The objective of this coursework is to segment images meaningfully into distinct objects. While this problem is fundamentally ill-posed, many algorithms and techniques have been developed to attempt accurate segmentation of images. One popular family of methods is the k-means algorithm mentioned in the course. However, k-means, being "hard" clustering, forces each point into full membership. Fuzzy C-Means (FCM) clustering is a "soft" clustering algorithm that overcomes this issue by allowing for partial membership of each point across clusters at the cost of added computational complexity (Suganya and Shanthi, 2012).

In this coursework, I will be using the Superpixel-Based Fast Fuzzy C-Means (SFFCM) clustering technique, proposed by Lei and colleagues in 2019, to approach this task. In a comparison against other FCM-based methods, this method came out on top over a range of performance measures, was more robust to noise, and converged significantly faster than most other FCM-based methods, which are generally more computationally intensive (Lei et al., 2019).

The general approach of the SFFCM method is as follows:

1. Implement multiscale morphological gradient reconstruction (MMGR) and watershed transformation (WT) operations to generate an image comprised of superpixels.
2. Implement a modified FCM objective function which incorporates proximal spatial information (in the form of a colour histogram derived from the superpixel image) for fast convergence.

As this is meant to be a succinct write-up of the approach, the reader is directed to the SFFCM paper for more details on this interesting methodology.

I utilised open-source code provided by two authors of this paper, Lei and Jia, with minor modifications for compatibility with this coursework. While most parameters were kept at default values (e.g. convergence condition, and maximal number of iterations, etc.), I experimented with various cluster and structural element (SE) values in a grid search. The optimal set of parameter values selected was selected based on average F1 scores across all 12 training images.

The best result obtained was an average F1 score of **0.70**, using 4 clusters and an SE of size 4x4. Using these parameter values, the algorithm performed best on image 9, with an F1 score of **0.91**. For comparison, I computed the average F1 score across all 12 training images using the Canny edge detector with default parameter values. The Canny edge detector achieved an average F1 score of 0.46, with visual inspection of the output revealing excessive noise pickup. We can see that the SFFCM method is more robust to noise, and thus performs significantly better than the Canny edge detector.

References:

Suganya, R., & Shanthi, R. (2012). Fuzzy C- Means Algorithm- A Review. *International Journal of Scientific and Research Publications*, *2*(11).

T. Lei, X. Jia, Y. Zhang, S. Liu, H. Meng and A. K. Nandi, "Superpixel-Based Fast Fuzzy C-Means Clustering for Color Image Segmentation," in *IEEE Transactions on Fuzzy Systems*, vol. 27, no. 9, pp. 1753-1766, Sept. 2019, doi: 10.1109/TFUZZ.2018.2889018.