SCALED DYNAMICS

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ABSTRACT

Scaled experimentation is an important experimental approach for the investigation of complex systems. Unfortunately, scaling is plagued by scale effects, where changes in behaviour with scale can be so significant to undermine any scaled investigation. The state-of-the-art in scaled experimentation remains dimensional analysis founded on dimensionless quantities and the over one-century-old (Buckingham Pi) theory [1]. Unfortunately dimensional analysis offers no solution to scale effects and consequently scaled experiments although important provide only limited usefulness at the present time.

This paper is concerned with a new approach to scaled experimentation founded on the theory of finite similitude [2] applied to continuous dynamical systems. The new theory applies the metaphysical concept of space scaling, where objects, prototypes, systems, experimental apparatus and facilities are scaled by the means of space contraction or expansion. Although space scaling is clearly practically impossible what is possible is an assessment of the effects of space scaling on the governing physics and a comparison with real experimental behaviours.

It is shown in the paper how the new theory accounts for all scale dependencies and unlike dimensional analysis is able to accommodate known scale effects. It provides also alternative scale-invariances that cater for the situation where scale effects are present but unknown. This aspect is the focus here with application of a first-order finite-similitude approach, which involves two scaled experiments at two distinct scales. The basic idea underpinning finite similitude is depicted in Fig. 1, where the scaling of space and its combination is illustrated. A particular nice feature of the space-scaling approach is that it can be applied to all physics and consequently scaled models for such things as planetary motion, mechanical systems, electrical circuits and all manner of complex behaviour can in principle be investigated. Attention here is limited to relatively simple mechanical-dynamical systems to illustrate the underpinning concepts but also to highlight the huge potential for the new approach.

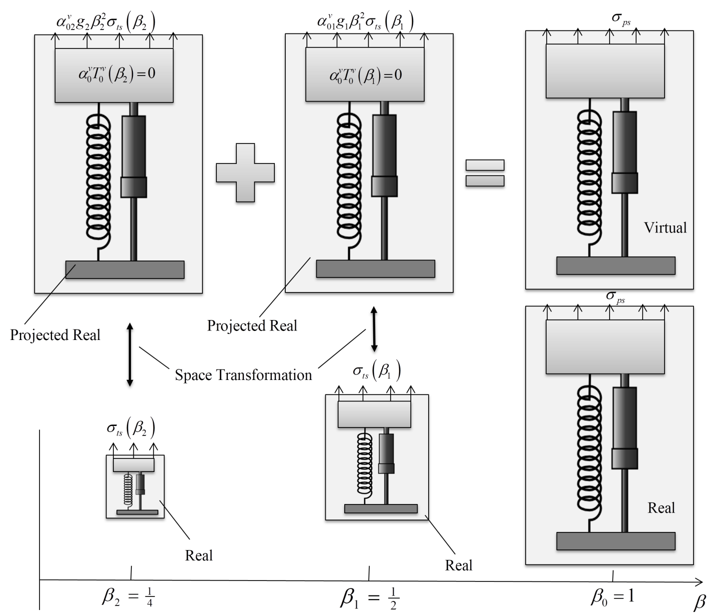

Figure 1: Two experiments are space scaled and combined to predict full-scale behaviour

Keywords: Scaled Experiments, Dynamical Systems, Finite Similitude.

[1] Buckingham, E. 1914 On physically similar systems; illustrations of the use of dimensional equations *Physical Review*, **4(4)**, p. 345.

[2] Davey, K., Darvizeh, R. and Al-Tamimih, A. 2017 Scaled metal forming experiments: A transport equation approach. *International Journal of Solids and Structures* **125**, pp. 184-205.