Executive Summary

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1. **Title of the Project:** ABDUL KALAM TECHNOLOGY INNOVATION NATIONAL FELLOWSHIP for **Development of a Soil-moisture Sensor, an Intracranial Pressure Sensor, and an Assistive Chair for the Elderly and Arthritics**

2. **Date of Start of the Project:** 01.01.2018

3. **Aims and Objectives:**

(i) In situ soil-moisture sensor.

To commercialize a soil-moisture sensor equipped with solar power and wireless transmission for long-term deployment in the field.

(ii) Implantable intracranial pressure (ICP) sensor.

To design a micromachined pressure sensor packaged for implantation in the subdural part of the brain and with integrated electronics for read-out.

(iii) An assistive chair for the elderly and arthritics to help in sitting and rising and possibly simple exercises.

To develop a safe and ergonomic chair that does not use external power but uses a customized compliant spring mechanism to provide resistive force while sitting and assistive force while rising, without reliance on a caretaker.

4. **Significant achievements (not more than 500 words to include List of patents, publications, prototype, deployment, etc.)**

A Dual-Probe Heat-pulse (DPHP) soil-moisture is fully developed, packaged, and tested in the laboratory and the field. A highlight of the sensor is that it can give the volumetric water content of the soil, in situ, with 3% accuracy, irrespective of the soil density. A comprehensive protocol was developed for calibrating the sensor. Furthermore, the performance of the DPHP sensors was enhanced by identifying an undesirable path of heat and subsequently eliminating it with re-design of the package through circuit modeling and experimentation. Through extensive experimentation, the factors that affect the reliability of the sensor were identified and rectified. We have also interfaced with three companies for widespread field testing. A picture of the sensor and its mounting are shown in Fig. 1. This project has resulted in two journal papers [Sensors and Actuators A: Physical, A 279 (2018), pp. 638-648.; Sensors and Actuators A: Physical, Vol. 318, 1 February 2021, 112520, https://doi.org/10.1016/j.sna.2020.112520] and one conference paper.

Fig. 1 IISc Soil-moisture sensor

In the assistive chair project, we have developed a mechatronic chair and an all-mechanical chair to ease sitting in and rising from a chair. The mechatronic chair used a series-elastic actuator and human modeling using multibody dynamic. The mechatronic chair enables the user to experience different designs and choose the most comfortable. The mechanical chair can be customized with two simple insertable cams that provide the same experience to the user. The mechanical chair has at its core, a new compliant hinge mechanism (shown in Fig. 2). It consists of an open-section shell that twists and bends simultaneously. The highlight is that it has no bearings and yet it makes the chair-seat tilt about a virtual axis as the user sits in or rises. It also gives customized torque about that axis to support the user during sitting and rising maneuvers. The torque-angle characteristic has negative-slope region and bistability that are critical to the operation. The cams—the critical elements used for individual and mass customization—are simple enough to make. We have developed a computational method to design the cam profiles for a user based on the experience on the mechatronic chair. The compliant mechanism has received PCT approval and the patent applications in India and elsewhere are under process. One journal paper [J. Mechanisms Robotics. Dec 2020, 12(6):

061010 (10 pages), JMR-19-1538 https://doi.org/10.1115/1.4047440] and two conference papers are published under this project. A company (Neu Integral Med Tech) has been incubated in IISc to commercialize the chair.

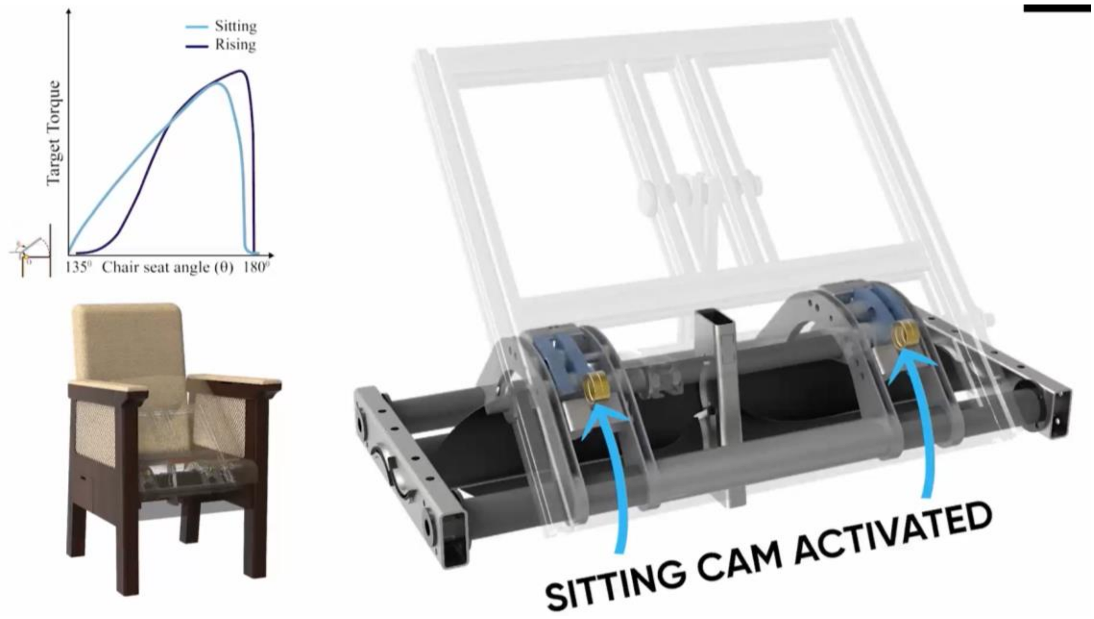

Fig. 2 A patented compliant hinge-mechanism in the mechanical chair. The cams are pointed by the arrows. There us a pair of cams for sitting and another pair for rising. The chair automatically switches between the two pairs as the user sits and rises.

In the third project on intracranial pressure sensor, we have stumbled upon an unusual problem of moisture or aqueous medium affecting piezoresitive sensors: the sensors that work perfectly in air show long-lasting drift in the presence of water. This fact was reported in two or three papers, but it was buried. There were no clear guidelines on how to passivate the piezoresisters. We have conducted extensive experiments to establish those guidelines. We are now in the process of finalizing the passivation technique to make the sensor robust to exposure to water.

5. Concluding remarks

The soil-moisture sensor project is funded by the Ministry of Electronics and Information Technology and the assistive chair project was funded by the Technology Initiative for the Disabled and the Elderly, Department of Science and Technology. The funding from the INAE Technology Innovation fellowship was used to augment these two sources of funding to explore newer approaches and to meet the unforeseen expenses.

The soil-sensor and assistive chair projects are well poised for commercialization. They have already reached Technology Readiness Level of 4. The intracranial pressure sensor project uncovered a hitherto less-known problem of influence of moisture on micromachined piezoresitive pressure sensors. The remedies developed as part of this project are likely to spur successful translation of the pressure sensor for this implantable biomedical application.

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Bhagini (IIT-B) [soil-moisture sensor] and Prof. K. N. Bhat (IISc) [intracranial pressure sensor] are also gratefully acknowledged.