Task-oriented Robot Control User Interface Designer For Cable-driven Soft Robots Without Kinematic Models

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Background & Aims

To control a soft robot:
- Model-based methods: Piece-wise Constant Curvature[1] or the Finite Elements Model[2]
- Data-driven methods: Goal Babbling Learning[3] or Neural Networks[4]

The challenge of building an appropriate kinematic model for soft robots restricts the development of soft robots, for either professional or casual users.

In CG field, a "re-parameterization" method has been proposed to solve the difficulties of the complex configuration on character animation or vector graphic:
- Simplicial Mapping[5, 6]
- RBF method[7]

Our Aims are:
- **Lower the bar of controlling a soft robot**
  - Avoid to define a kinematics model by physics or analystic methods
- **Create user-friendly control UIs for soft robot tasks rapidly.**

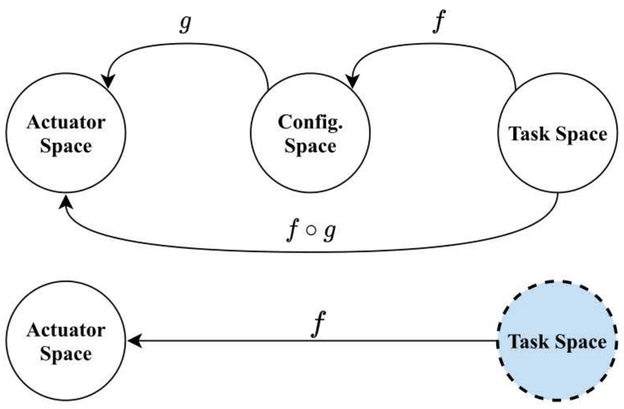

Figure.1 Comparison between inverse kinematics methods and our proposal

Methodology

Our proposed method supposes that a user has task imagery in mind as a graph structure, whose nodes correspond to the states of the robot, which are also in the user's mind.

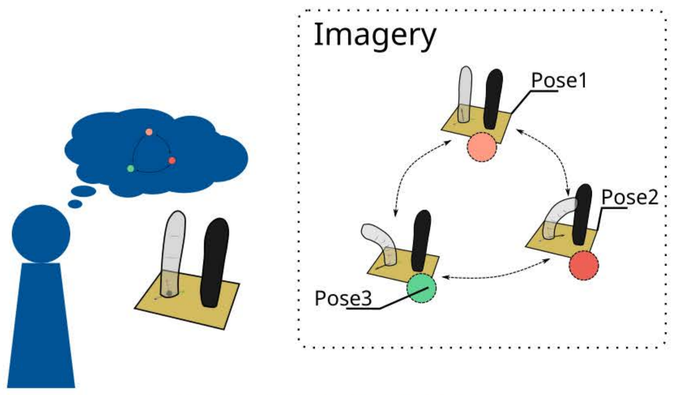

Figure.2 Imagery of soft robot tasks

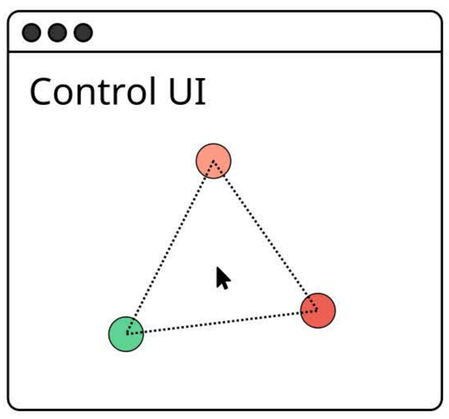

Figure.3 Control UI created from task imagery

The method then translates the graph into a graphical user interface on a two-dimensional display.
The process to create a control UI:
1. Copy the graph of the task imagery into a graph on the GUI, which represents the task space.
2. Transform the graph into a simplicial complex, where points inside could be interpolated.
3. Assign actuator's displacements that direct the state of the robot corresponding to each node in mind.
4. Use this continuously defined simplicial complex as the robot control UI by manipulating a control point on the simplicial complex to make the soft robot adopt desired postures.

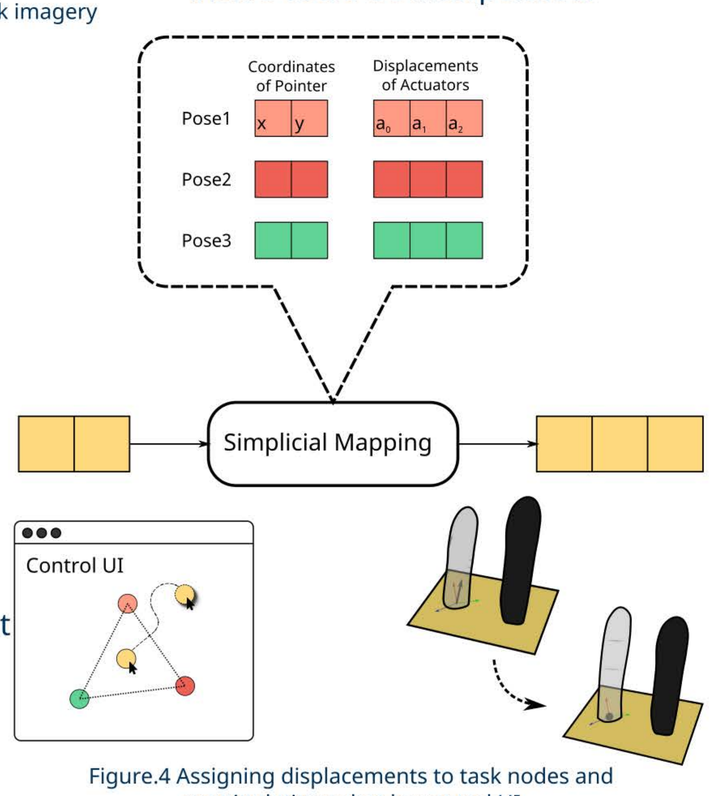

Figure.4 Assigning displacements to task nodes and manipulating robot by control UI

Results

1. Manipulate Single Robot Arm

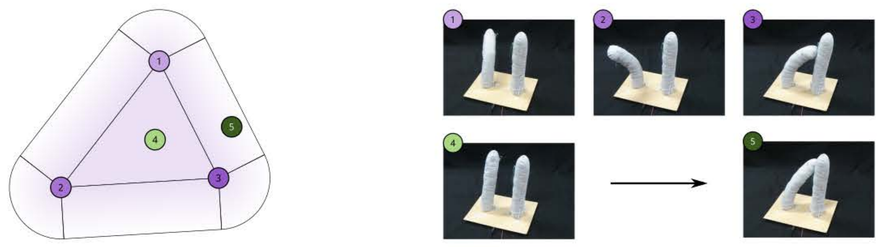

Figure.5 Manipulating single robot arm

2. Manipulate Soft Dice with Two Robot Arms

Figure.6 Manipulating soft dice with two robot arm

3. Qualitative User Study

Three questions to be answered:
1. Is the proposed method convenient for casual users?
2. Is the proposed method usable to create control UI for soft robots?
3. How long will it take to create desired control UI by this proposed method in practice?

Workshop to create control UI with 5 paticipants
- Groups: "Experienced with Soft Robots", "Non-experienced with Soft Robots"
- Procedures:
  1. Experimenter created a control UI for the left arm of the soft robot as an example.
  2. Participants would be asked to create a control UI for the right arm of the soft robot in the same procedure as the experimenter showed before.
  3. Participants would be asked to create a high-level control UI for the manipulation task to generate a synchronized motion of both soft arms.
- Paticipants would be interviewed after the evaluation.

Results
- Interviews
  - Achieved the task in their way and the completeness of task was acceptable
  - Had a clear awareness of the proposed concept
  - Desired an advanced usage of the system
- For all paticipants, the workshop finished within 1 hour.
- Observations
  - Most participants: enjoyed the UI they created
  - The control UIs created by different participants:
    - Showed some similarities in spatial-related layouts
    - Non-experienced group: more flexible in the geometric
    - Experienced group: prefer to use a precise numerical representation

Disscussions
- Similarity in spatial-related layouts
  - Influenced by prior knowledge of the participant
- Task-oriented robustness to unspecified geometric representations
  - Benefited by the topological aspect of the simplicial complex

Conclusion

- A method to create control UIs rapidly according to specific soft robot tasks, without kinematic models.
  - No any extra device or adopting and calibrating a complicated kinematics model, which is attracitive to causal users who would like to create and control a soft robot.
- Two typical cases showed the method could create valid control UIs rapidly for various tasks of a cable-driven soft robot.
- An user study as an early assessment
  - The system would be helpful, especially for the casual users.

Future Works
- Quantitative user study
- Extensions of the proposed method

References

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