

Wearable Exo-Skeleton Rorot, Skil Mate
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1. Introduction

The authors are proposing a new robotic system concept, "Skil Mate", a wearable exo-skeletal robot for skilled workers. A concept of Skil Mate is created to revitalize almost all human work's skill on production sites introducing cooperation by human and robotic machines.

Skil Mate is designed to have no intelligence and memory such as a conventional robot systems however, it works synchronized with skilled workers when were put on by them. Skil Mate has an exo-skeletal structure covering the workers' arms, hands, fingers, body and legs, if necessary, for their skillful work. Each skeletal shell is driven by actuators getting action commands from workers will. To get the will, authors are introducing haptic receptors and sensors set close with workers' skin.

Skil Mate project was launched in early 1998 and aiming to apply to ground human works such as automobile assembly works and construction field works as a final goal however, set milestones for its technical research and model developments. One of them is space suite application making astronaut's orbital EVA (Extra-Vehicular Activity) easier and faster on their skillful activities.

This paper shows an outline of the concept and technology on Skil Mate and plan for its application to EVA suite.

2. Concept of "Skil Mate"

The authors define a new concept named Skil Mate. The name means its partnership with skilled workers. Skil Mate is defined as a generic name of machines or devices characterized as below.

- (1) It is to be worn by a man of skill is case that he should unavoidably work to accomplish tasks as an expert under various environment including a hostile environment such as in space. He may wear it just he want to have simple power assist to increase his force, or to decrease muscle strain to work longer time. To make Skil Mate wearable, it is composed of light-weight and small mass components, and flexible materials with cloth-like texture.
- (2) It is preferably exo-skeletal structured to envelop the man's body from fingers to toes except face and head however, it is movable enough flexibly

as the man of skill is able to move as his will for skillful work. Exo-skeletal components are shells made from rigid light-weight material and connected each other with mechanical hinges and actuators. It looks as if a smart and powered armor. To get commands for the actuators from human body action as a sign of his will, Skil Mate should be mounted with haptic receptors or sensors as interface between the human body and the object to be manipulated in order to enhance intelligent workability. Consequently it looks like an anthropomorphic robot when it is worn.

- (3) Control system for Skil Mate is designed to follow in response quickly to the movement of the man. Its response must be quick enough as the worker with Skil Mate has feeling without suite and attachments nuisance for their action, supporting his skill as if he is in the most desirable circumstance. Skil Mate requests so quick response without any delay by an electric device and signal processing, and more sometimes faster than his actual action. There may be no robotic technology to forecast human activity except to get a signal from human brain such as electric signal for autonomic nervous system. To make Skil Mate concept more easy to apply to the human, the surgical approach and to insert electrode into his muscle must be avoided. Skil Mate is introducing the quickest signal processing system and modern servo mechanisms to get command input from human force to minimize the time delay.
- (4) Skil Mate covers human body for its exo-skeletal shells and it make easy to protect worker from any force and contingency. Workers in hazardous environment will get benefits from Skil Mate with such special protection layers out side or inside. Skil Mate may be the inevitable work suite for the works in the environment such as under water, low temperature and radiation exposure. Even if the protection layer were so stick making human action slow as a wear for fire-fighting, powered Skil Mate will compensate its mass, inertia and stiffness by its power servo system. Wearing Skil Mate is to feel wearing no clothes and no working suites at all.

3. Application to construction work suite

Nowadays, "industrialized" and/or "advanced" construction systems are more popular in Japan, and they realized more effective production in shorter term and less labor power providing better business profit to construction industries. On their sites, major work is done by powerful construction machines supervised by a high performance information networks with a lot of computers. Some of automatic systems and robots are participating to the sites. It may be true to reduce the cost for manpower on sites means to make business more profitable.

On such construction sites, human workers are going to be one of the construction system segments as a machine operator, or an intelligent transportation device, or a flexible handling machine. Modern and advanced construction systems, such as automated and robotic construction systems, are transplanted high-level performance from human workers to realize human dexterity and skill. The technology might reach our production system at the unmanned construction site in the future. At this time in the future, who can train up the system? Is a robot which can work as the same as the skilled human worker train up its skill by itself? Our answer is "No" and only human can make innovation for the production for the future construction even site works.

There will be no objection to prepare intelligent machine making human worker healthy and safe. Automation and robotization should continue research and development to make human more easy-to-work. Dirty, Dangerous and Hard works will be transferred to machine systems however, human participation for these works should not be avoided to make them make progress to fit the future construction works.

The most advanced car assembly line in Japan are going to have more people not a robot, and it is becoming more handmade not automation. This shows to much advanced production system is hazardous for human worker even if the cost might be minimized and difficult to change its performance to fit the requests from the consumer's and market. They are introducing again human skill to make production flexible, workers specialist and grow the production system more advanced by their workers.

Construction sites are not so automatic and robotized yet like an modern automobile assembly line, but there may be the same situation with them could be seen in the near future.

In the construction sites, there is very few words on missing human skill. It has some special meanings longing for old-fashioned buildings and artistic decoration. Words such as applied for or unmanned system with a lot of machines and computers instead. Engineers and researchers in construction industries look only interested in labor saving, information system, new materials, safety, economics, business and the earth. The authors believe Skil Mate could be one of the most applicable strategy for the future production and human work cooperating machine and human. Harmonized advanced technology must be welcomed to its market and all of the human for

its production.

4. Research and development strategy

Strategy for Skil Mate research and development, the authors found there are several technology and products for it. Belows are some of them.

1) Haptic receptors and sensors

Haptic receptors and sensors are brand-new technology in the robotics. In order to set them between the exo-skeletal shell and human skin very thin, flexible and fine sensors are needed. Finger tip is one of the keys for human skill to grip objects and feel its texture and reaction force. As its area to be fix the sensors is so small, there must be a very fine film type and multi directional sensors. And also actuators to transfer the information from the receptors and sensors must be the same specifications of the sensors. Some new materials could be used for it.

2) Light-weight actuators

Actuators for Skil Mate is a kind of human muscle and there might be not any robotic component that has the close weight/output performance with humans' muscle. Power for the actuators are independent to make human moves by his will, and, such as electric cable and air tube as the umbilical must be avoided. Skil Mate project is introducing air powered rubber as its artificial muscle. (Fig 1) To apply air pressure, not only actuators but control valves are also light-weight and small enough for the Skil Mate.

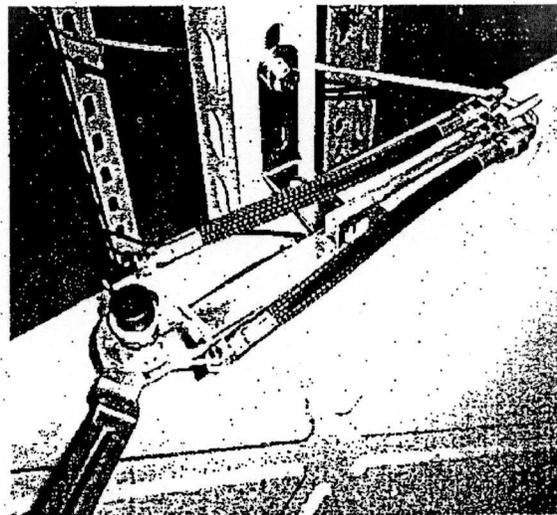


Fig 1 Test model for rubber actuator

3) Exo-skeleton structure

Skeleton structure is one of the vital issue for Skil Mate. There were several idea and models for the exo-skeleton robot system. The most popular image of it is seen on movies and cartoon. Almost all of the have higher performance than human on its work speed and output force. Recent studies shows to utilize power-up human force and reach for specific tasks. (Fig 2,3) The purpose of these ideas are to

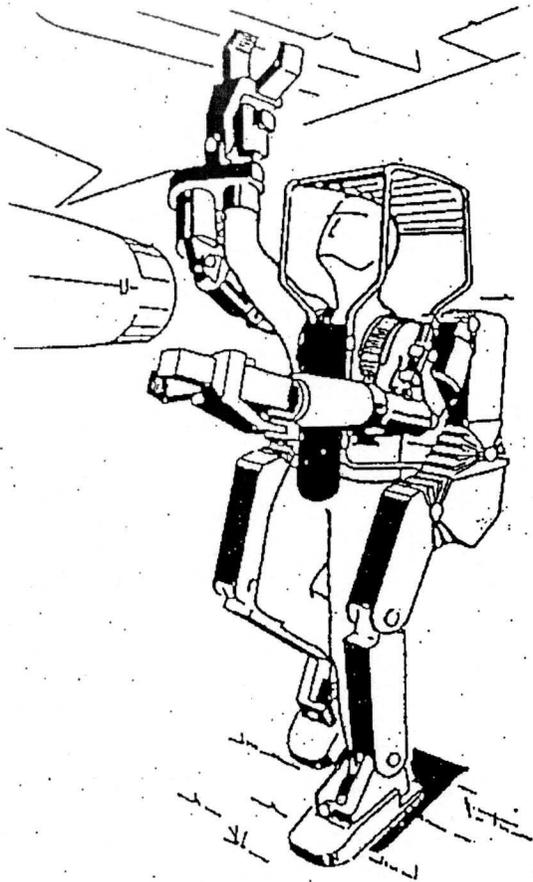


Fig 2 Exo-skelton robot for airplane maintenance

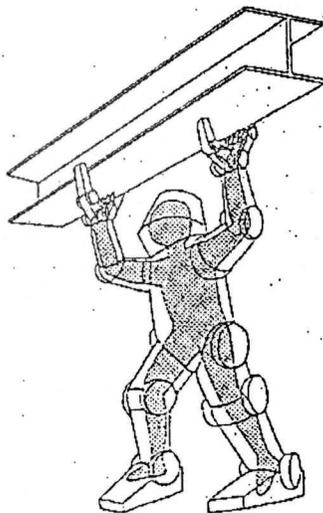


Fig 3 Exo-skelton robot for construction

human workers more powerful with force, and Skil Mate target is to perform human skill with workers.

5. Application to EVA Suits

There were many R&D projects in Japan, aiming at robotizing or automatizing various kinds of manipulation works under hostile or hazardous environments. For instance, in-service inspection on the atomic power station, welding works to steel

constructions for marine rigs in the deep sea, or rescue of persons who with a disaster at the site of fire of chemical plants. In practicing these projects, the authors have learned a marginal utility of advanced robotics. It means that even the most advanced technology of intelligent robotics is not sufficient for the robots carry out necessary manipulation tasks, and consequently we still need the skill of human workers on site. This results another problem whether we can design and produce a safe protection suit model for a skilled worker to perform his dexterity and special tasks without any obstruction to his skill from the suit. Skil Mate is proposed for the protection suits which preserves the wearer's skill. One of the applicable cases is that to the space suits for EVA.

1) EVA suits

To protect human life in space, pressurized suites are used for EVA. The suits is composed from three major parts; liquid cooling and ventilated garment, air-tight and thermal insulation over coat, and life support equipments for oxygen supply etc. including helmet. (Fig 4, Space Suits, Fig 5 Garment, Fig 6. Wearing space suits)

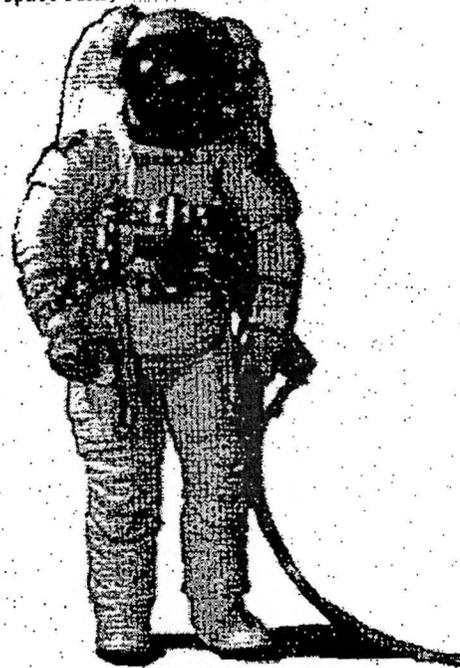


Fig 4 Space suits (NASA)

Preparation for EVA on orbit takes about 20 hours for 7 hours EVA execution to make astronauts can survive under 1/3 atmospheric pressure environment. Materials for the EVA suits cover are not so soft for needed performance and its stiffness makes human skin cut by rubbing. (Fig 7, Space suits cover material composition)

2) Issues for space suits

The difficult actions in space suits are pointed out and two of major issues are; to handle with pressurized gloves and fixed sequential arm action accessing switches located on the chest. Apacc gloves' tip is covered with rigid plastics and astronauts can get no fine touch through its materials.

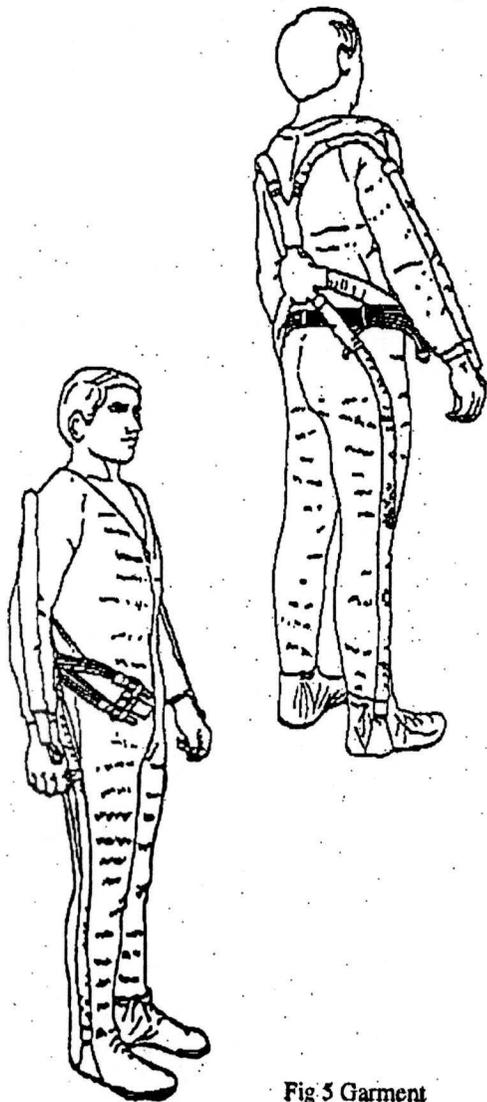


Fig 5 Garment

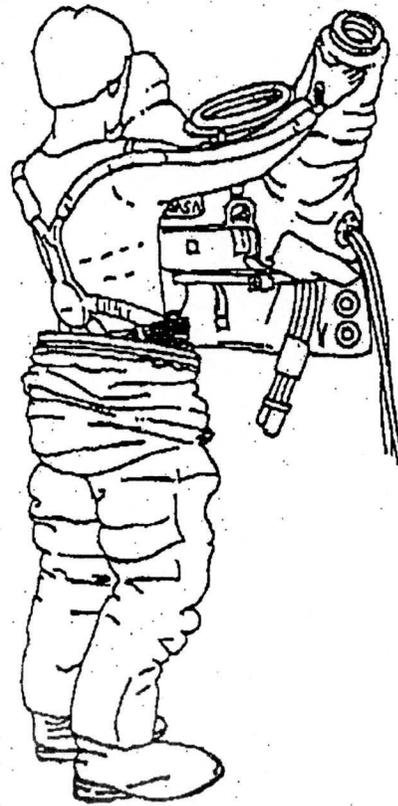


Fig 7 Wearing space suits

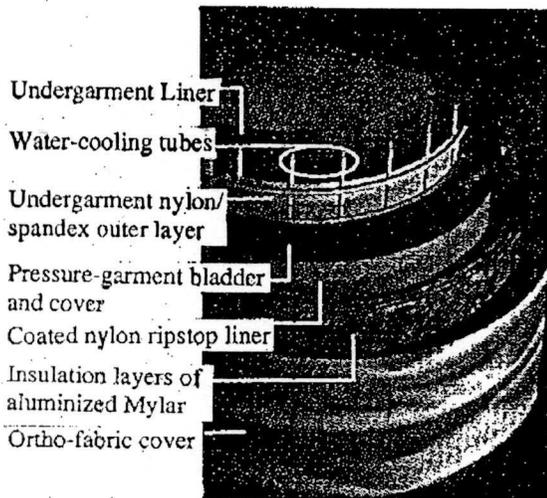
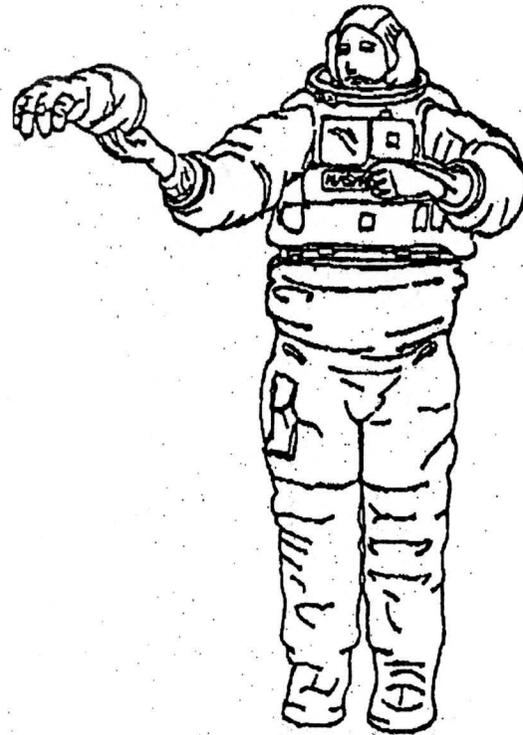


Fig 6 Space suits cover material composition ¹⁾



They can do grip hand rail and push something with their hands however, handling tools and tighten screws are quite hard and time consuming task. Another is caused from the bearings located on the

shoulder and upper arm. As the space suits is not so soft and there must be rotating function is needed to expand its work area. Normal EVA works demands the bearings to the suits for astronauts to open, to close, to raise, to drop their arms.(Fig 8 EVA gripping hand-rail)



Fig 8 EVA, gripping hand rail (NASA)

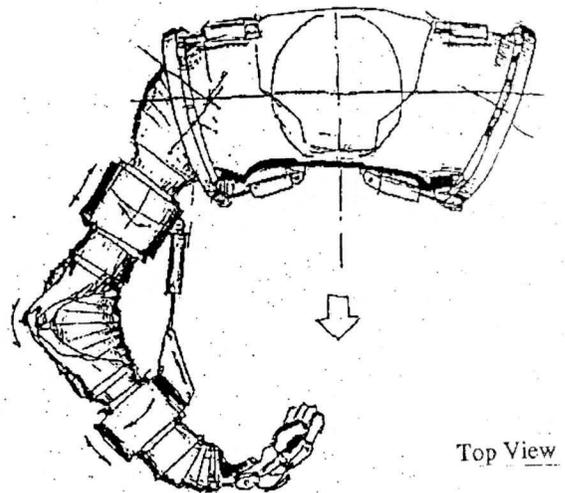
6. Goal of Skil Mate project

Skil Mate project is put into practice since August in 1998. This project aims to manufacture mainly an exo-skeletal structure assembly to be worn by astronauts for EVA as the first goal by the end of 2000.

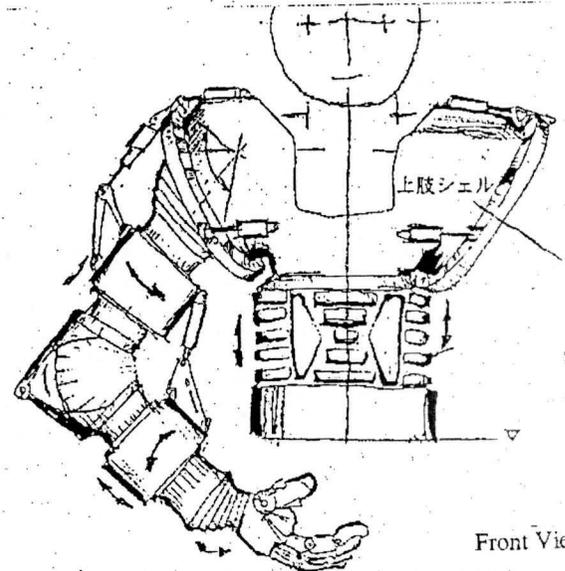
This structure assembly will consist of three parts, the upper torso, the lower torso assembly, and a pair of arms with the gloves. Similar to SSA (Space Suit Assembly), these parts are to be assembled when it is worn. The movement of every joint (shoulder, elbow, wrist, and so on) is controlled with servo-actuators which assist the intentional movement of the astronaut. (Fig 9 Upper structure of Skil Mate, Fig 10 Body configuration of Skil Mate)

Components for Skil Mate is located between garment and cover materials, minimizing their size. As this Skil Mate is expected to be used on 0-gravity environment, on orbit, the weight for the components is not a major technical issue.

The structure of glove and interface between astronauts' hands will be studied and carefully designed introducing haptic devices such as tactile or slipping-off sensors/displays. These are indispensable to maintain the skill of the astronauts and most important for reliability of Skil Mate.

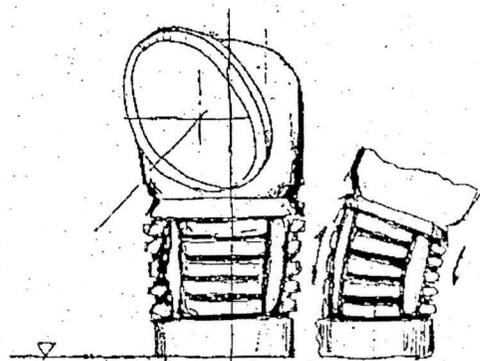


Top View



Front View

Fig 9 Skil Mate mechanism concept for EVA



Side View

Fig 10 Skil Mate body parts

6. Conclusions

A concept of Skil Mate and its development's backgrounds are discussed. Skil Mate might be a key for future construction site work innovation applying human worker skill more than before. To much system progress to the unmanned production technology research is going to be spoil human worker and industries.

Skil Mate project is introduced showing its strategies and goals. Its first goal is to develop Skil Mate for EVA, and issues are pointed out for its application.

7. Acknowledgements

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