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Kinematic synthesis of planar, shape-changing rigid body mechanisms for slat design profile

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ABSTRACT – This paper presents a kinematic procedure to synthesize planar mechanisms that are capable of approximating a shape change defined by a set of morphed slat design profiles. This work applies a chain of rigid bodies connected by revolute and prismatic joints that can approximate a general set of design profiles that have significant differences in arc length. To achieve a single degree of freedom (DOF), a building-block approach is employed to mechanize the fixed-end shape-changing chain with the helped of Geometric Constraint Programming technique as an effective method to develop the mechanism.

1. INTRODUCTION

Some mechanical systems function by their capacity to vary between specific shapes in a controlled fashion. Consider the advantages of an aircraft wing that can change between different profiles for loiter versus attack modes. The US military constantly search for exotic technologies that will enable aircraft wings to actively change shapes to achieve a wider range of aerodynamic performance and flight control not currently achievable by traditional wing technology [1].

An alternative to the above technologies is shape-changing rigid-body mechanisms with the advantage of lower cost, greater displacements and higher load carrying capabilities. Additionally, rigid-body linkages have a well-established set of mechanical design principles. The concept has been applied to open design profiles [2,3] and closed design profiles [4].

A new shape-changing slat design is proposed where the profiles are considered to move from loiter to attack modes. The synthesis process is started with a segmentation phase that creates segments, which are optimized in shape and length so that they approximate corresponding portions on each desired profile. To complete the synthesis, a mechanization phase applies building-block approach to a selected segment and adds binary or ternary link in order to achieve a lower degree-of-freedom (DOF) linkage. If possible, a 1-DOF system is preferred for simplicity in control.

2. TARGET PROFILES

The design profiles may be defined by any number of points spaced at various intervals, producing a wide range of c_{j_i}. To proceed with kinematic synthesis, the design profiles are converted to target profiles that have common features. It is important for the target profiles to have common features so comparisons can be made and a chain of rigid-bodies can be formed that when repositioned will approximate all design profiles. In earlier work [3], the design profiles were assumed to be of roughly equal arc lengths, $C_1 \approx C_2 \approx ..... \approx C_p$. In that case, the design profiles could be converted to target profiles that all have the same number of defining points n distributed equally along the design profile so that each segment has roughly the same length, $c_{1_1} \approx c_{1_2} \approx .....c_{1_n} \approx c_{p_n}$.

3. SEGMENTATION

Prismatic joints are introduced among the rigid-bodies to approximate the target profiles in order to change between shapes of different lengths using rigid-bodies. Shamsudin and his colleague [5] show a method in preparing the target profiles to convert into prismatic joint(s). The curvature of target profiles is calculated to identify regions where prismatic joint(s) can be implemented and a scheme is adopted to inspect the target profiles for regions of similar curvature that can be candidate for locating the prismatic joints.

A complete segmentation of shape-changing slat where the revolute and prismatic joints are implemented on the segment is shown in Figure 1. In this design, the prismatic joints are applied into Segment 1 through Segment 3 and Segment 5 with Segment 6.

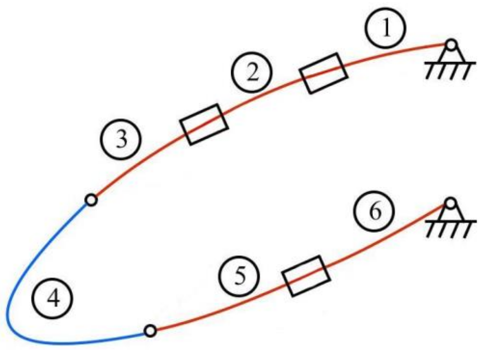

Figure 1 Segmentation of the shape-changing slat that consists of revolute and prismatic joints.

4. MECHANIZATION

Once a set of rigid-body segments has been generated through the segmentation process, these segments are accordingly joined together to form a linkage as the prismatic joints are used to join in between prismatic links while the remainder links are joined together at the end points with the revolute joints. In order to achieve 1-DOF for mechanism with prismatic joint, the application of building-block approach [6] is needed for mechanization stage as it is widely accepted for analysis [7,8] and synthesis [9,10] of planar mechanism. The rigid segments are constructed in the sketching mode of a parametric design software package, and Geometric Constraint Programming (GCP) [11] techniques are employed.

4.1 Mechanism

The development of mechanism of shape-changing slat is based on precision position synthesis. In this approach, the linkage is designed such that the coupler passes through three prescribed positions. Figure 2 represents the movement of slat mechanism in three prescribed positions where the slat deployed from cruise through landing position. Position 1 represents the slat is on cruise state, Position 2 refers to takeoff state while landing state when the slat at Position 3. As the input force is applied, the slat moved to Position 2 as ternary link is rotated at the angle of a. Position 3 is achieved when ternary link is rotated until the angle reached at the angle of b.

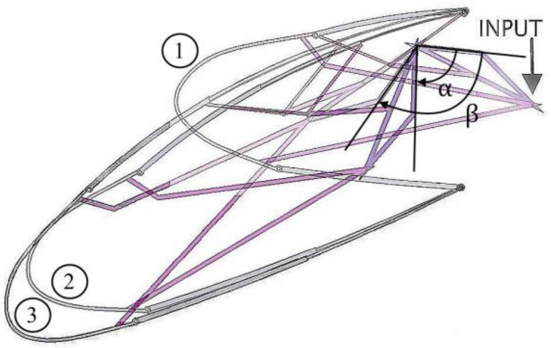

Figure 2 The slat is deployed according to three prescribed positions; Position 1 at cruise state; Position 2 at takeoff state; and Position 3 at landing state.

5. CONCLUSIONS

The work in this article proposes a synthesis procedure to synthesize mechanism compose of combination of rigid links joined together with revolute and prismatic joints to approximate a desired shape change of profiles defined by three prescribed position. By applying prismatic joints into the segments in result the mechanism can be simplified by decreasing the number of link of each segment. To achieve 1-DOF mechanism for the fixed-end changing chain, subchains referred to as building-blocks are assembled, and prismatic joints can be implemented in any of these building blocks except the binary link auxiliary blocks. With the application of GCP technique, the development of the mechanism is easier as GCP gives a comprehensive graphical representation of the large and complex constraint set thus provides a very effective method to design the mechanisms.

6. ACKNOWLEDGEMENT

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