3. Classification and basic techniques.**


**Topic 4. Frequent Itemset Mining and Association Rules.**


**Topic 5. Feature Selection and Dimensionality Reduction.** Outlier detection.


**Topic 6. Recommender Systems and Algorithms**

**Content:** Collaborative filtering. User-based and item-based methods. Slope one. Association rules based and bicluster-based techniques. Quality assessment: MAE, precision and recall. SVD-based approaches: SVD++ and time-SVD.

**Topic 7. Ensemble Clustering and Classification.**

**Content:** Ensemble methods of clusterization for k-means partitions’ aggregation. Ensemble methods of classification: Bagging, Boosting, and Random Forest.

**Topic 8. Multimodal relational clustering**

**Content:**

**Topic 9.** Artificial Neural Methods and Stochastic Optimization. Elements of Statistical Learning.

**Content:**

**Topic 10.** Machine Learning Tools and Big Data.

**Content:**
Orange, Weka, Knime, and Scikit Learn. Machine Learning for Big Data: Mahout and MALLET.

11. **Term Educational Technology**

The following educational technologies are used in the study process:
- discussion and analysis of the results of the home task in the group;
- individual education methods, which depend on the progress of each student;
- group projects on analysis of real data.

12. **Recommendations for course lecturer**

Course lecturer is advised to use interactive learning methods, which allow participation of the majority of students, such as slide presentations, combined with writing materials on board, and MLDM software tools for demonstration and practicing purposes. The course is intended to be introductory, that is rather broad in nature, but it is normal to differentiate tasks and projects in a group if necessary, and direct fast or more dedicated learners to solve more complicated tasks. The final group project and computational homework tasks are inevitable constituents of the course.

13. **Recommendations for students**

Lectures are combined with classes. Students are invited to ask questions and actively participate in-group discussions and projects. There will be special office hours for students, which would like to get more precise understanding of each topic. Teaching assistant will also help you. All tutors are ready to answer your questions online by official e-mails that you can find in the “contacts” section. Note that the final mark is a cumulative value of your term activity and final results.

14. **Sample final exam questions**

1. For the given dataset define unknown labels of objects by three different machine learning techniques (Decision Tress, Naïve Bayes, 1-Rule).

<table>
<thead>
<tr>
<th>Gender</th>
<th>Age</th>
<th>Education</th>
<th>Salary</th>
<th>Grant credit</th>
</tr>
</thead>
<tbody>
<tr>
<td>M</td>
<td>young</td>
<td>higher</td>
<td>high</td>
<td>+</td>
</tr>
<tr>
<td>F</td>
<td>young</td>
<td>special</td>
<td>high</td>
<td>+</td>
</tr>
<tr>
<td>F</td>
<td>middle</td>
<td>higher</td>
<td>moderate</td>
<td>+</td>
</tr>
<tr>
<td>M</td>
<td>old</td>
<td>higher</td>
<td>high</td>
<td>+</td>
</tr>
<tr>
<td>M</td>
<td>young</td>
<td>high</td>
<td>low</td>
<td>-</td>
</tr>
<tr>
<td>F</td>
<td>middle</td>
<td>high school</td>
<td>moderate</td>
<td>-</td>
</tr>
<tr>
<td>F</td>
<td>old</td>
<td>special</td>
<td>moderate</td>
<td>-</td>
</tr>
</tbody>
</table>
8 F young special high t
9 F old higher moderate t
10 M middle special moderate t

2. For the given dataset and minimal values of support=1/3 and confidence=1/2 find a) all frequent itemsets and b) generate corresponding associations rules.
3. For the given dataset obtain different partitions into clusters and compare the results (k-means, k-medoids, hierarchical clustering) using one of the appropriate distance measures (Hamming, Euclid, or Manhattan distance).

15. Reading and Materials

15.1. Required Reading


15.2. Recommended Reading


Supplementary reading:


15.3. List of review papers

2. Rakesh Agrawal, Maria Christoforaki, Sreenivas Gollapudi, Anitha Kannan, Krishnaram Kenthapadi, Adith Swaminathan: Mining Videos from the Web for Electronic Textbooks. ICFCA 2014: 219-234


**15.4. Course telemaintenance**

All material of the discipline are posted in informational educational site at NRU HSE portal [www.ami.hse.ru](http://www.ami.hse.ru). Students are provided with links to research papers, electronic books, data and software.
16. Equipment

The course requires a laptop, projector, and acoustic systems. It also requires opportunity to install programming software, such as

- Python
- Matlab
- Orange, Weka, Scikit-learn, SPMF or their analogs on student personal computers.

Lecture materials, course structure and syllabus are prepared by Dmitry Ignatov.