IV. CONCLUSIONS

A location recognition system using a Fast Learning Artificial Neural Network for sensor fusion is presented. Representative nodes are generated automatically for key locations and routes. The learned FLANN network was used for key location and route recognition. The system developed was able to classify key locations at a high accuracy.

Combining different types of sensors provides improved recognition capability and speed. For example, visual descriptors are excellent features for localization. However, visual descriptor is usually used to construct a topological map. This is the furthest it can perform unless an accurate visual odometry model can be developed. Topological maps alone cannot provide sufficient information for navigation. In order for navigation to become possible, it will be necessary to combine compass sensors or other information about the vehicle's position so that a direction for navigation to the target location can be derived. In this paper a simple fusion of visual and compass sensors is presented. However, the framework enables utilization of more sensors for fusion. The advantage of the proposed framework is that a sensor can incrementally be included in the fusion by a suitable tolerance setting and vigilance test. The parameter settings for each sensor can be tuned separately to provide optimal performance. Simply embedding anther attribute for vigilance test enables fusion of more types of sensors.

In future investigations on more flexible FLANN configurations for learning of different routes will be conducted. A more complex testing location and map are also necessary for further evaluation of the proposed algorithm.

REFERENCES

[1] S. Thrun, *et al.*, "Robust monte carlo localization for mobile robots," *Artificial Intelligence,* vol. 128, pp. 99-141, May 2001.

[2] A. L. P. Tay, *et al.*, "Biologically inspired KFLANN place fields for robot localization," in *International Joint Conference on Neural Network*, 2006, pp. 4201-4208.

[3] J. J. Leonard and H. F. Durrantwhyte, "Mobile robot localization by tracking geometric beacons," *IEEE Transactions on Robotics and Automation,* vol. 7, pp. 376-382, Jun 1991.

[4] A. Torralba, *et al.*, "Context-based vision system for place and object recognition," in *International Conference on Computer Vision*, 2003, pp. 273-280.

[5] J. Q. Wang, *et al.*, "Coarse-to-fine vision-based localization by indexing scale-invariant features," *IEEE Transactions on Systems Man and Cybernetics Part B-Cybernetics,* vol. 36, pp. 413-422, Apr 2006.

[6] C. Siagian and L. Itti, "Rapid biologically-inspired scene classification using features shared with visual attention," *IEEE Transactions on Pattern Analysis and Machine Intelligence,* vol. 29, pp. 300-312, Feb 2007.

[7] G. Schindler, *et al.*, "City-scale location recognition," in *Conference on Computer Vision and Pattern Recognition*, 2007, pp. 1378-1384.

[8] J. N. Wu and J. M. Rehg, "Where am I: Place instance and category recognition using spatial PACT," *2008 Ieee Conference on Computer Vision and Pattern Recognition, Vols 1-12,* pp. 2221-2228, 2008.

[9] I. Ulrich and I. Nourbakhsh, "Appearance-based place recognition for topological localization," in *IEEE International Conference on Robotics and Automation*, San Francisco, 2000, pp. 1023-1029.

[10] M. Cummins and P. Newman, "FAB-MAP: Probabilistic localization and mapping in the space of appearance," *International Journal of Robotics Research,* vol. 27, pp. 647-665, Jun 2008.

[11] D. Filliat, "Interactive learning of visual topological navigation," in *International Conference on Robots and Intelligent Systems*, 2008, pp. 248-254.

[12] G. Csurka, *et al.*, "Visual categorization with bags of keypoints " in *Workshop on Statistical Learning in Computer Vision, ECCV*, 2004, pp. 1-22.

[13] A. Angeli, *et al.*, "Visual topological SLAM and global localization," *Icra: 2009 Ieee International Conference on Robotics and Automation, Vols 1-7,* pp. 2029-2034, 2009.

[14] A. Pronobis, *et al.*, "Multi-modal Semantic Place Classification," *The International Journal of Robotics Research,* vol. 29, pp. 298-319, 2010.

[15] T. Oskiper, *et al.*, "Multi-modal Sensor Fusion Algorithm for Ubiquitous Infrastructure-free Localization in Vision-impaired Environments," in *International Conference on Intelligent Robots and Systems*, Taipei, 2010.

[16] X. Zhang and A. L. P. Tay, "Fast learning artificial neural network (FLANN) based color image segmentation in R-G-B-S-V cluster space," in *International Joint Conference on Neural Networks*, 2007, pp. 563-568.

[17] H. Bay, *et al.*, "Speeded-up robust features (SURF)," *Computer Vision and Image Understanding,* vol. 110, pp. 346-359, 2008.

[18] J. Sivic, *et al.*, "Unsupervised discovery of visual object class hierarchies," in *IEEE Conference on Computer Vision and Pattern Recognition*, 2008, pp. 2182-2189.

[19] L. Fei-Fei and P. Perona, "A Bayesian hierarchical model for learning natural scene categories," in *IEEE Computer Society Conference on Computer Vision and Pattern Recognition*, 2005, pp. 524-531.

[20] E. Nowak, *et al.*, "Sampling strategies for bag-of-features image classification," *Computer Vision - Eccv 2006, Pt 4, Proceedings,* vol. 3954, pp. 490-503, 2006.

[21] A. L. P. Tay, *et al.*, "The hierarchical fast learning artificial neural network (HieFLANN) - An autonomous platform for hierarchical neural network construction," *IEEE Transactions on Neural Networks,* vol. 18, pp. 1645-1657, Nov 2007.

[22] X. J. Zhang and A. L. P. Tay, "A binocular vision system with attentive saccade and spatial variant vergence control," *Cybernetics and Systems,* vol. 42, pp. 45-63, 2011.

[23] X. J. Zhang, *et al.*, "Neural classification of objects based on Gabor signature," in *International Joint Conference on Neural Networks*, 2008, pp. 893-900.