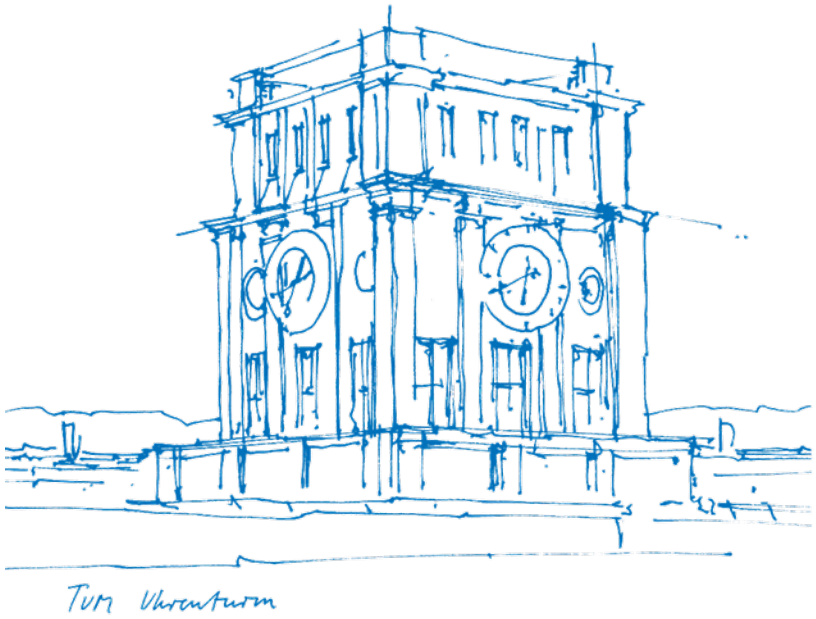
I5 - Scientific Computing in Computer Science
School of Computation, Information and Technology
Technische Universität München

Master Praktikum: Machine Learning in Crowd Modeling & Simulation

Kickoff meeting 2023-07-11



Outline

Machine Learning in Crowd Modeling & Simulation

- Instructor
- Motivation, examples, challenges, state-of-the-art

Lab course organization

- Topics covered in the course
- Software and course requirements
- Organizational issues

Instructor: **Dr. Felix Dietrich**

Machine Learning in Crowd Modeling & Simulation

1. Emmy Noether Group Leader at TUM (AI Initiative from DFG, 2022–)
2. PostDoc at TUM (2019–2022)
3. PostDoc at Princeton University (2017–2019)
4. PostDoc at Johns Hopkins University (2017–2019)

Research:

- Data science for complex dynamical systems
- Algorithms for high-dimensional data
- Approximation of operators on manifolds
- Doctoral thesis @ TUM: *Data-driven surrogate models for dynamical systems*

More here: `www.fd-research.com`

Machine Learning in Crowd Modeling & Simulation

Motivation - Modeling and Simulation

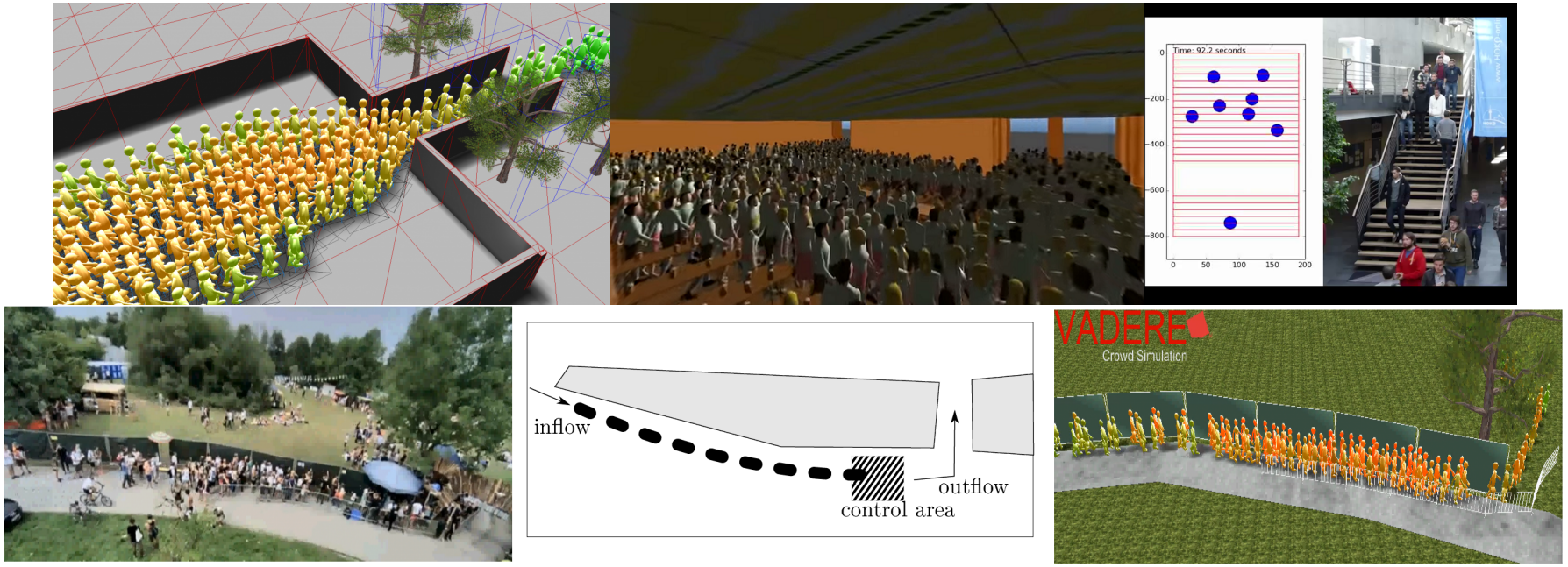


Figure: Left: Simulated pedestrians (colored by density) evacuate a room through a bottleneck. Center: Simulation and 3D visualization of an evacuation of a beer tent. Right: Experiment with students to evaluate dynamics on stairs. Bottom: Comparison of real video footage from an entrance to a music festival (left) with a simulation (right). The scenario setup of the simulation is shown in the center.

Machine Learning in Crowd Modeling & Simulation

Motivation - Machine Learning

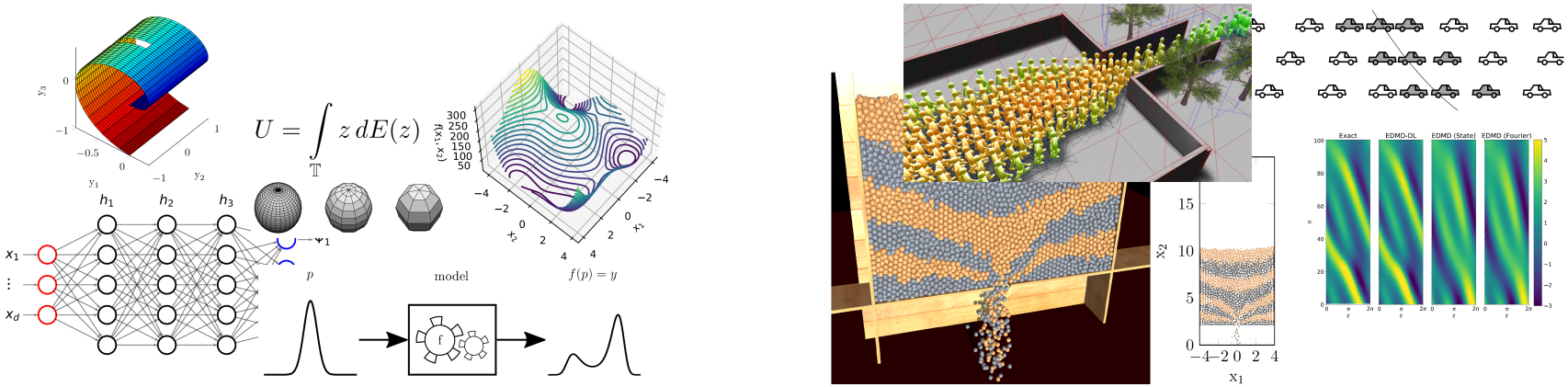


Figure: Left: Zoo of methods in machine learning. Right: Applications with complex systems.

Lab course: ML in Crowd M&S

What will you know after this course?

1. State of the art in mathematical modeling of crowds, validation of models to data
2. Implementation of simulation software, visualization of results
3. Machine learning techniques for the numerical analysis of complex dynamical systems:
   - 3.1 Bifurcation analysis
   - 3.2 Representation learning (manifold learning)
   - 3.3 Extraction of predictive dynamical systems from observation data

Lab course: ML in Crowd M&S

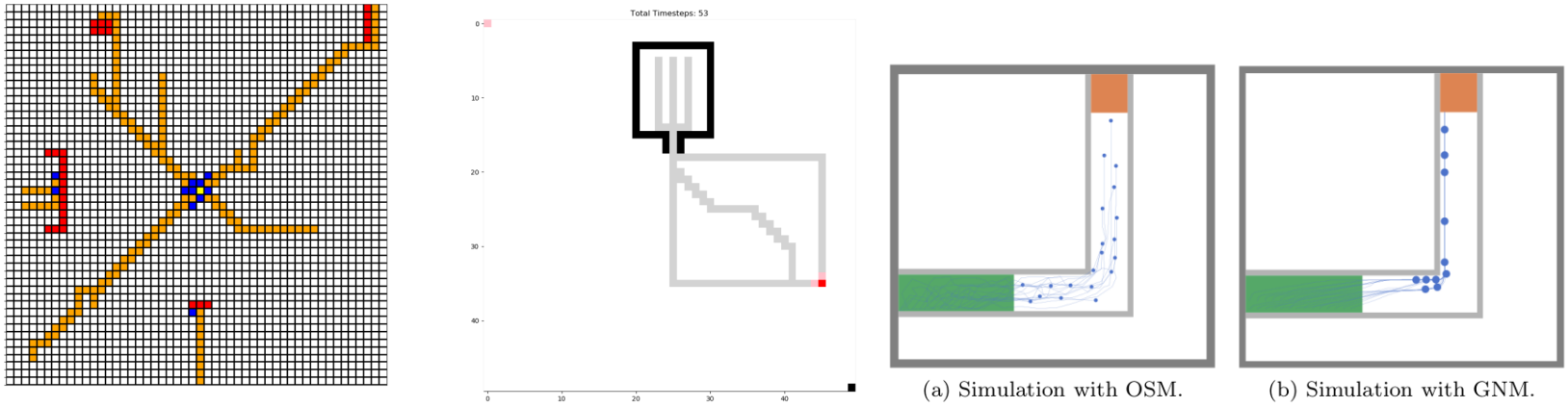
What will you know after this course?

- **Lecture 1 (CM): Modeling crowd dynamics**
  Modeling approaches, verification and validation
- **Lecture 2 (CM): Simulation software**
  Introduction to the Vadere software, SIR models
- **Lecture 3 (ML): Representation of data**
  Principal Component Analysis, Diffusion Maps, neural networks
- **Lecture 4 (CM): Dynamical systems and bifurcation theory**
  Introduction to the theory and examples
- **Lecture 5 (ML+CM): Extracting dynamical systems from data**
  Function approximation, vector fields, time-delay embedding, (final projects)
- **Lecture 6 (ML and/or CM, your choice): Future directions of machine learning**
  Challenges in data science, master's thesis topics, final projects

ML: machine learning topics **CM**: crowd modeling topics

Lab course: ML in Crowd M&S

Previous course: highlights

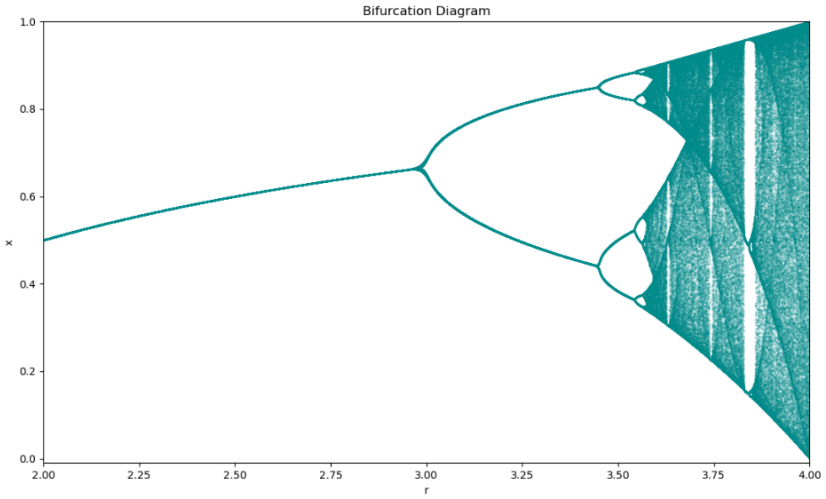


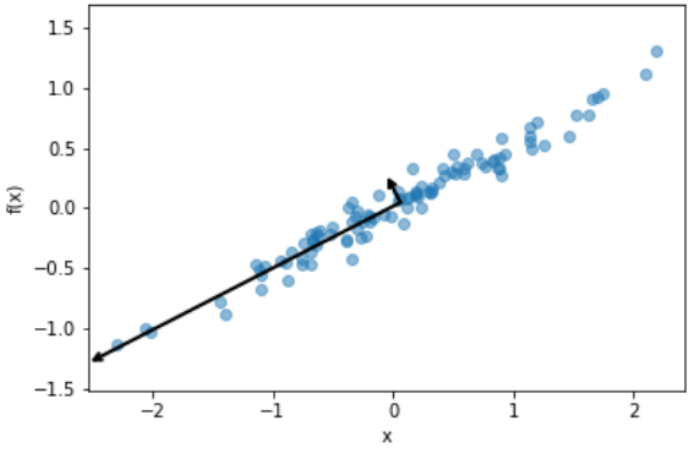
(a) Simulation with OSM. (b) Simulation with GNM.

Figure: Visualizations of a cellular automaton implemented by two groups, and simulation results from VADERE.

Lab course: ML in Crowd M&S

Previous course: highlights



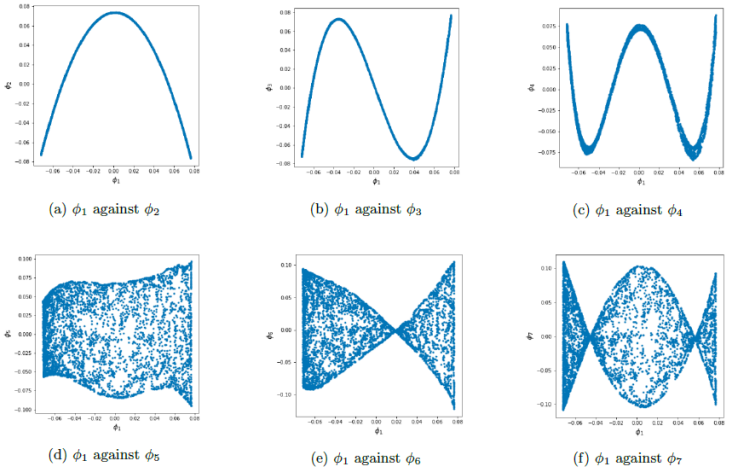


(b) Direction of 2 PC marked in original data-set.

Figure: Bifurcation diagram of the logistic map and principal components of a data set.

Lab course: ML in Crowd M&S

Previous course: highlights



(a) ϕ_1 against ϕ_2 (b) ϕ_1 against ϕ_3 (c) ϕ_1 against ϕ_4

(d) ϕ_1 against ϕ_5 (e) ϕ_1 against ϕ_6 (f) ϕ_1 against ϕ_7

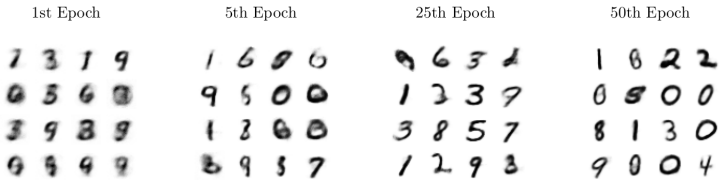


Figure 11: Reconstructed results obtained with a 32 dimensional latent space

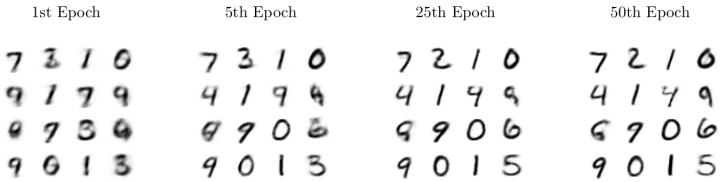


Figure: Diffusion Map embedding of the “swiss roll” data set and training results of a variational auto-encoder of the ”MNIST digits” data set.

Lab course: ML in Crowd M&S – Requirements

1. **Familiarity in Python** (C++, Java are also possible but not used in examples)
2. Familiarity with ML basics (train/test split, supervised learning, TensorFlow/PyTorch)
3. Basic concepts of linear algebra (matrix/vector computations, eigendecomposition)
4. Basic knowledge of dynamical systems (ordinary differential equations)
5. Being able to work together in a small group (3-5 students), GIT version control
6. Ideal: knowledge about proper documentation (docstrings!), modular software
7. **This lab course is a lot of work, especially if you have difficulties with programming**

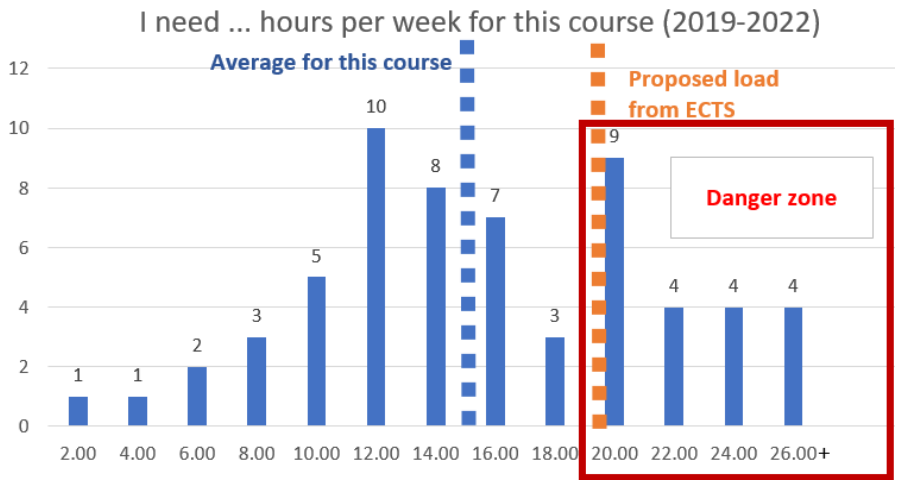


Figure: Working hours as reported in the student council evaluation. Data from six courses (Winter 2019/20–Summer 22).

Lab course: ML in Crowd M&S

Organization

1. 10 ECTS course
2. Language of instruction: English (exercises, slides, videos)
3. 5 exercise sheets (implementing a model, visualization, numerical analysis, surrogate models, ...)
4. 1 final project (propose or choose a topic in the field of machine learning / crowd modeling)
5. The grade for each exercise sheet is an averaged grade from the code submission (50%) and the discussion of the results (written reports and in class, 50%). The first 5 sheets will have the same weight factor of 15% each, the final project 25%.
6. All exercises and final projects in groups of 5 students
7. Lectures and new exercises every 2 weeks
8. Grading based on discussions of software, general concepts, and continuous participation
9. Videos on six course lectures all available on Moodle throughout the course
10. QnA sessions on-site, streamed on-line, and through Email/Chat (zulip.in.tum.de or chat.tum.de)
11. **Special for Winter 23/24:** the course can be completed completely online. I will offer on-site sessions every second week (QnA) as long as regulations allow it.

Lab course: ML in Crowd M&S

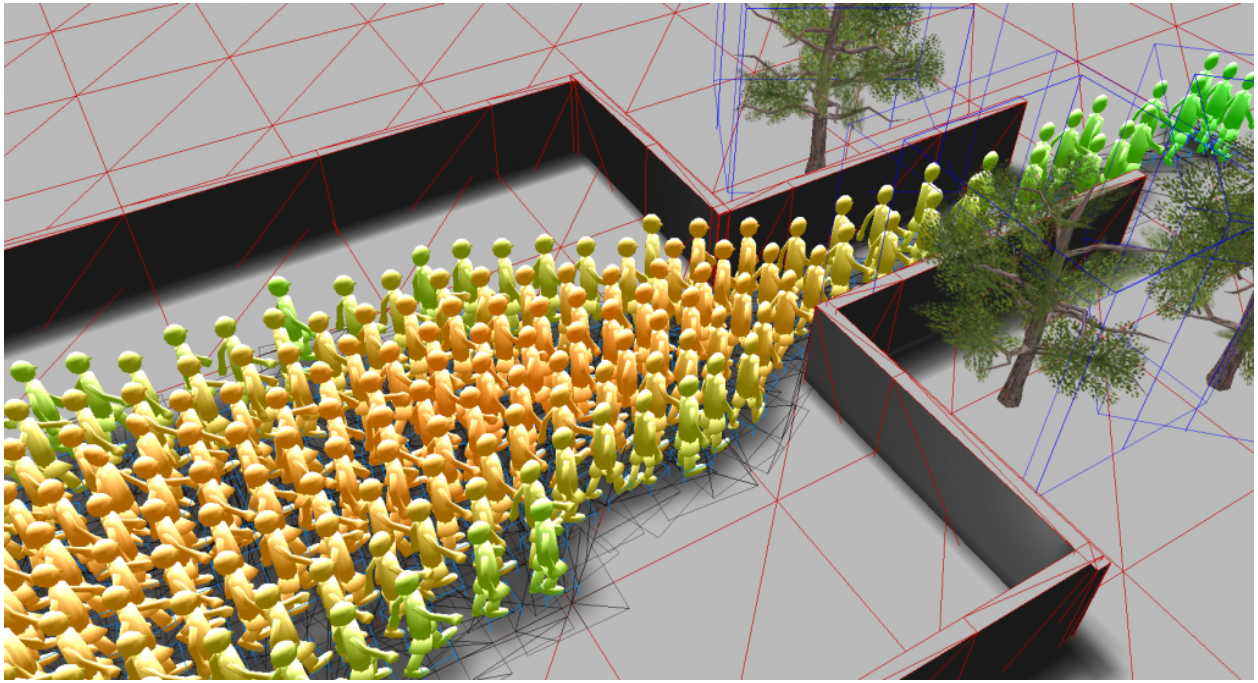
How do I get admitted to the course?

1. If you *really* want to get in: send an email with 2-3 sentences describing your motivation to `felix.dietrich@tum.de`
2. Otherwise, just select the course as high priority in `docmatching.in.tum.de`.

Moodle page for more information, recording, and slides:

`https://www.moodle.tum.de/course/view.php?id=90636`

Questions?



Homework: read about VADERE at `www.vadere.org`.
More questions: `felix.dietrich@tum.de`.