MANIPULATOR ARMS AND MEASUREMENTS WITH THEM ON HUNVEYOR COLLEGE LANDER: SOIL HARDNESS MEASUREMENTS IN THE TEST-TERRAIN SURROUNDING THE LANDER.

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Abstract: We studied different manipulating arm systems and developed two special ones onto Hunveyor experimental university lander. Modular units build up them, special effectors work at their ends. In a college course a) we formulated basic principles of the mechanical constraints and manipulation (+space geometry), b) we aimed different goals for manipulators on landers: soil mechanics, instrument assemblage placing, c) motions around lander, (movable structures and instruments), d) we built and studied soil hardness measuring experiment, e) carried out soil hardness measurements in the test-terrain around Hunveyor.

Introduction: In robotics human body is an example of moving structures. Muscles have motor counterparts, the arms, legs, skeletal elements also have rigid counterparts, connected by movable hinges and junctions. Direction and control is neural type which has electronic counterpart. If collective motions of functional units (like arm with 3 hinges, or fingers on a hand) are the ideal units to be realized in robotics, we focus the requirement: can we build mechanisms which move like the human body? Important restriction of this system is: We introduce motion at one point but make moving all the structural unit of "hand" or arm. That is: a complex assemblage of arms, hinges and motors are to be moved. This bionics principle was first realized in robotics designs.

Bionics, principles: However, the use of bionics principle in robotics can not be the one-to-one copying. For example: the vertebra in spine are fixed and moved by small muscles between vertebra. Instead of copying the details of such spine some functions of the fine control and direction by small muscles in a multiple knuckled arm can be replaced by mechanical constraints built in the structure, in the element connections of the arm knuckles.

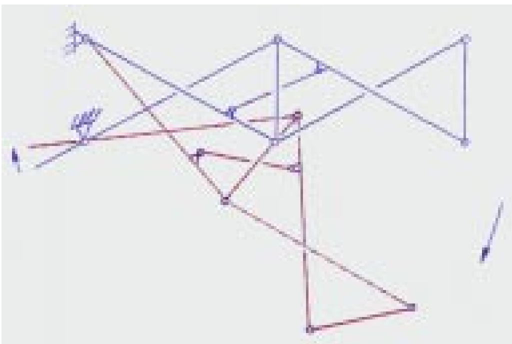

Fig. 1. Unusual connection of consol elements results in nonlinear motion at the end of the consol.

So, not the structure itself (with knuckles and muscles) is copied but the whole moving character is modeled by such new arm with central electric engine and new structure [1].
Further possibility to use these mechanisms as legs instead wheels for motion. We need wheels as big as possible for easy motion on a rough terrain. But there is a limit for its size. A huge complete wheel is a luxurious solution. We need only the actually used section of the wheel. Legs are imaginable as a section of a wheel with rigid spoke. It would be an economic solution for space and weight. (We could substitute wheels by legs on a space capsule.) Here we deal with different arms in details.

Multiplication: First step in development of such unit was the principle known as "scissors of Nürnberg" [1]. This means multiplied scissors sequentially connected at their shank-end pairs with the next one. Such was the mechanical structure of the Surveyor's [2] telescopic robotic arms extended from a folded box by one extending engine. (For extending by continuous motion see [2].)

Maneuvering space: In design of maneuvering units of various geometrical and multiplication constructions (with their manipulation spaces) were studied. Requirements (i.e. holding the horizontal level, or keeping in a fixed direction) and constraints (the length of maneuvering space) characterized these designs. We show in details a 3 hinged arm structure and a soil hardness measuring telescopic arm.

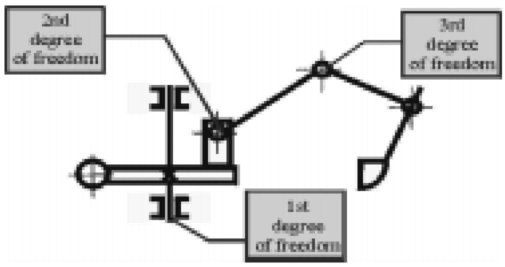

Fig. 2. The structure of a grab arm with 3 degrees of freedom and with extended maneuvering space.

Application on lander: The most important use of arms are: soil mechanics, instrument assemblage placing, and any kind of motions around lander. Of these roles soil mechanics instruments and measurements were applied on Hunveyor: soil excavation and soil hardness determinations were programmed. (Some works may be roles on a rover, too.)

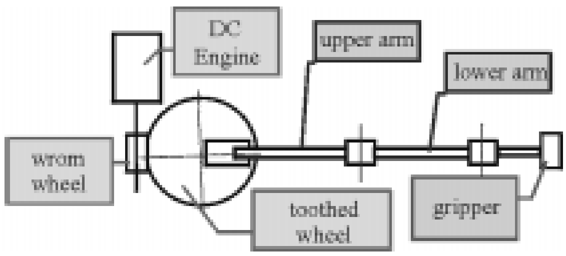

Fig. 3. The corresponding abstract design with skeletal, engine and hinge elements to the grab arm.

Some basic characteristics of the arm: a) it is fixed to the rigid skeleton, b) rigid arm units can move at hinges, c) by moving motors, and d) they make moving the instrument on the end of the arm: so called effector. We show examples from the arm of Hunveyor-2.

Hunveyor-2 soil hardness measurements: We use a string, fixed telescopic arm to this function. At the end of this arm there is an auxiliary structure with a special drilling unit. The arm with larger mass is moved by an 12 V and 700 mA DC engine opening and closing the arm along a worm thread axis. (This arm has 1 degree of freedom.) The drill at the end of this arm is also with 1 degree of freedom. The drilling head was moved by a 7 V, 200 mA engine, also along a worm thread axis, but in perpendicular direction to soil surface.

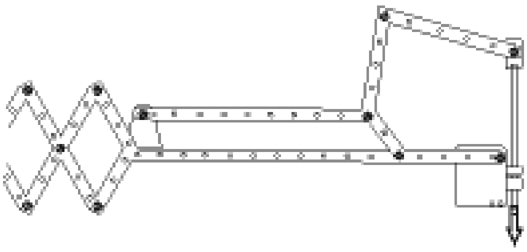

Fig. 4. Hunveyor-2 soil hardness measuring arm. Left: the end of the telescopic segment, at right end is the drill.

Drilling head: The arrangement of the drilling head makes possible to measure three hardness grades. The worm thread axis push a cylinder with a nodose, and this cylinder push a spring. The drilling head has 2 nodosus for end cleat. As drilling advances spring compresses. Compression depends on the soil hardness. More compressed spring forces nodose to close the middle circuit, much compressed case reach the third end cleat.

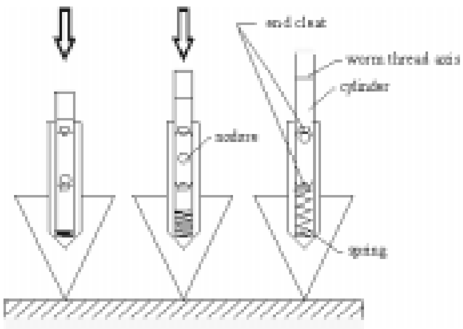

Fig. 5. The 3 stages of the drill at different soil hardness. Left: hardest soil, center: middle soil hardness, right: loose soil.

Measurements: In initial position the spring push the cylinder to the upper end cleat. When drilling is in a loose soil, the moving of the drilling head does not need larger force and the end cleat remains at its initial position. Middle hardness soils push the spring and cylinder moves to a lower position, where no end cleat is closed, till the hardest soil position is not reached at a distance of the second end cleat. This way three hardness grades can be distinguished with this measuring unit.

Electronics: The direction and control was made by two controller-4 units of which one could direct two motors with two directions each. The controller-4 units are specific computers for control which contain microcontroler, memory units, amplifying and power circuits. It contains 4 canals to be programmed.

Test-terrain measurements: On the test-terrain formed around Hunveyors [5] we made connected measurements of camera and soil hardness measuring arm. Loose soil was the sand of the desert. Middle hardness soils were the wet clay and the gravel type soil. Larger blocks of limestone and volcanic rocks, (basalt, gabbro, komatiite, etc.) represented the hard soils and rocks. We observed both the electronic sign for hardness grades and the activity seen through the TV camera in Surveyor type (mirror reflected) arrangement.

Transitional cases were formed, when the harder soil was covered by looser soil cover, which can be formed by soil transports on the planetary body with atmosphere, or by precipitation of some light snow layer (both in Mars). Stratification of soils with different hardness and strength was observed by Surveyors on the Moon by the footprints of their legs. Our soil hardness measuring instrument was the first step toward a more complex soil hardness analyzer.

Summary: The sequence of steps in our course was some introductory theory of manipulating arm systems. Then we made two special arms and used them on Hunveyor experimental university lander for measurements in the test-terrain. With soil strength analyzer we distinguished different soil environments and relations. This complex activity was interesting for our students both in planetary geology, physics and robotics, and programming the motions and final comparisons of the soils. We continue to build more complex manipulators on Hunveyor landers.

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