MODELS, REPRESENTATIONS, AND ANALYSES
OF
TOLERANCED ONE-DIMENSIONAL ASSEMBLIES

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Cornell University 2000

Manufactured mechanical parts exhibit variations of geometric form and material properties. To insure interchangeable assembly and proper function, mechanical designers use tolerances to specify allowable limits for these variations. Manufacturing engineers select suitable processes and inspection techniques to insure that these tolerances are met.

Designers assign dimensional tolerances to parts that are *sufficient* for assembly – i.e. the parts are guaranteed to assemble if the tolerances are satisfied. We show in this thesis that current tolerancing practices are overly conservative (and hence the parts so toleranced are overly expensive) because no systematic methods are known to determine complete sets of *necessary* conditions for assembly.

We resolve this deficiency for one-dimensional assemblies. More specifically, this thesis uses graphs to represent one-dimensional assemblies, and formulates the necessary and sufficient conditions for assembly from information obtained by traversing certain cycles (called *assembly cycles*) on the graphs. We show that important assembly metrics – the maximum relative motion between parts and the maximum "gap" that can occur in an assembly – can also be formulated in terms of assembly cycles.

These concepts are used to define GapSpace, a vector space model of the distances between specified feature pairs in an assembly. GapSpace may be divided into two orthogonal complementary subspaces: assembly space and position space. We show that three assembly criteria – non-interference, maximum relative motion, and maximum possible gap – may be combined to define bounded regions in assembly space. Bounded regions may also be defined by dimensional tolerances, and if a tolerance region is contained within an assembly-criteria region, parts satisfying the tolerances will meet the assembly criteria.