Colloidal systems represent a class of materials consisting of mesoscopic particles of different compositions, functionalities and shapes. Such nanoparticles can self-assemble in a range of different two- and three-dimensional superstructures exhibiting an incredibly large surface-to-volume ratio and non-trivial positional and orientational order, which make them perfectly suited for many technological applications. In the past few years, we have witnessed enormous advances in the development of both physically-inspired empirical and machine learning (ML) potentials for simulations of atomistic models. However, atomistic simulations of colloidal systems are severely limited by the length- and time-scales that can be achieved with present-day computers. Hence, computational studies of their phase-and self-assembling behaviour relies heavily on the use of coarse-grained (CG) models based on effective CG interactions.[1] In our research, we develop multi-scale ML approaches to construct accurate and computationally-efficient CG many-body interaction potentials for complex colloidal systems composed of particles of arbitrary shape and with highly anisotropic interactions.[2] In our proposed approach, either the CG forces[3] or many-body effective interactions,[1,2] which are extracted from reference fine-grained simulations, are represented by ML models constructed in terms of structural descriptors of local particle environments. This simple yet accurate coarse-graining framework may enable the characterisation, understanding, and prediction of the structure and phase behaviour of relevant soft-matter systems by direct and efficient simulations.