In this thesis, new algorithms for formation control of multi-agent systems (MAS) based on continuum mechanics principles will be suggested. For this purpose agents of the MAS are considered as particles in a continuum, evolving in an n-D space, whose desired configuration is required to satisfy an admissible deformation function. Considered is a specific class of mappings that are called homogenous where the Jacobian of the mapping is only a function of time and is not spatially varying. The primary objectives of this thesis are to develop the necessary theory and its validation on a mobile-agent based swarm test bed that includes two primary tasks: 1) homogenous transformation of MAS and 2) deployment of a random distribution of agents on to a desired configuration. Developed will be a framework based on homogenous transformations for the evolution of a MAS, under 1) no inter-agent communication (predefined motion plan); and 2) local inter-agent communication.

Homogenous transformation with no communication: A homogenous transformation of a MAS under zero inter agent communication is first considered. Here the homogenous mapping, is characterized by an n x n Jacobian matrix and an n x 1 rigid body displacement vector, that are based on positions of n+1 agents of the MAS, called leader agents. The designed Jacobian and rigid body displacement vector are passed onto rest of the agents of the MAS, called followers, who will then use that information to update their positions under a pre-defined motion plan. Consequently, the motion of MAS will evolve as homogenous transformation of the initial configuration without explicit communication among agents when in motion.

Homogenous Transformation under Local Communication: We develop a structure for homogenous transformation of MAS under a local inter agent communication topology. Here we assume that some agents are the leaders, that are transformed homogeneously in an n-D space. In addition, every follower agent of the MAS communicates with some local agents to update its position, in order to grasp the homogenous transformation that is prescribed by the leader agents. We show that some distance ratios that are assigned based on initial formation, if preserved, lead to asymptotic convergence of the initial formation to a final formation under a homogenous mapping.

Deployment of a Random Distribution on a Desired Manifold: Deployment of agents of a MAS, moving in a plane, on a desired curve, is another interesting task that is considered as an application of the proposed approach. In particular, a 2-D MAS evolution problem is considered as two 1-D MAS evolution problems, where x or y coordinates of the position of all agents are modeled as points confined to move on a straight line. Then, for every coordinate of MAS evolution, bulk motion is controlled by two agents considered leaders that move independently, with rest of the follower agent motions evolving through each follower agent communicating with two adjacent agents.