Learning the buckled geometry of 3D printed stiffeners of pre-stretched soft membranes

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In this work, we propose an Artificial Intelligence (AI)-based methodology to learn the buckled configuration of stiffeners 3D printed onto a pre-stretched soft membrane. The membrane acts as a muscle and, if properly pre-deformed, leads to buckling of the stiffeners so that the resulting configuration can provide new system functionalities. Fused deposition modeling was carried out through a Voron 2.4 3D printer, specifically calibrated for PLA printing on a Lycra fabric. The printed PLA allows a controlled deformation of the substrate-stiffeners system; different patterns or stiffeners geometries were investigated, to better understand their effects on the buckled configuration. A finite element model was then set to numerically reproduce the results obtained in the experimental campaign; to catch at best the outcomes, in terms of out-of-plane deflection in the buckled mode, an inverse problem was solved to tune the (nonlinear) constitutive models adopted for PLA and Lycra. Since the numerical model proved to be excessively time-consuming, a surrogate was developed by way of deep learning. In the first stage, YOLO (You Only Look Once) was used and trained properly for feature selection: different geometries of the stiffeners were allowed for and their classification was carried out, in addition to the numerical estimation of their relevant features related to the in-plane geometry. In the second stage, a regression part was added to the AI-based tool to learn the out-of-plane deflection, handled as a label in the learning stage. Results are shown to testify the capability of the proposed approach, and its efficiency for next use in a shape optimization of the 3D printed geometry to attain specific targets of coupled system response.