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Self-Adapting Robotic Auxiliary Hand (SARAH) for SPDM Operations on the International Space Station

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Abstract

The development of the Self-Adapting Robotic Auxiliary Hand (SARAH) for the Special Purpose Dextrous Manipulator (SPDM) is motivated by the need for robotic devices to support increasingly complex dextrous robotic operations on the International Space Station (ISS). SARAH's ability to grasp a large range of geometrical shapes, makes it an ideal multi-purpose tool used for unstructured and unrehearsed ISS operations. Further, it is anticipated that the use of the SARAH could save important Extra Vehicular Activity (EVA) time primarily in the areas of work site setup, work site support and EVA equipment handling.

SARAH is being developed as a collaborative effort between MD Robotics Limited and Laval University. It consists of three under-actuated fingers mounted on a common structure. The fingers can envelop various shapes including cylindrical and spherical geometries. The key novelty of SARAH's design is that it is a completely self-contained, passive mechanism requiring only the existing SPDM-OTCM drives mechanism to actuate its fingers. The opening/closing of the fingers and the finger orientation are performed by the OTCM-Torque Drive Mechanism, while the switching between the two modes of operations are done by the Advance Mechanism of the OTCM.

Possible Extra Vehicular Robotics (EVR) operations for SARAH include: SPDM stabilization when operating on the end of SSRMS in an unplanned environment, load application for stuck mechanisms, thermal blanket manipulation, temporary ORU storage location, auxiliary ORU manipulation, and EVA work site set-up (WIF insertion, PWP manipulation etc.). Ideally, this tool would provide increased SPDM functionality for unplanned operations and emergency situations. EVA operations include general work site support where SARAH would provide temporary stowage of EVA tools and equipment and ISS apparatus.

1 Introduction

The Self-Adapting Robotic Auxiliary Hand (SARAH) is a dedicated tool designed to be used by the Special Purpose Dexterous Manipulator (SPDM) (see Figure 1), a sophisticated robotic system that is part of the Canada's contribution to the International Space Station (ISS).

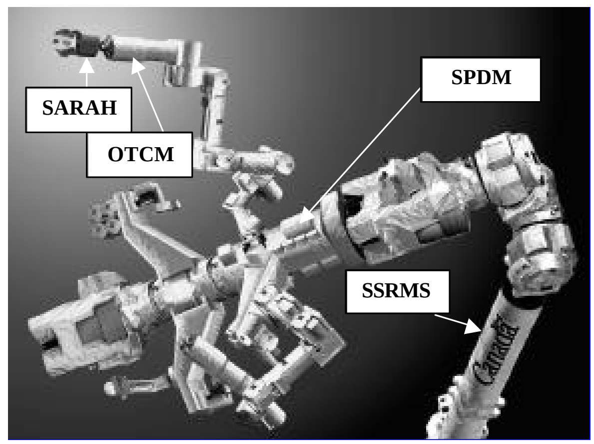

Figure 1: Special Purpose Dextrous Manipulator (SPDM)

The SPDM's main function is to support maintenance operations on the ISS. It consists of a robot with two arms and an articulated body coupled with sophisticated vision, force sensing, and control subsystems. The ends of both the SPDM's arms are fitted with two general purpose end-effectors called the ORU-Tool Change Out Mechanism (OTCM), see Figure 2. During SPDM operations, the OTCM function is to support manipulation of Orbital Replacement Units (ORUs) and SPDM tools. The OTCM acquires ORUs and tools by gripping specially designed standard interfaces (Micro Interface), torquing and untorquing bolts, and by providing umblilical electrical power. An additional function of the OTCM is to act as a stabilizer for SPDM operations. The same OTCM mechanisms used to acquire the ORUs and tools are used to actuate SARAH without any modifications. The main performances of the OTCM are shown in Table 1.

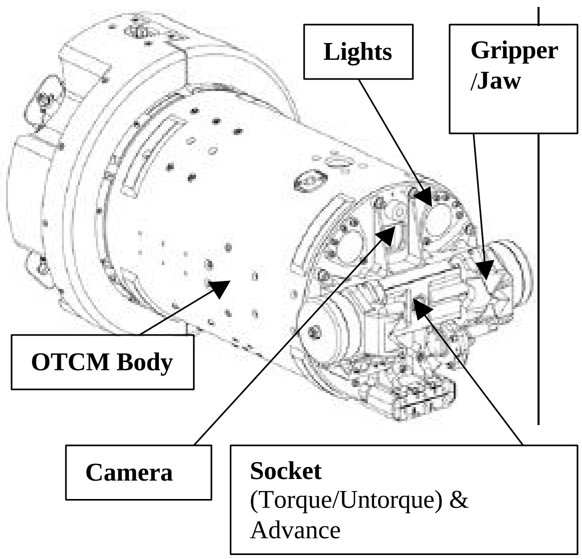

Figure 2: ORU Tool Change Out Mechanism (OTCM)

Table 1: Comparison OTCM vs. SARAH Performances

Performance	**OTCM**	**SARAH**
Interface Capture	Micro & H	Various Geometrical Shapes
Force Capability	2000 lbs.	50 lbs.-Cylindrical Power Grasp 30 lbs.- Cylindrical Tip Grasp
Compatibility with EVA performed tasks	No	Yes Extension of EVA hand
Flexibility	No	Yes, SARAH can support a large number of tasks
Envelope	Diameter 10" Length 24 "	Diameter 7" Length 14" SARAH same envelope as an astronaut hand
Weight	120 lbs.	11 lbs.

2 SARAH Description

SARAH (see Figure 3) is a reconfigurable hand with three self-adapting and orientable fingers. Each of the fingers has three independent phalanges automatically adapting to the shape of the grasped object.

Figure 3: SARAH Prototype

An additional degree of freedom is provided to rotate the fingers to better match the general geometry of the object. SARAH includes only passive mechanisms that are actuated by the OTCM (see Figure 4).

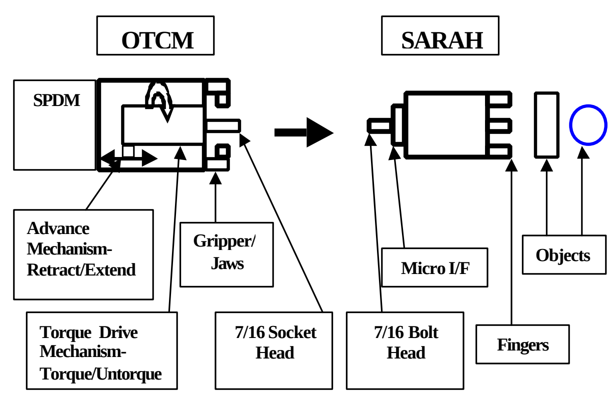

Figure 4: Interaction SPDM/OTCM and SARAH

The OTCM contains two jaws driven by its internal Gripper Mechanism. These jaws are capable of capturing a standard Micro Interface located at the base of SARAH's body. In addition, the OTCM includes a Socket Head that engages a captive hexagonal bolt head (7/16") located at the centre of the Micro Interface. Once SARAH is acquired and secured by the OTCM jaws, the Advance Mechanism of the OTCM extends the OTCM's Socket Head to engage the captive hexagonal bolt at the center of SARAH's Micro Interface. While the OTCM advances/retracts the OTCM socket head, a mechanical switching mechanism inside SARAH selects between two modes of operation: finger positioning (for adapting to various shapes) or closing/opening the fingers.

SARAH includes three fingers consisting of a special linkage topology allowing the fingers to progressively envelope the object being grasped and eventually reach a static equilibrium, see Figure 5, can acquire different shapes due to the opening/closing of the fingers, as well as the finger orientation function are performed by the OTCM-Torque Drive Mechanism while the switching between the two modes of operations are done by the Advance Mechanism of the OTCM.

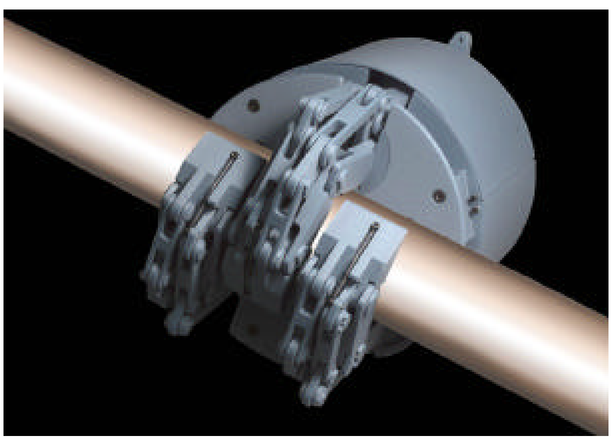

Figure 5: SARAH Grasping/Enveloping a Cylindrical Part

Self-adaptability

A mechanism is said to be *underactuated* when the number of actuators in the mechanism is smaller than the number of degrees of freedom of the mechanism. When applied to mechanical fingers, the concept of underactuation leads to *self-adaptability*. Self-adaptive fingers will envelop the objects to be grasped and will adapt to their shape although each of the fingers is controlled by a reduced number of actuators. In order to obtain a statically determined system, elastic elements and mechanical limits must be introduced in the self-adaptative fingers. Simple linear springs are often used.

In the case of a finger closing on an object, for instance, the configuration of the finger at any time is determined by the external constraints associated with the object. In addition to the selfadaptability *within* the fingers, selfadaptability *among* the fingers is an important feature of SARAH. Indeed, the underactuation between the fingers is implemented by a special one-input/multiple-output mechanism, see Figure 5.

3 Possible Application of SARAH on the ISS

The development of SARAH with dexterous handling capabilities is motivated by the increasing need of robotic devices to support the EVA activities on the ISS. Figure 6 and Table 2 summarise potential applications that may be supported by SARAH. The orientation of the fingers is related to the general geometry of the object, such as cylindrical, spherical and planar. The overall functional requirements of SARAH have been selected to ensure that it is compatible with some possible EVA activities scheduled on ISS. It is anticipated that SARAH will save important EVA time primarily in the areas of work site setup and other related activities. SARAH may also serve as an emergency tool to retrieve hazardous items, or perform unplanned operations.

Space Elements/Objects Handled by SARAH

Typical objects that could be handled by SARAH include EVA tools designed for astronaut use (anthropomorphic interface) on the ISS. The following is a list of potential objects or geometrical interfaces that may be captured and handled by SARAH in support of EVA activities (see Figure 6):

a) EVA handrails are standard fixtures installed around the Space Station to facilitate stabilization and movement of astronauts. SARAH may be used by the SPDM to handle payloads that are fitted with EVA handles and provide restraint for a crewmember in a space suit.
b) Micro and H Interfaces are standard grapple fixtures installed on all ORUs to be grasped by the SPDM.
c) WIF-Passive, Worksite Interfaces (WIF) are standard interfaces providing temporary storage (securing) of EVA hardware. Examples include the Articulating Portable Foot Restraint (APFR) and the Temporary Equipment Restraint Aid (TERA).
d) SARAH may handle a large number of EVA tools in support of EVA missions and emergency operations. SARAH could also handle emergency tools used for retrieving hazardous items.
e) SARAH may be used to support an EVA in setting up the work site and in handling EVA aids on the ISS.

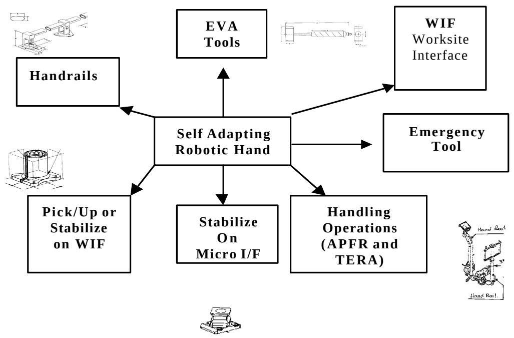

Figure 6: Self-Adapting Robotic Auxiliary Hand–Applications

Table 2: Potential applications of SARAH on the ISS

ISS Applications	Geometrical Shape/ Performances	Remarks
Support of EVA activities in Handling ISS elements	Cylindrical, spherical and planar configurations up to 5 inch	Handling Articulating Portable Foot Restraint (APFR) Temporary Equipment Restraint Aid (TERA) Temporary Equipment Restraint Aid (TERA)
Emergency Tool In Retrieving Hazardous Items	Cylindrical, spherical and planar configurations up to 5 inch	Various shapes
Eva Tool Handling	Cylindrical and Spherical Configuration up to 5 inch Diameter.	80 % of EVA Tools may be Graspped
Limited Stabilisation of the SPDM	Handholds Micro I/F H Interface Space Station Trusses :Diam eter 3inch	SARAH can react a fraction of the I/F loads
Retrieving Orbital Replacement Units (ORUs)	Micro I/F H Interface	SARAH can grasp a Micro or H Interface

4 Conclusions

The development of SARAH and future integration of sensory control will expand the operational range and flexibility for the SPDM on the ISS.

5. References

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