Design and characterization of an array of micro-twisted-string actuators

Universität Stuttgart

S.A. D souza, S. Janzen, J. Liu, P. Mühlbauer, P.P. Pott
Institut für Medizingerätetechnik, Universität Stuttgart, Deutschland

Institut für Medizingerätetechnik

Background

- The basic function principle of the Twisted String Actuator (TSA) is the one-sided rotation of two or more cords with a circular cross-sectional area which causes a contraction and a tensile force at the opposite end and achieves the principle of a rotary-translatory transmission gear [1].
- The TSA is a type of linear actuator that is simple, low-cost, compact and lightweight in nature. It is particularly suited for highly integrated robotic devices designed to interact with humans or unknown environments due to its negligible inertia and limited stiffness [2].
- Disadvantageous is its scalability with regards to its geometric dimensions because it can achieve a maximum relative contraction of 29.3 % independent of string diameter [3].

Goals

- Scaling the mechanism in terms of the number of compact and powerful actuator modules connected to each other, similar to the structure of a muscle.
- Developing an inexpensive design concept for a scalable system of spatially arrangeable Twisted String Actuator Modules (TSAMs).
- Implementing it using additive manufacturing methods and to characterise it in terms of the tensile force generated and total stroke achieved by the system.

Results

- A modular, low-cost, lightweight, spatially arrangeable and function integrated TSA Module design is achieved.
- A 6 x 3 array of TSAMs has been built and characterised.
- An anti-torsion passive return mechanism has been developed.

Table 1: Characteristic values for the TSAM and TSAM Array

Description	Value
Length of the string available for twisting	69 mm
Total length of the TSAM (dovetail connector to connector)	117 mm
Voltage applied to the H-bridge	9 V
Peak current drawn by the TSAM	2.5 A
Total displacement of TSAM with a force of 5.4 N	13 mm
Total length of the array (from plate to end of the linear bearing)	425 mm
Peak current drawn by the TSAM Array	15.6 A
Total weight TSAM (without electronics)	13.4 g
Total displacement of TSAM Array with a force of 15 N	3 mm
Total weight TSAM Array (without electronics)	400 g

Conclusion

- The array built shows that a parallel and serial connection can generally increase overall tensile force and stroke.
- A stronger motor could be implemented to increase both force and stroke.
- The TSA Module Array did not provide a multiplication of force as expected due to different internal resistances of each module which led to modules twisting at different speeds in turn causing an uneven force distribution. The modules would not come back to their initial positions on untwisting due to insufficient motor control which can be solved by introducing a revolution counter to get the angle of rotation.

Methods

- The methodology to develop and design technical systems following the VDI 2221 guideline was used. Evaluations took place following the VDI 2225-3 guideline.
- Additive manufacturing was used to develop the prototype. The materials used were PLA and TPU 95A and were printed using 3D printers utilizing the Fused Deposition Modelling (FDM) technique.
- The array uses three force sensors, a photoelectric slot sensor and three dual H-bridges which are all controlled using a microcontroller based on the Arduino Nano architecture.

Spatially arrangeable Twisted String Actuator Module (TSAM)

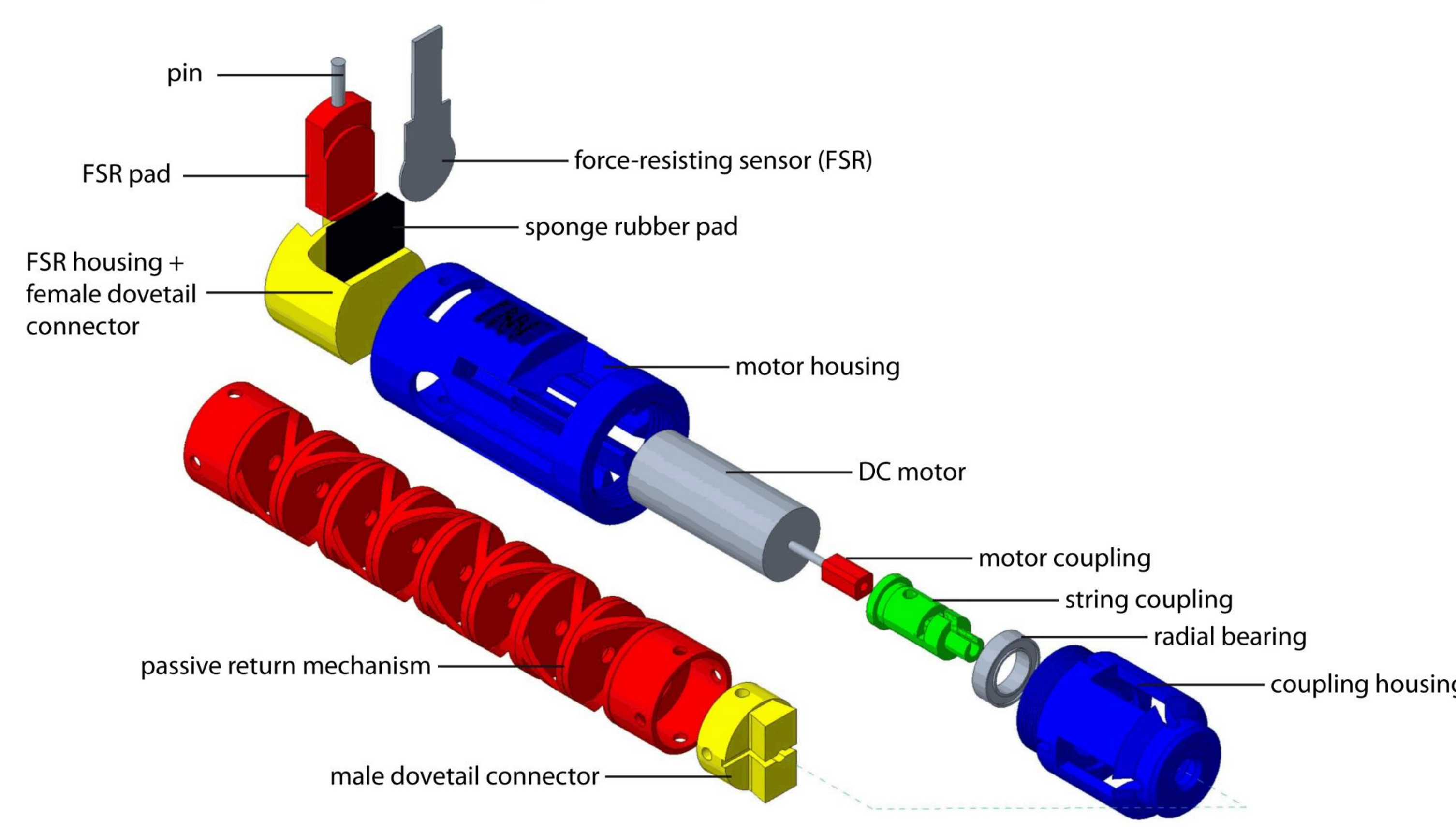

Figure 1: Explosion view of the concept design for the TSAM.

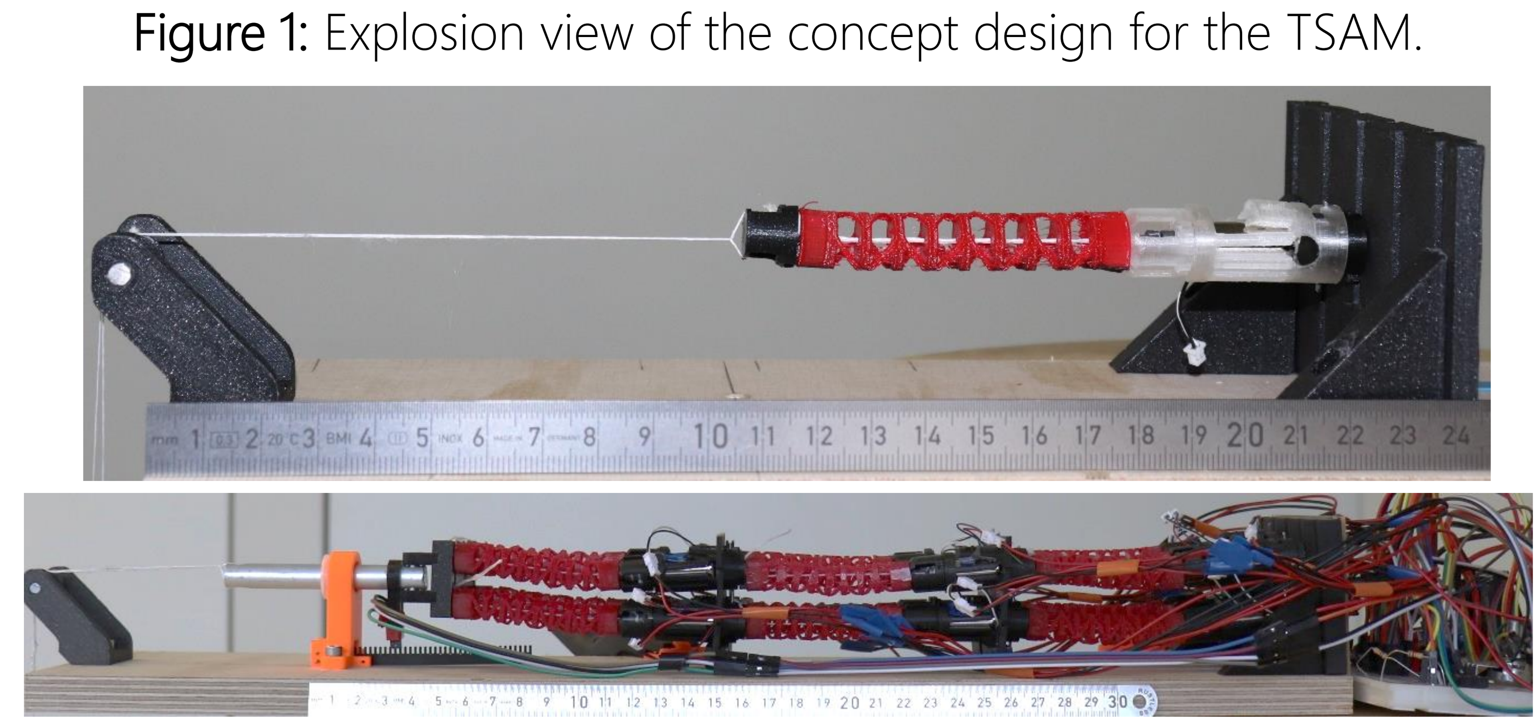

Figure 2: Test bench setup for the TSA Module (above) and TSAM Array (below).

Characterisation Results

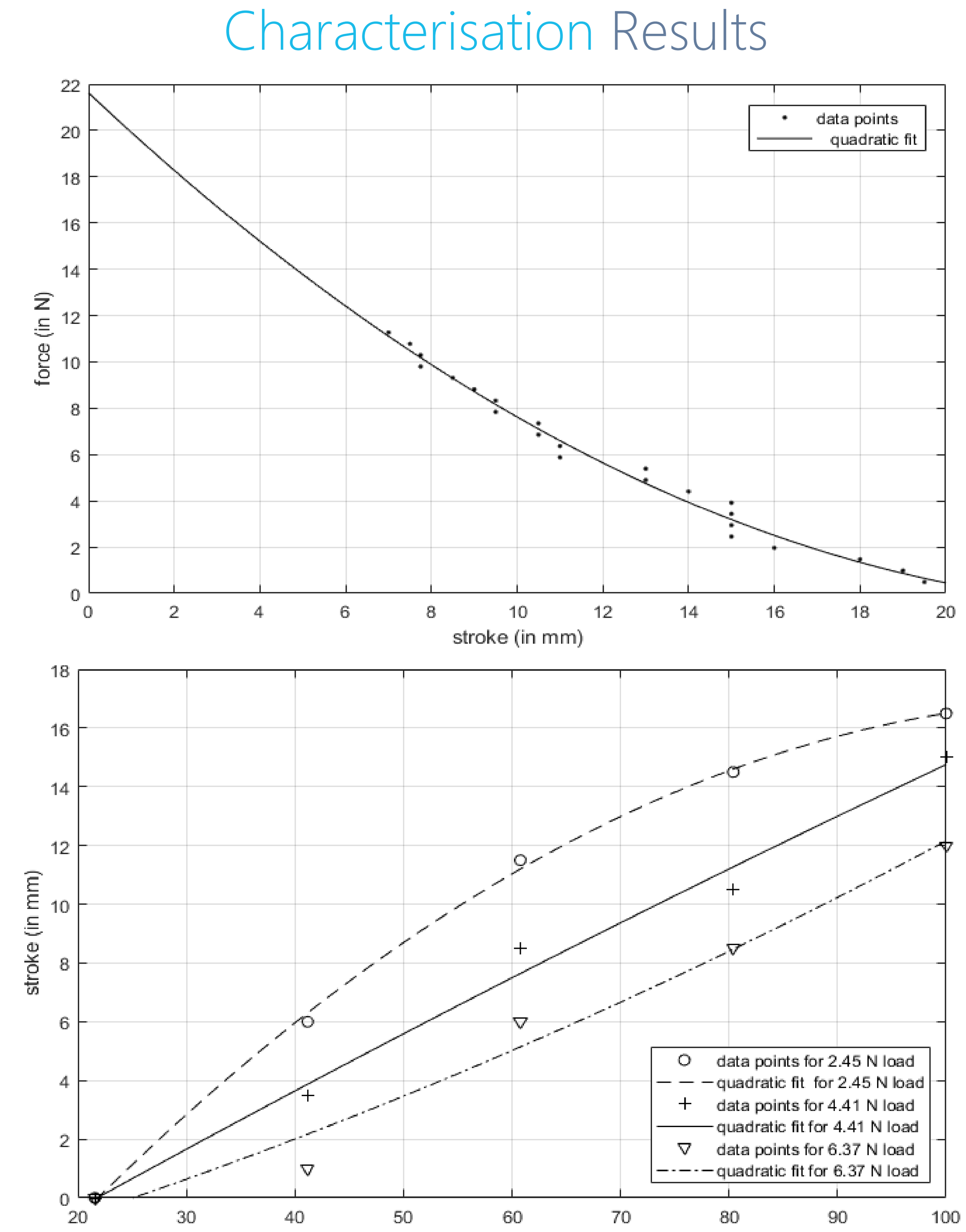

Figure 3: Characterisation curves for the TSAM: force VS. stroke (top) and stroke VS. PWM duty cycle (below).

Literature

1. R. Müller, "Leichtbauantriebe mit hohen Kräften für Orthesengelenke," Dissertation, EMK, Technische Universität Darmstadt, 2017.
2. G. Palli, M. Hosseini, and C. Melchiorri, "Experimental Evaluation of Guided Twisted Actuation," IFAC-PapersOnLine, vol. 49, no. 21, pp. 380–385, 2016.
3. A. Tomalka, "Determination of biomechanical and architectural muscle properties : from single muscle fibre to whole muscle mechanics," Dissertation, Stuttgart, 2018.