14 Conclusion

A new and data-driven approach for cluster analysis and visualization is introduced in this work. The projection based clustering combines structures preserved in two dimensions with underlying high-dimensional structures (see also [Thrun et al., 2017, Thrun/Ultsch, 2017a]). It is a flexible and robust approach for cluster analysis that consists of three independent modules which can be optionally combined into the Databionic swarm (DBS). Here, the attention is focused on data for which the generation process is complete and for which the size and amount of information can be managed using a personal computer with standard hardware; consequently, the realm of Big Data is not discussed here. To the author's knowledge, DBS is the first swarm-based technique showing emergent properties while simultaneously exploiting the concepts of swarm intelligence, self-organization and the Nash equilibrium concept from game theory, which results in the elimination of a global objective function and of the setting of parameters.

Alternatively, the visualization by the generalized Umatrix and the DBS clustering can be applied to every projection method for connected or compact structures based on discontinuities of high-dimensional data [Thrun/Ultsch, 2017a]. Through the use of the generalized Umatrix visualization, results of common clustering methods can be verified by the structures found by the data-driven Pswarm or any other projection method.

This work introduced the fundamental principle of considering compact versus connected structures in the clustering of data. However, in this context, only unsupervised indices, called QMs for projection methods, were analyzed. A similar analysis of supervised indices should be conducted in the future with the help of the FCPS. There is sufficient literature available to do so (e.g., [Charrad et al., 2012; Dimitriadou et al., 2002; Handl et al., 2005]).

Another goal of future research should be to find a strong Nash equilibrium. However, a strong Nash equilibrium is mathematically difficult to prove. In the opinion of the author, if each DataBot were able to assess all possible jump positions in a given neighborhood instead of only four, then a strong Nash equilibrium could be achieved. However, the time complexity of this approach is too high for practical testing unless the algorithm is parallelized. Additionally, deep swarming should be extensively tested.

Symmetry considerations were applied to the two-dimensional toroidal output space, resulting in the use of polar coordinates in the DBS framework. Additionally, it should be possible to explore and exploit connections with solid-state physics. Perhaps it would be beneficial to define the Bravais lattice, apply a Fourier transformation to the reciprocal lattice [Hunklinger, 2009, pp. 83-88], and perform calculations in the reciprocal space, where boundary effects could be easily eliminated and a low computational time complexity could be achieved.

Further research on these possibilities is required.

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