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Title: A Building-Block Approach to the Conceptual Design of Shape Adaptive Structures

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Structural instabilities have traditionally been regarded as a failure mechanism; more recently, they have been exploited as a means of designing shape adaptive structures. We are designing a passively actuated morphing aerodynamic device which will utilise structural instabilities as a means of deploying. There are three main requirements of this device; Firstly, it must exhibit large elastic deflections in response to small changes in a controlling parameter. Secondly, the structure must not exhibit significant deflections until the controlling parameter reaches a critical level. Finally, it must not undergo further shape change once it has traversed this large deflection regime. In effect, this creates a ‘binary’ device, which is either fully stowed or fully deployed depending on the level of the controlling parameter.

These needs are partially met by a structure with a snap-through instability, which exhibits a sudden shape change when a limit point is reached. However, there will normally be significant deflections before this point, which violates the second design requirement. A super-critical branching point structure is also only partially satisfactory; whilst output deflections are initially small, out of plane deflections after the critical point occur gradually. Such structures also rapidly re-stiffen, limiting the amount of possible shape change.

Taking a building-block approach, we combine structural components with different fundamental instabilities into a morphing structure with the desired response. To aid the conceptual design of such a structure, we first explore simple analytical bar-and-spring models with limited degrees of freedom. To achieve the desired response, the output of one structure is connected to the input of a second—for example, the output deflection of a branching point structure becomes the controlling parameter for a second structure with a snap-through response. The total potential energy of the whole system is computed to identify the equilibrium paths and their stability.

Using these simple models, we demonstrate that structures which combine basic instabilities can be used to create ‘binary’ devices which meet our requirements. We show that these models can be used to capture the behaviour of more complex structures which operate using the principle of combining instabilities. Future work will focus on using such models as a tool for designing shape adaptive structures.