Karlsruher Institut für Technologie

Institut für Programmstrukturen und Datenorganisation (IPD)
Lehrstuhl für Systeme der Informationsverwaltung, Prof. Böhm

Masterarbeit

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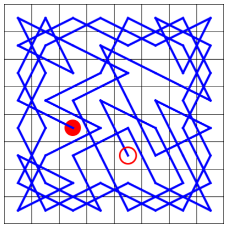
Reinforcement Learning for Solving the Knight's Tour Problem

The Knight's Tour Problem is one of the most famous chess puzzle and a well-known mathematical problem. A Knight's tour is a sequence of moves of a knight on a chessboard such that the knight visits each square exactly once. If the knight can reach its starting position from its final position, then the tour is said to be "closed". Otherwise, it is "open".

The Knight's Tour Problem can be seen as an instance of the Hamiltonian path/cycle problem or of the Travelling Salesman Problem (TSP) on graphs. However, unlike those general problems, algorithms exists that can solve it in linear-time, but they typically do not work on every problem instance. Attempts to solve the problem systematically have led to the development of several algorithms and heuristics. Warnsdorff's rule is perhaps the most famous and simplest heuristic [1], but it does not always lead to a valid solution. Recent solutions involve neural networks [2], divide-and-conquer approaches [3] or biology-inspired heuristics [4].



A closed knight's tour on a 8x8 chessboard.

In this work, we want to approach this problem from an agent-based point of view. One can see the knight as an agent, which sequentially decides on its next move, based on a learned policy. The goal of the agent is to maximize its total number of moves, without visiting any square more than once. It is interesting to explore various strategies to learn a respective policy, e.g., based on reinforcement learning (Q-learning and co.) or contextual bandit algorithms. See also this blog post[a].

The following questions are of particular interest:

- How do policies learned that way differ from existing heuristics/algorithms?
- How general are such policies? Are they compatible with other problem instances? For example, knight tours on larger/rectangular boards? How much more difficult is it to find closed versus open tours? Can we transfer such policies to more general problems, such as the TSP?
- What is the quality and computational runtime of such techniques w.r.t. existing methods?

This results in the following tasks:

- Literature review focusing on existing solutions for the Knight's Tour Problem.
- Proposal of a reinforcement learning approach to model and solve the problem.
- Extensive experiments to evaluate the success of the approach w.r.t. existing work.

To successfully conduct this thesis project, the student must possess:

- Knowledge of Python or Scala. A strong interest in Reinforcement Learning.
- The ability to plan and work independently. A working knowledge of English.
- A high level of motivation, enthusiasm and curiosity.

To help you with this task, we offer:

- Thorough mentoring and recurrent meetings with your advisor.
- Access to our institute's computing infrastructure (if required).
- Help to "go for the extra mile" and publish parts of your results in scientific conferences.

Throughout this work, the student will acquire knowledge and practical experience in Reinforcement Learning, and make an interesting contribution by solving an ancient problem with novel techniques.

[1] K. Alwan and K. Waters. "Finding re-entrant knight's tours on n-by-m boards". In: *ACM SE Regional Conference*. 1992.
[2] Y. Takefuji and K. C. Lee. "Neural networks computing for knight's tour problems". In: *Neurocomputing* 4.3 (1992).
[3] I. Parberry. "An Efficient Algorithm for the Knight's Tour Problem". In: *Discret. Appl. Math.* 73.3 (1997), pp. 251–260.
[4] A. Banharnsakun. "Artificial Bee Colony Algorithm for Solving the Knight's Tour Problem". In: *Intelligent Computing & Optimization*. Ed. by P. Vasant et al. Cham: Springer International Publishing, 2019, pp. 129–138.

[a] `https://edouardfouche.com/Digital-Art-&-the-Knight's-Tour-Problem/`

Ansprechpartner

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