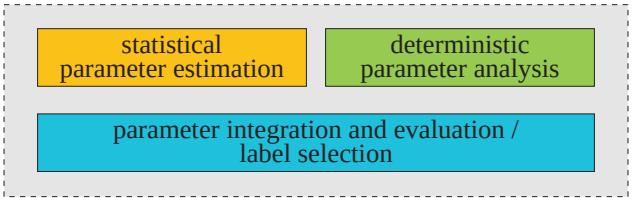
Nuclear Medicine Image Segmentation Using a Connective Neural Network

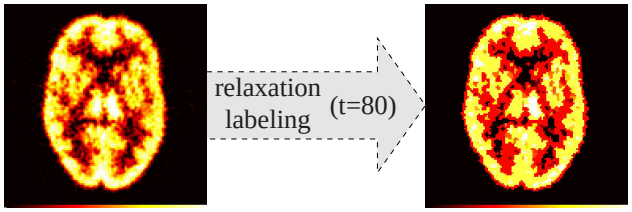
Objective: To develop a method for post-reconstruction nuclear medicine image segmentation based on the concepts of synergetic and logistic dynamics in analogy to the Ising model of a two-dimensional square lattice of N particles (pixels).

Methods: A reconstructed 2-D slice image is analyzed as a multi-pixel system where pixels correspond to a 2-D lattice of points with non-zero interaction energy with their nearest neighbors. The model assumes that pixel intensities belonging to the same homogeneous image region are relatively constant, where region intensity means (or labels) are determined by both statistical parameter estimation and deterministic image analysis. The change in value of each pixel during the segmentation process depends on (1) the statistical properties in the reconstructed image and (2) the states of its nearest neighbors. These changes are either in the direction of statistically estimated intensity means or other previously analyzed regions of significance. The segmentation technique uses a new innovative relaxation labeling (RL) connective network. The global relaxation dynamics of the network are controlled by the interaction of local synergetic and logistic functions assigned to each pixel.

Discussion: The dynamics of the RL models are different from the known RL approaches in their sigmoidal characteristics providing a more sensitive labeling especially for ambiguous labeling cases. Furthermore, the relaxation dynamics is not applied to elements of probability vectors but to the intensity values of the pixels themselves. This results in a redundancy-free RL algorithm having a significant better time performance compared with classical probabilistic RL algorithms. The improvement of the segmentation results is primarily a result of the suggested associative initialization model. Once the network dynamics is started, the solution process can be compared with neural processes in the early state of the human visual system: by self-organization principles in the micro-systems forming a structure on the macroscopic scale. Introducing a stochastic function, the system can be extended to a stochastic labeling network. This allows the RL process to be driven as a non-convex optimization approach based on consistence, entropy or global optimization criteria such as anatomical priors.

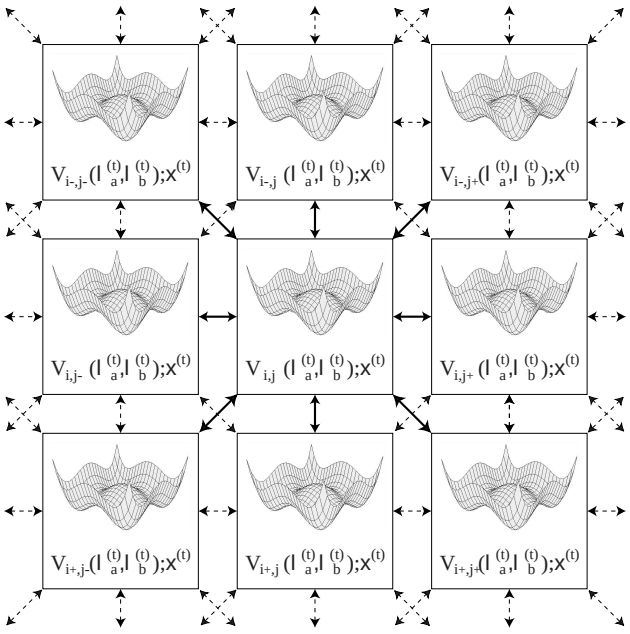


Associative initialization model



Reconstructed SPECT image (experimental acquisition) and segmentation result

The dynamics of each node system is determined by a potential function V which depends on the assigned labels $\{l_k\}^{(t)}$ and its related pixel value $x^{(t)}$. Since a stochastic disturbed function may be superimposed on the completely deterministic relaxation process, the system is capable of independently achieving energetically more optimum solutions and follows mechanisms of evolutionary models.



Neural network topology

Painting by Giuseppe Arcimboldo: Vertumnus.
The whole is sometimes more than the sum of its separate parts.

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