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A* WITH LLM-DRIVEN HEURISTIC FOR CREATION OF ROBOTIC DANCE PERFORMANCES

Project for Artificial Intelligence in Industry

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AGENDA

INTRODUCTION

The main purpose of our project is the definition and implementation of Custom A* algorithm for the creation of dance choreographies tailored for NAO robots, that mimics the structure of an A* algorithm and that relies on an LLM-based heuristic.

Custom A*

The algorithm should compose a choreography trying to make it as ‘cool’ as possible while ensuring that it meets the following constraints:

- there are no incompatibilities between moves;
- all the moves in a list of mandatory moves are included;
- a minimum fixed number of moves in a list of intermediate moves are included;
- the total execution is constrained to take **about 2 minutes**.

WAYPOINTS

The LLM in our Custom A* is firstly used once before the beginning of the search: following the approach proposed in [2], we ask the LLM to define an ordered set of moves (waypoints) that the final choreography should respect.

The advantages of this approach are:

- Significant reduction of computational and memory cost, since the choreography creation is guided;
- More homogeneous choreography, since the skeleton of the choreography is generated by a single call to the LLM that will therefore define waypoints with a global wiew over the choreography.
- More customization capabilities since waypoints are defined by means of a single prompt that can be enriched with instructions that can contain details about the music, the rythm, the vibes and so forth.

TASK DEFINITION

Custom A* arguments

- A directed graph *G* whose nodes are the dance moves and the edges connect each dance move *m* to the positions that can follow *m*;
- Two dance moves m_i and m_f that are respectively the initial and the final move;
- A sequence *t* of waypoints;
- A set *M* of mandatory dance moves;
- A set *I* of intermediate dance moves and a natural number $N \geqslant 0$;

CONSTRAINTS SATISFACTION

Custom A* search

- At each iteration select the most promising choreography. If *m* is its last move, consider only the nodes of *G* reachable directly from *m* as possible following moves;
- A choreography is a valid solution only if it contains all the dance moves in *M*;
- A choreography is a valid solution only if it contains at least *N* of the moves in *I*;
- A choreography is a valid solution only if it lasts more or less 2 minutes.

SOLUTION SCORING

At each iteration new choreographies are considered. Each candidate solution is scored by a weighted sum of the following 4 scores:

1. **COOLNESS (LLM - BASED)**
2. **WAYPOINT PROXIMITY**
3. **CONSTRAINTS SATISFACTION**
4. **DURATION BONUS**

1. COOLNESS (LLM-BASED)

The coolness is the sum of two evaluations, one on the most promising choreography met so far and the other on the possible continations.

- **G - Function :** The LLM is asked to evaluate the top-rated choreography producing one score from 1 to 5 for each of the objectives defined in [1]: Storytelling, Rhythm, Movement Technique, Public Involvement, Space Use, Human Characterization and Human Reproducibility.
  The final g-score is computed by averaging the generated seven scores (equally weighed).

- **H - Function :** The LLM is asked to evaluate all the future traces, i.e. the compatible continuations given the current choreography being our starting point.
  This procedure eventually outputs a n-tuple containing one h-score for each new choreography, defined as the starting choreography followed by one of the possible moves.

2. WAYPOINT PROXIMITY

The possible continuations of the most promising choreography met so far are scored based on their proximity to the next waypoint, acting as a progress indicator.

- **Domain:** The output values range from 0 to 1, where the former indicates little to no progress (i.e., far from the next waypoint) and the latter indicates perfect progress (i.e., onto the next waypoint)
- **Computation:** It uses the shortest path distance from the considered move to the next waypoint, normalized by the maximum possible distance.

Once the next waypoint is reached succesfully, we update the target for the involved sequencies.

3. CONSTRAINTS SATISFACTION

Furthermore, the possible continuations of the most promising choreography met so far are scored based on the amount of included intermediate and mandatory positions, normalized by the total amount.

4. DURATION BONUS

To speed up the procedure, we boil down the search space by rewarding the sequences whose duration is in line with the desired duration. To this end, we designed an asymmetric distribution, that behaves as a Gaussian for values below the desired duration and as a negative exponential for values above it.

CONCLUSIONS

- *The proposed solution correctly solves the defined task;*
- *The proposed solution takes into account the coolness of the choreographies.*

LIMITATIONS & FUTURE DIRECTIONS

- *Evaluation doesn’t follow strict and well defined guidelines;*
  ***Possible solution:** fine tuning of the LLM to improve consistency and align the model with domain-specific requirements;*
- Scoring function is a trade-off between coolness, constraints satisfaction, waypoints and search efficiency;
  Possible solution: weight optimization;
- No human evaluation was taken into account for coolness evalutaion;
  Possible solution: human coolness evaluation.

REFERENCES

[1] De Filippo, A., & Milano, M. (2024). Large language models for human-ai co-creation of robotic dance performances. Proceedings of the Thirty-ThirdInternational Joint Conference on Artificial Intelligence, 7627–7635. https://doi.org/10.24963/ijcai.2024/844

[2] Pagnotta, A. (2024). LLAMA 2 AS A NEXT - Generation Partial Order Programming Tool: Performance Benchmarks and Implications for Autonomous Systems - Master’s thesis - Supervisor: Milano, M.

[3] Meng, S., Wang, Y., Yang, C.-F., Peng, N., & Chang, K.-W. (2024). LLM-A*: Large Language Model Enhanced Incremental Heuristic Search on Path Planning. https://doi.org/10.21203/rs.3.rs-4613568/v1

THANK YOU

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