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Comparison of Deformation Models of Flexible Manipulator Joints for use in DEMO

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A hybrid kinematic manipulator (HKM) is being designed at RACE (Remote Applications in Challenging Environments) to handle the large breeder blanket segments for DEMO. The payload of this HKM is around 80 tonnes, and its trajectory requires stringent position accuracy as it passes key points, in order to manoeuvre the blanket into and out of position in the vacuum vessel. The TARM (Telescopic Articulated Remote Mast) at RACE is also under upgrading, and it is necessary to investigate its's deformation displacement due to its massive weight and the payload.

From the past experience of heavy duty robotic machines, it is noticed that deformation of the manipulator joints contribute significantly to the end-effector displacement. In order to compensate such end-effector deformation displacement in the control system, it is necessary to develop computation-effective deformation model of the flexible joints. In addition the deformation model can be further utilized to optimize the end-effector trajectory by using the iterative algorithms.

In order to support the large payload, the joints of the manipulator are complex, making it unreasonable to employ the truss and beam simplifications from the structural mechanics. The finite element analysis (FEA) method can estimate the deformation of a complex structure with high accuracy given the payload, however, its computation consumption makes it prohibitive to apply to the control system and in the iterative algorithms.

The paper proposes two approaches to model the joint deformations: a non-parametric ANN (artificial neural network) model and a parametric model using the Bayesian Markov Monte Carlo method. Both models are trained and identified off-line using a basic dataset from the FEA of the target joints. After the models are well established, they can be used in the control system or iterative optimization algorithms in real-time. In practice, the proposed methods can also be carried out to model the deformation of joints incorporating the transmission mechanisms, based on real on-site measurement data.

The comparative results of applying proposed deformation models on different joints are presented in the paper. The validation of the non-parametric ANN model and the stochastic process based parametric model are conducted, individually, by comparing with the results of applying the FEA on several joints of HKM and TARM. The study can provide a good premise for constructing the entire computation-effective deformation model of manipulators that will be employed in the DEMO.

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