

## Persistent Submanifolds of $SE(3)$

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**Abstract:** A machine or mechanism is made up by rigid bodies, called *members* or *links*, coupled by *kinematic joints* or *pairs*. Usually, one body is fixed to ground, whereas one, called {end-effector}, interacts with the environment. Innovation in mechanism analysis and synthesis calls for the characterization and classification of the end-effector task space, namely the ensemble of end-effector poses. A smooth task space is readily modeled by a submanifold of the special Euclidean group  $SE(3)$ , which we refer to as a *motion manifold*. Much important, in engineering applications, is also the study of velocity fields, namely the infinitesimal instantaneous motions, called *twists*, that a link (especially the end-effector) may perform. The instantaneous motion can be seen as a local linearization of the end-effector motion manifold. Moreover, the instantaneous motion is related, by the principle of virtual work, to the forces and moments, called *wrenches*, that the end-effector may transmit. Mechanisms in practice often share the following fundamental property: the instantaneous twist space generated by the end-effector at a generic pose is a rigidly-displaced copy of the one generated at the home configuration, i.e., the tangent spaces at all points of the motion manifold are mutually congruent. Such a *persistent manifold* can be seen as the *envelope* of a persistent twist space rigidly moving in  $SE(3)$ . In this paper, we shall summarize, in a chronological order, three important classes of persistent manifolds that have so far been systematically investigated in the literature and have paramount engineering relevance, namely the *Lie subgroups*, the *persistent product-of-exponential* manifolds, and the *symmetric subspaces*. In each case, the persistence property arises from a distinct manifold structure that dictates the ensuing classification and synthesis problem. In this regard, we present classification and synthesis of persistent manifolds for a general audience.