Extended Autonomy for Robots under Uncertainties and Resource Constraints in Spatiotemporal Fields

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Problem and Challenges

Fig. 1: Spatiotemporal fields, e.g., contaminated aquatic sources

Problem: ***How to synthesize decision-making strategies (policies) for a group of autonomous surface vehicles with multi-modal sensors for gathering in-situ measurements from spatiotemporal fields during a long-term mission?***

Challenges:

- [–] Motion uncertainty: imperfect actuation
- [–] Sensing uncertainty: noisy sensor readings
- [–] Environment uncertainty: moving objects as obstacles
- [–] Resource constraints: limited energy budgets and time

Scientific Impact

This research aims to advance

- [+] Marine robotics
- [+] Statistical modeling
- [+] Combinatorial optimization

The proposed framework will bridge a gap in existing approaches by integrating

- Task allocation subject to resource constraints that will enable robots to gather measurements parallelly from spatiotemporal fields
- Motion planning under uncertainties in dynamic environments that will enable robots to navigate with variable planning horizons

The proposed theoretically analyzed planning framework will be generic. The software and hardware prototypes will offer testbeds to study various environmental phenomena.

Solution

Approach

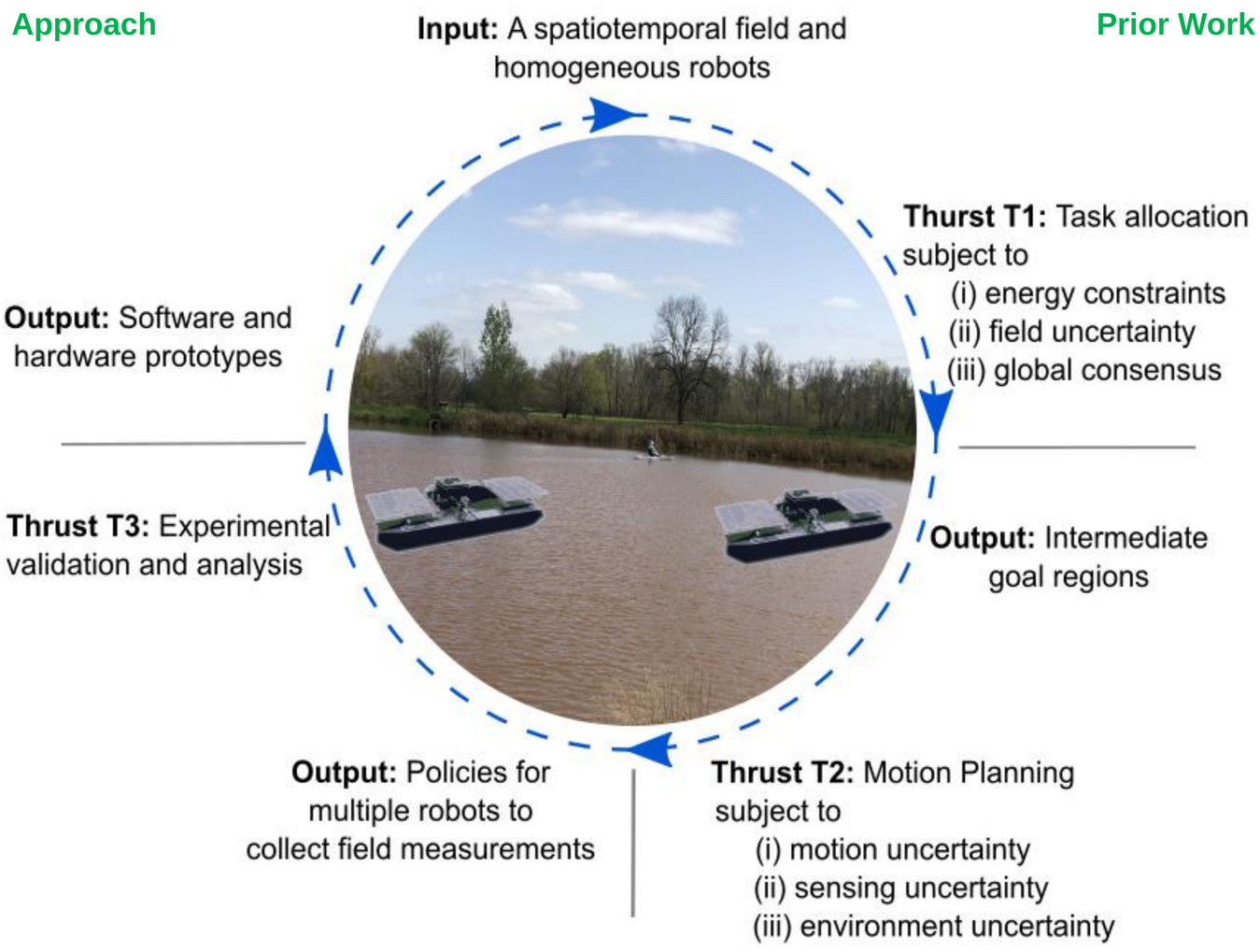

Fig. 2: Proposed integrated task and motion planning framework

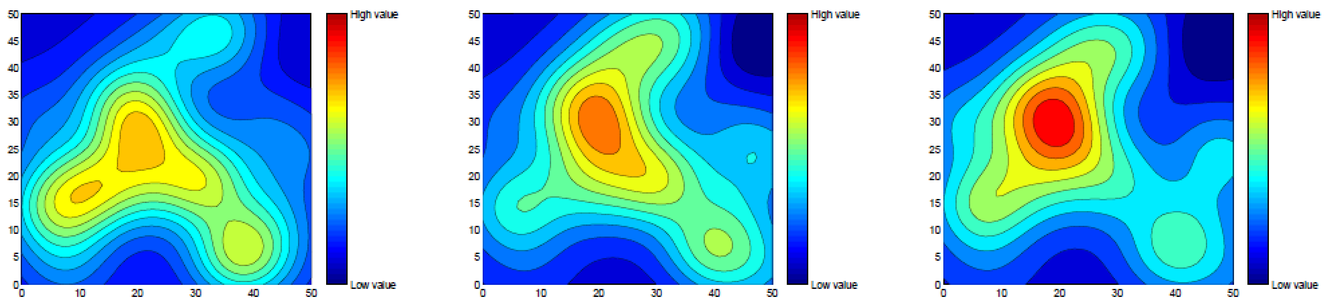

Fig. 3: Dynamic spatial field [3] is changing from time t_0 to t_2, where $t_0 < t_1 < t_2$

Prior Work

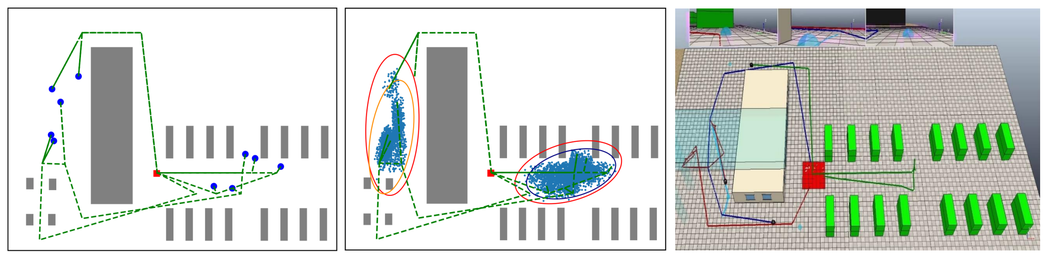

Fig. 4: Path and trajectory planning for robotic information gathering under resource constraints [1]

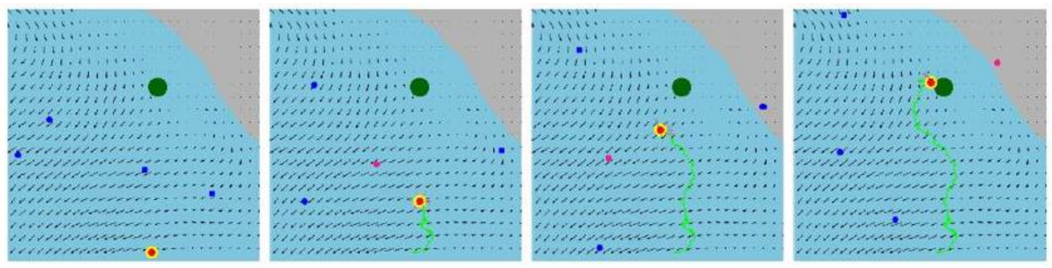

Fig. 5: Applying the synthesized policy under uncertainties on a water current layer [2]

Fig. 6: The trajectory execution of the offline policy with an AUV mission [2]

Fig. 7: Robots, sensors, and a field site to be used for experimental validation

Broader Impacts

Societal impact:

- Early interventions through successful environmental studies
- Gain insight into the changing nature through in-situ measurements of spatiotemporal fields
- Applications: nuclear radiation fields, soil parameter fields, electric fields, chemical fields, and greenhouse gas fields

Education and outreach:

- Robotics research into curriculum development
- Retention of female and underrepresented students
- Workshops, training, and summer camps

Project website:

- Collected data
- Software tutorials
- Surveys

Evaluation plan:

- The number of website visitors
- The number of downloads or uploads
- Feedback through preproject and postproject surveys
- Questionnaires at the end of workshops, training, and summer camps

References

1. Al Redwan Newaz, T. Alam, J. Mondello, J. Johnson, and L. Bobadilla, “Multi-robot information gathering subject to resource constraints,” *IEEE International Conference on Robot and Human Interactive Communication (RO-MAN)*, pp. 1–6, 2021.
2. A. Al Redwan Newaz, T. Alam, L. Bobadilla, and R. N. Smith, “Long-term autonomy for AUVs operating under uncertainties in dynamic marine environments,” *IEEE Robotics and Automation Letters*, vol. 6, no. 4, pp. 6313–6320, 2021.
3. X. Lan and M. Schwager, “Rapidly exploring random cycles: Persistent estimation of spatiotemporal fields with multiple sensing robots,” *IEEE Transactions on Robotics*, vol. 32, no. 5, pp. 1230–1244, 2016.