RECONFIGURABLE SLAM UTILISING FUZZY REASONING

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Motivation

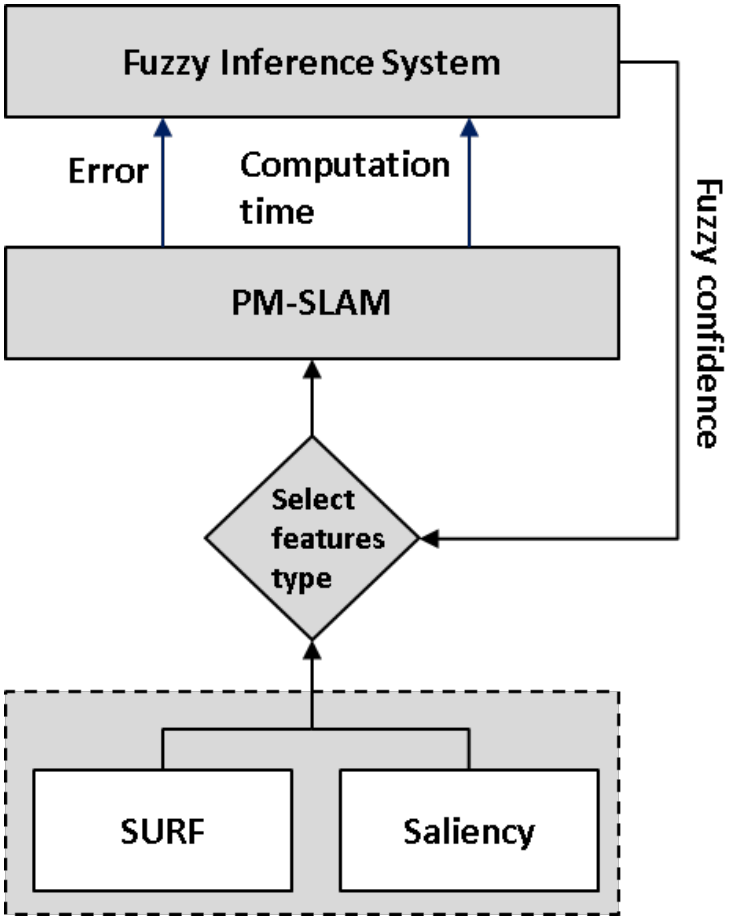
- Autonomous planetary rovers require complex localisation and navigation systems
- Complex systems should follow a distributed modular architecture rather than isolated engineered approaches
- Modular architectures offer great potential for '*reconfigurability*'
- Reconfigurability: generate system-wide hardware or software changes in response to any anomalous sensory feedback or external perturbations
- Reconfigurable systems: Robust against external perturbations, system failures or fallible sensors

Reconfigurable SLAM

- Research objective:
  - Develop a software-based reconfigurable SLAM system using top-down fuzzy logic reasoning
  - Use top-down fuzzy logic reasoning to reconfigure the lower-level visual feature detection stage to maintain optimal performance
  - Quantitative analysis of the proposed method using data generated with the Planet and Asteroid Natural scene Generation Utility (PANGU)

- SLAM system:
  - Planetary Monocular-Simultaneous Localisation and Mapping (PM-SLAM) system
  - PM-SLAM requires monocular vision-based features for environmental perception and mapping, along with control inputs

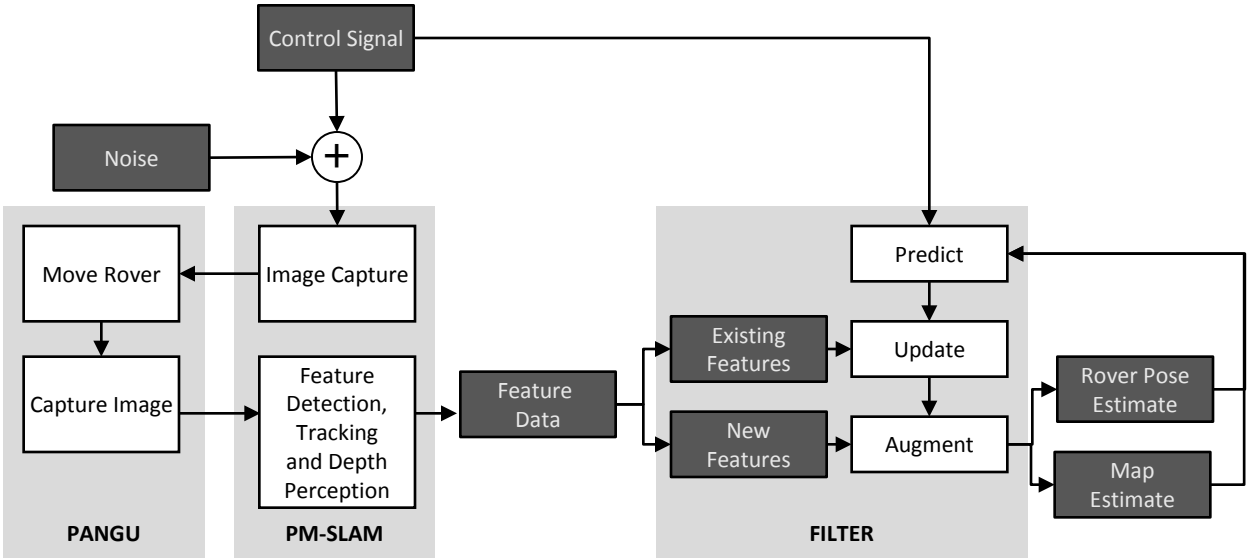
Reconfigurable SLAM



System diagram of the fuzzy inference-based reconfigurable PM-SLAM

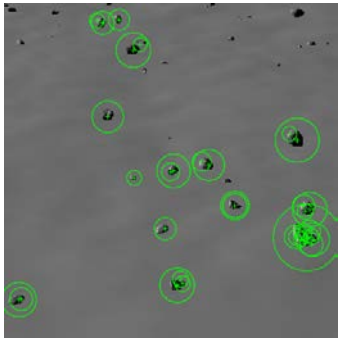
PM-SLAM

- Designed for autonomous rover navigation on extra-terrestrial planets
- Modular localisation and mapping technique, which uses monocular images to identify and track visual features in order to determine a pose
- Main components:
  - a visual feature detection & tracking in 2D (e.g., SURF, Saliency features)
  - a module that provides depths perception
  - a SLAM filter, e.g., Extended Kalman filter (EKF)

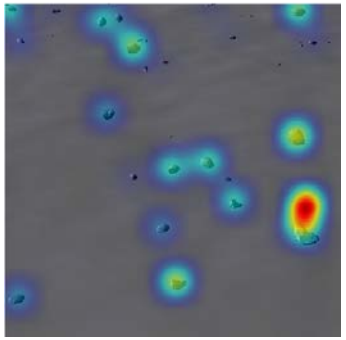


Visual Feature Detection

- SURF:
  - Speeded Up Robust Features [1]
  - Increase in computation time due increase in number of feature points



- Visual Saliency Features [2]:
  - Models are inspired by the information selection property of biological visual systems
  - Blob-based features, low complexity and computation time



[1] Herbert Bay, Andreas Ess, Tinne Tuytelaars, and Luc Van Gool". *Speeded-up robust features (surf)*. Computer Vision and Image Understanding, 110(3):346 – 359, 2008. Similarity Matching in Computer Vision and Multimedia.

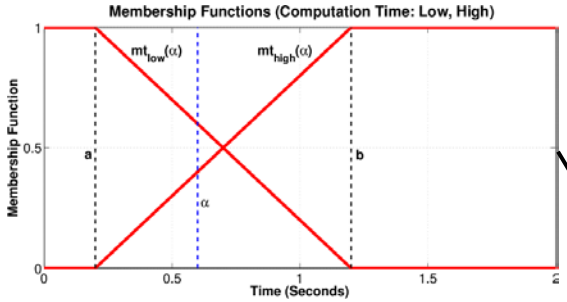
[2] Affan Shaukat, Conrad Spiteri, Yang Gao, Said Al-Milli, and Abhinav Bajpai. *Quasi-thematic features detection and tracking for future rover long distance autonomous navigation*. In 12th Symposium on ASTRA, Noordwijk, the Netherlands, 2013. ESA, ESTEC.

Fuzzy Inference System

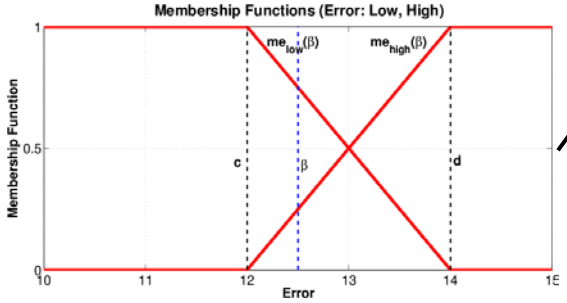
- Fuzzy inference systems (FIS) utilise fuzzy set theory in order to map the input space to outputs
  - Input space: low-level feature inputs
  - Output space: fuzzy decisions based on confidence values
- Fuzzy inference systems are used for logical decision-making and discerning patterns within inputs
- Inputs and outputs of FIS are associated with fuzzy confidence values using class membership functions (fuzzy sets)
- Definition and optimisation of membership functions within FIS is mostly carried by:
  - Learning-based methods (e.g., neural networks)
  - Empirical knowledge of the underlying sensory system (current case)
- Current model based on Mamdani FIS [3]:
  - Simple structure of min-max operations
  - High degree of successes in other complex control architectures, making it appropriate for PM-SLAM

[3] E. H. Mamdani and S. Assilian. An experiment in linguistic synthesis with a fuzzy logic controller. Int. J. Hum.-Comput. Stud., 51(2):135–147, Aug 1999.

Fuzzy Inference System

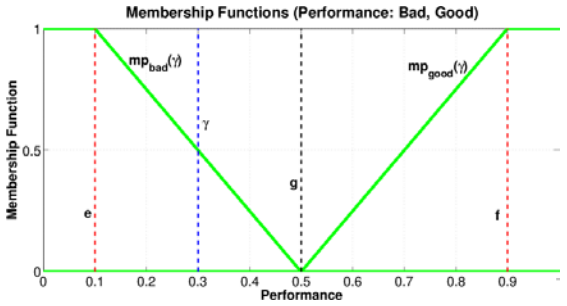


Membership function
(computation time)



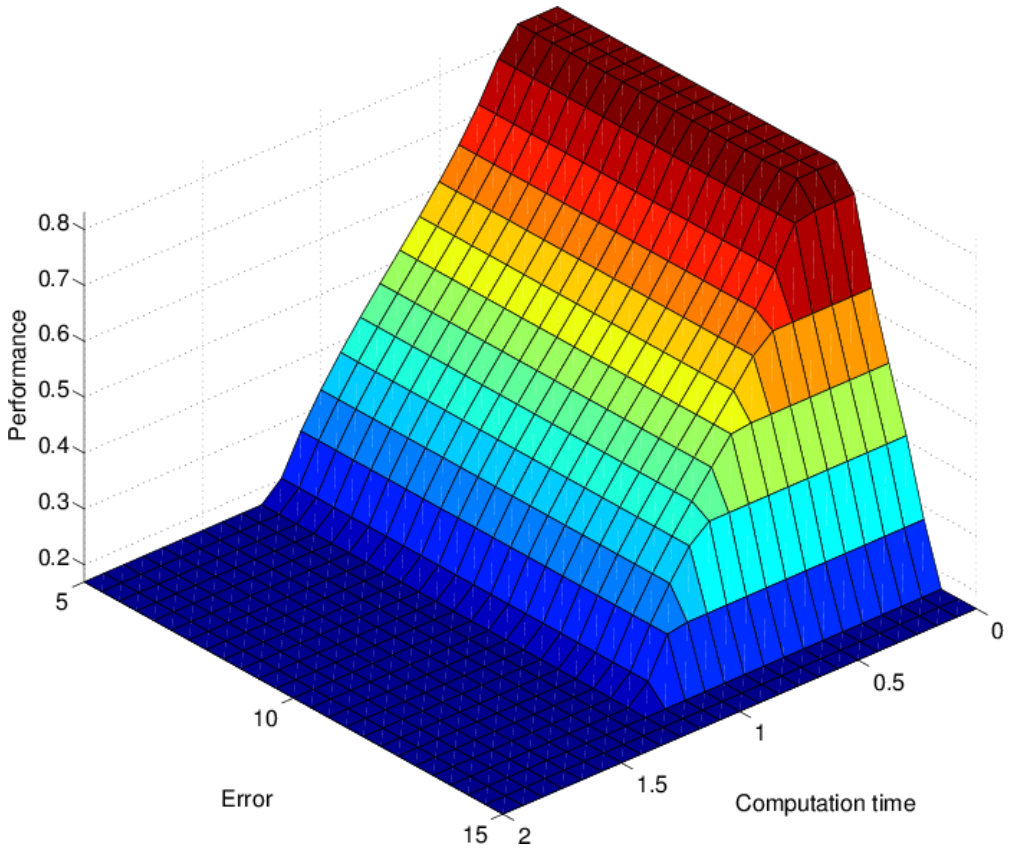
Membership function
(Error)

FIS
(Mamdani)



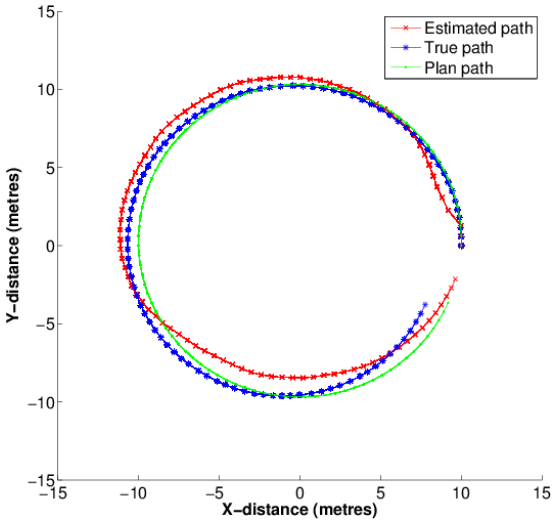
Membership function
(Decision)

Fuzzy Inference System

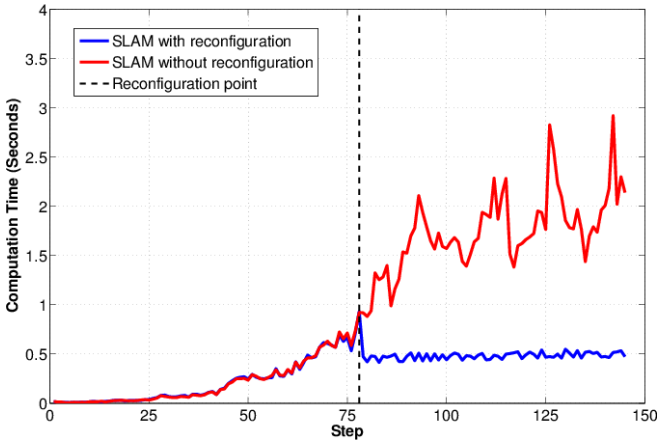


Plot of the output surface of the proposed FIS using the inputs variables

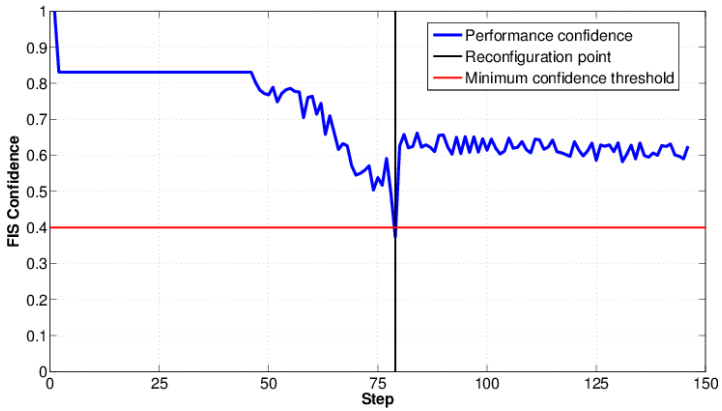
Experimental Results



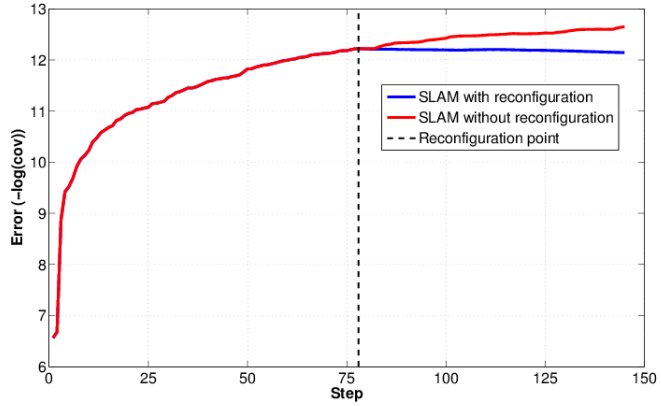
Pose estimation by PM-SLAM against truth and planned path using PANGU data



Plot shows the computation time for the proposed reconfigurable SLAM system against a system without reconfiguration



FIS performance-based confidence output for the proposed SLAM system



Plot shows the posterior error generated by the EKF for the proposed reconfigurable SLAM against a system without reconfiguration

Conclusions

- This research introduced a reconfigurable PM-SLAM system potentially for application to the problem of autonomous rover navigation
- A higher level fuzzy inference system generated system performance-based confidence measures based on the EKF posterior error and computation time
- The proposed framework performed reconfiguration within the low-level feature detection stage in order to improve the performance of PM-SLAM
- Using dataset generated from (PANGU), quantitative analysis of the proposed system was carried out to test the performance of the proposed framework
- Experiments showed that the proposed system was able to maintain optimal PM-SLAM performance

Acknowledgements

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Thank you!

Questions?