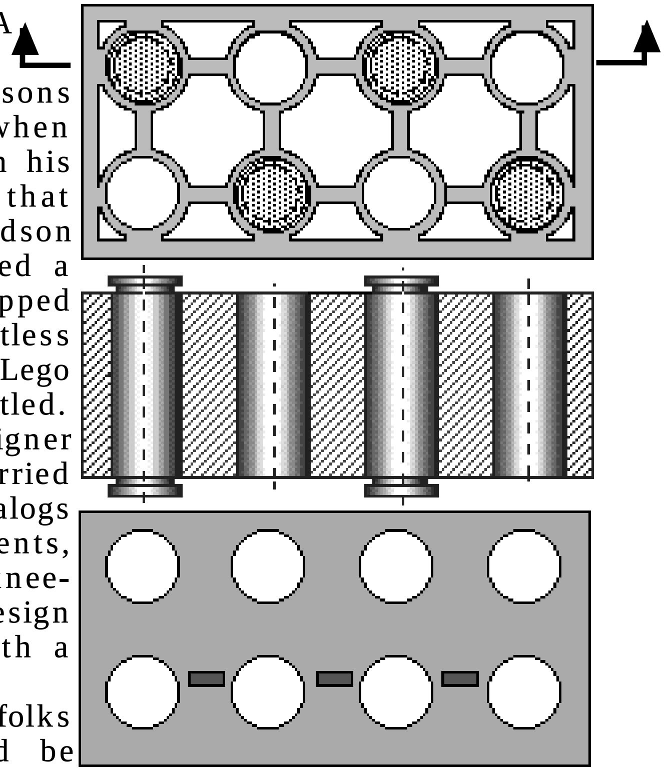
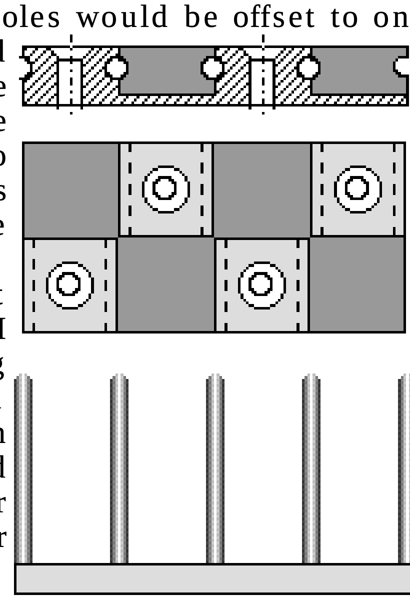
To: all mtseng discussion group members
From: old person in Houston, TX USA



The first of my two grandsons inspired the first of these notions when he was about six years old. He is in his second year of college this year so that must have been a while back. Grandson and grandmother had just assembled a Lego pirate ship when grandson dropped it with the same result that countless other children have observed when a Lego construction has been dropped or jostled.

I was a contract machine designer and draftsman of the type that carried bags of drafting instruments and catalogs when they reported for new assignments, so this maritime disaster set off a “knee-jerk reaction that resulted in the design of an Improved Lego Brick (ILB) with a positive attachment feature,

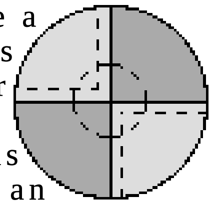
I wrote a letter to give the Lego folks the good news their bricks could be improved, but instead of a delegation of happy Legovites I finally received a letter to let me know that they don't review unsolicited suggestions from outside sources. These sketches show what ILBs might have looked like with holes that passed through them and studs with grooved ends that children could press into holes where they were required. ILBs would be assembled by placing a layer of locking plates over a layer of ILBs so studs projecting from the tops of the ILBs would pass through some of the holes in the plates. A second layer of ILBs would be placed over the plates so studs projecting from the bottoms of these ILBs passed through the rest of the plate holes and entered holes in ILBs under the plates. The plate holes would be offset to one side, so at this time the edges of the plates would extend beyond the sides of the ILBs. Pushing the edges of the plates in to alignment with sides of the ILBs would cause the rims of the plate holes to capture the undercut studs of both layers of ILBs and lock everything together until the plates were pushed out of alignment again.



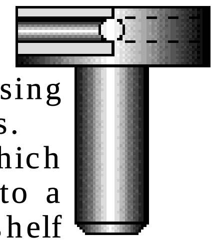
After learning that the Lego company doesn't consider suggestions from outside sources, I designed a similar mortise and tenon fastening system consisting in attachment surfaces with “checker board” patterns of raised squares with grooves on their sides and locking rakes that would be inserted so their tines entered the grooves after two attachment surfaces had been stacked so their raised squares meshed with one another.

The tines would resist shear forces along their lengths, rather than across their widths or diameters as shear pins normally do, so very strong attachments could be provided by using this kind of attachment surface.

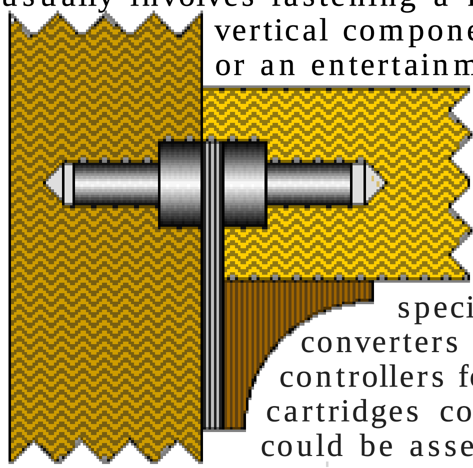
There could be several applications as I have tried to show with this sketch of a flat-headed stud with parts of two raised squares to provide a manufacturers' joint for things like the flat pack furniture that is shipped as pieces that must be assembled by retailers or their customers.



Assembling products that come with confusing instructions and arrays of parts that don't resemble the drawings is not an experience most people would willingly repeat so furniture of this kind might become more popular if it could be assembled in the same way that Lego toys are assembled and also disassembled for easier moving and subsequent reassembly without worrying losing any special threaded fasteners that might be hard to find in stores.



This sketch shows a typical joint for flat pack furniture which usually involves fastening a horizontal component like a shelf to a vertical component like the back of side of a bookshelf or an entertainment center. Locking members might be disguised to resemble strips of molding.

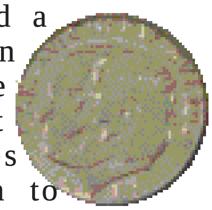


By the time I learned that the Lego people like their bricks as they are, I had decided ILBs should be used in kits for mechanical things, and because millions of kids had the first Nintendo game systems by this time, I thought special cartridges and optical to electrical signal converters could be developed to use game systems as controllers for robotic toys. My notion was that special game cartridges could open with menus of motion segments that could be assembled and tested graphically before switching to run modes that would control toys. Arrays of plastic optical cables would be attached to TV screen areas high lighted by the special cartridges so color-coded optical pulses generated by assembled programs could be transmitted to converters with prisms, photodiodes and circuitry that would separate the optical pulses and convert them into electrical pulses for small stepping drives in robotic toys, using TV scan cycles as clocks to coordinate the motions of drives in the toys.

This would have required small stepping drives that ran slowly, cranked out a respectable amount of torque, required minimum numbers of control channels, were relatively kid proof and CHEAP. I didn't think there were any drives like that so I started thinking about how they might be developed.

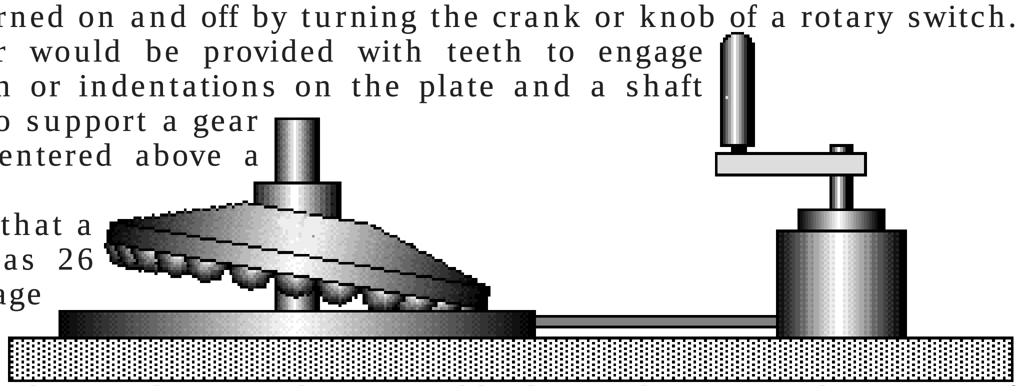
The requirements for low speed, high torque and a minimum number of control channels indicated that a motor with three or four steps per revolution might be coupled to gearing with a reduction ratio of about 30-to-1. This would have made a drive larger and more expensive, so I started thinking about ways to combine the functions of propulsion and speed reduction in the same mechanism. I needed some kind of speed reducer to start with. Cycloidal types like the old planocentric reducers and newer Harmonic Drives require fewer parts for high ratios than spur gear reducers do, so I decided to base the conceptual drive on some kind of cycloidal reduction principle that would allow electrically generated forces to be applied directly on a reducer's input gear.

Planocentric reducers and Harmonic drives didn't seem suitable for this purpose, so I based the idea for simple drives on a "wobbler" phenomenon that has been investigated as a scientific curiosity and used in things like the old "rattle back" toys, but hasn't, to the best of my knowledge, been used as the basis for abt gear motors. For a wobbler demonstration, stand a coin on its edge on a smooth surface and spin it. And as the coin goes from spinning to wobbling, notice that it rotates in the direction of the wobbling motion, but at a slower rate of speed. It rotates because its circumference is larger than those of the circles it traces out during its wobbling phase, causing its rotation to advance by an amount equal to the differences between circumferences during the wobble cycles. The traced circles become increasingly larger as the wobbling subsides, causing the quarter's speed of rotation to diminish and stop when the wobbling motion stops.



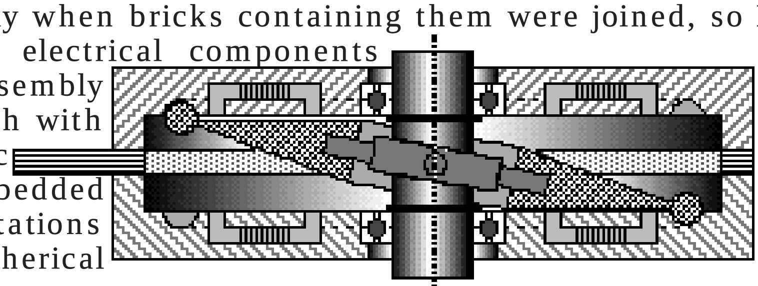
Engineers don't like machines that wobble, so I should mention that coins don't really wobble, but roll around in tight circles that make them look like they are wobbling, when they are actually just as dynamically balanced as a steel wheel might be while as rolled along on a railway track. Coins look like they are wobbling so that is probably why they are called wobblers, not rollers.

This sketch shows a "breadboard" gear motor with a "coin," or wobble gear, made to wobble by the action of three or four electromagnets embedded in a plate and turned on and off by turning the crank or knob of a rotary switch. A wobble gear would be provided with teeth to engage matching teeth or indentations on the plate and a shaft with a collar to support a gear and keep it centered above a plate.

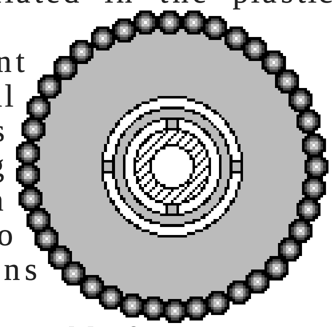


Assume that a wobble gear has 26 teeth to engage 25 teeth or indentations on the plate, and it can be seen that it would advance by one tooth position of 25 during each wobble cycle and have 75 stepping positions per rotation if three electromagnets were used, or 100 if four were used. I didn't know this at the time I came up with these notions, but learned about a month ago that a company in the US state of Arizona uses open drives similar to this to position the shafts of large flow control valves.

Some Lego bricks contained LEDs, enunciators, switches and batteries that were connected electrically when bricks containing them were joined, so I thought ILBs could contain electrical components that would be connected by assembly as indicated in the next sketch with a section view of two plastic housing sections with embedded electromagnets and indentations that would be engaged by spherical

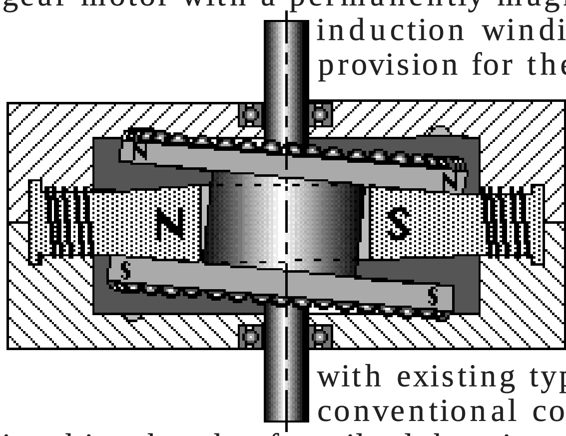


teeth around the perimeter of a wobble gear between the housing sections. The tab would be part of a plate similar to the plates that would have been used to lock ILBs together, and might have had printed circuits on its sides and contacts for edge connectors and conductors encapsulated in the plastic housing sections.

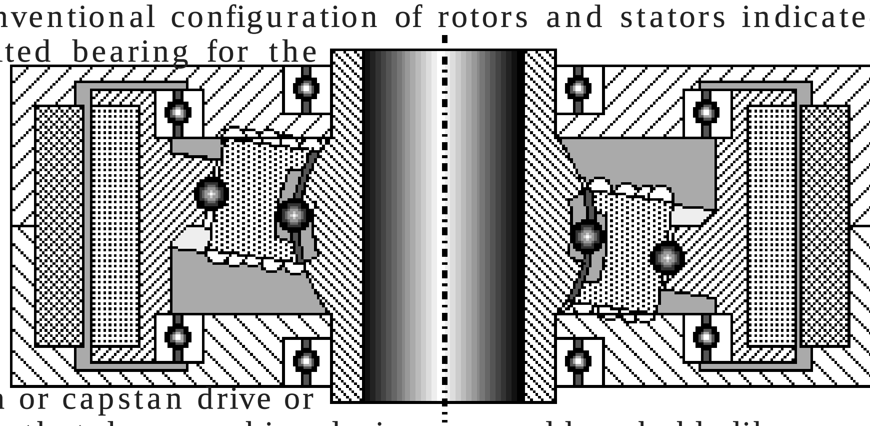


The sketch shows a Cardan type of universal joint coupling the wobble gear to the output shaft, but flexural couplings would probably have been used in gear motors for toys, to make them cheaper, and to provide spring loading so the wobble gears would release from loads when the power was off and allow robotic toys to be picked up to let gravity restore their limbs to their benchmark positions and thereby eliminate the need for feedback circuitry.

This sketch shows what could be either a DC or a variable frequency AC gear motor with a permanently magnetized wobble gear that might also have an induction winding around its center. I haven't shown any provision for the commutation a DC version might require, but this could be provided by using the wobble gear as a rolling switch that would sequentially connect an annular conductor to embedded conductive segments connected to two or more windings similar to the field winding shown in this sketch.



The reduction principle might also be used in gearboxes that could compete with existing types of speed reducers and possibly with the conventional configuration of rotors and stators indicated in this sketch of a tilted bearing for the generation of wobbling motion in a gear coupled to a hollow output shaft by a universal joint of the Rzeppa type used in front wheel drive cars.

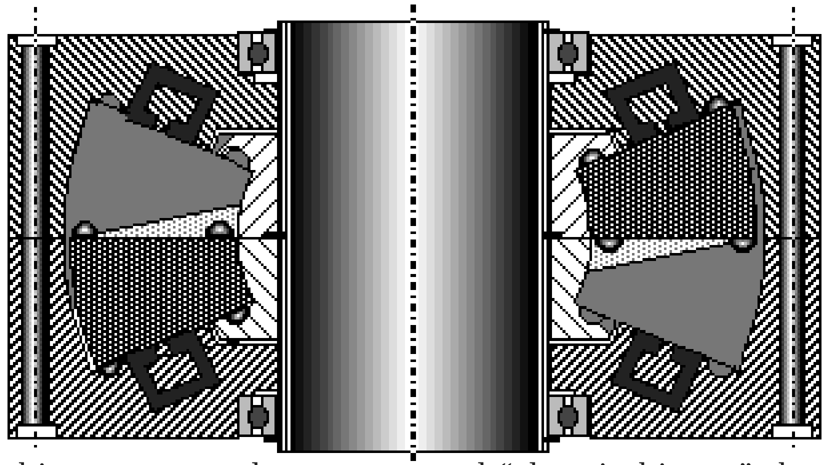


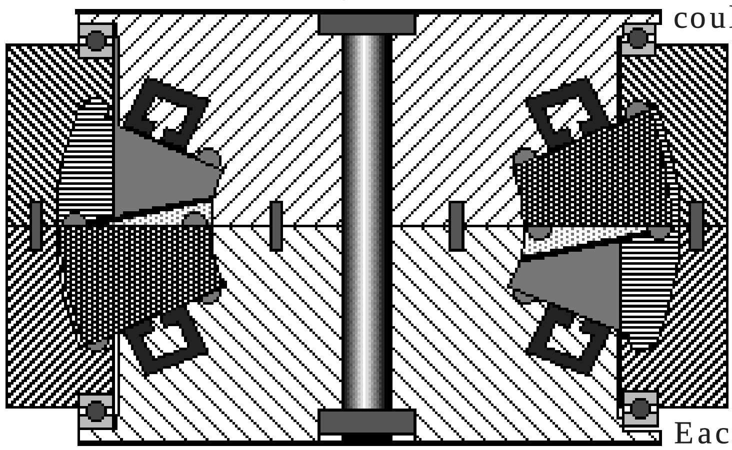
This version could be used as an integral part of a winch or capstan drive or a shaft mountable drive,that lazy machine designers would probably like.

The next sketch shows that differential gearing could be used to drive the output shaft of a gear motor rather than a universal joint. Each side of the wobble gear would have two circles of teeth. Teeth on the outer circles would mesh with matching teeth or indentations on the inner surfaces of the housing sections and teeth on the inner circles would mesh with matching teeth or indentations on a spherical assembly keyed to an output shaft to keep the wobble gear centered. Differential gearing works by the subtraction of one primary ratio from another one to provide a secondary output ratio

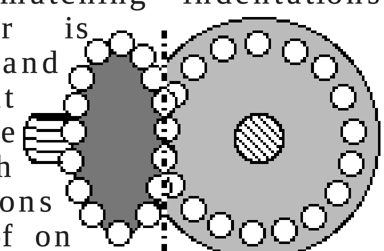
In contrast, compound gearing works by multiplying primary ratios to provide a secondary output ratio. In some cases the result is the same, but when primary ratios that are almost the same are used in differential reduction systems, very high ratios of output speed reduction can be obtained.

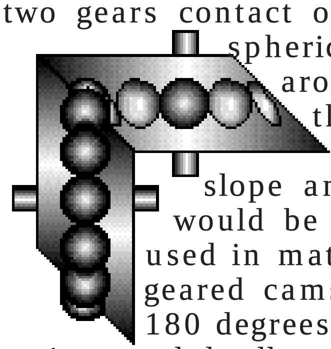
The sketch after this one shows an "inside out" gear motor that combines hav differential reduction with an external ring that could be designed to function as a gear, pulley, sprocket, gear, cam or wheel This kind of gear motor could be used as an integrated component of electrically powered things like the paper feed rolls for printers, plotters, copy machines. etc., and cam actuated "electric hinges" that could open and close doors, control rudders and other control surfaces, and drive the joints of prosthetic hands, exoskeletal power gloves and various kinds of end effector mechanisms for robotic machines.



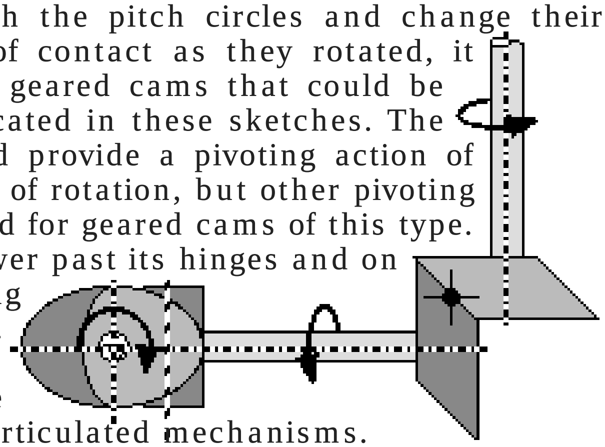


The hinges would be similar to geared universal joints that have two gears, one with hemispherical teeth and one with matching indentations. Each gear is mounted in a clevis-like frame that straddles the gear and the frames are joined by hinge pins on a pivot axis that passes through the point where the pitch circles of the two gears contact one another. By using gears with spherical teeth and matching indentations around their perimeters, instead of on their sides, and by adding contacting cam surfaces that would pass through the pitch circles and change their slope angles along a line of contact as they rotated, it would be possible to develop geared cams that could be used in matching pairs as indicated in these sketches. The geared cams shown here would provide a pivoting action of 180 degrees during 180 degrees of rotation, but other pivoting actions and dwell zones could be provided for geared cams of this type.

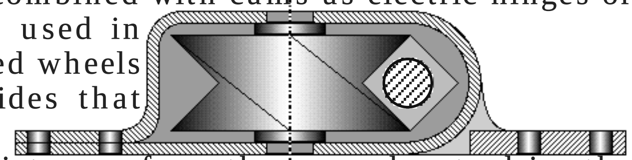


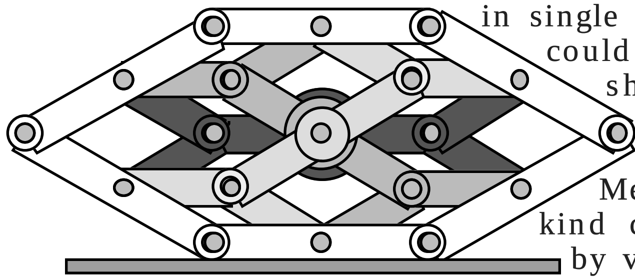


A pair of geared cams could transmit power past its hinges and on to other pairs of geared cams with pivoting motions in the same, or different planes. Each pair of geared cams could carry out its own agenda without affecting the actions of other pairs of geared cams in articulated mechanisms.

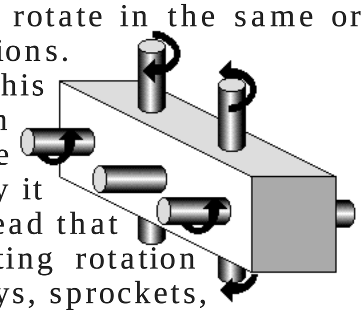


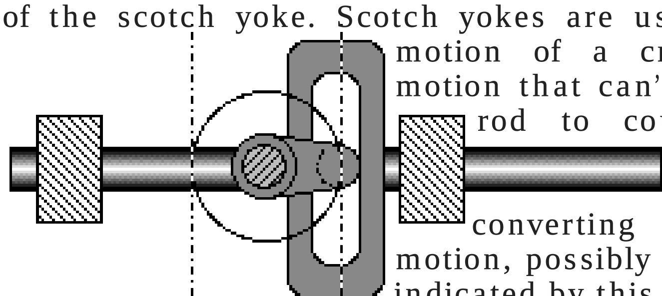
Inside out gear motors could be combined with cams as electric hinges or with conjugate cams similar to those used in some indexing drives to drive articulated wheels and pulleys with either four or six sides that would change shapes as they rotated to maintain their centers at constant distances from the ground or to drive the links of tabletop conveyor chains along straight paths and turn them around in single pitch lengths. Inside out gear motors could also drive mechanisms with multiple shafts that could point in different directions and rotate in the same or opposite directions.





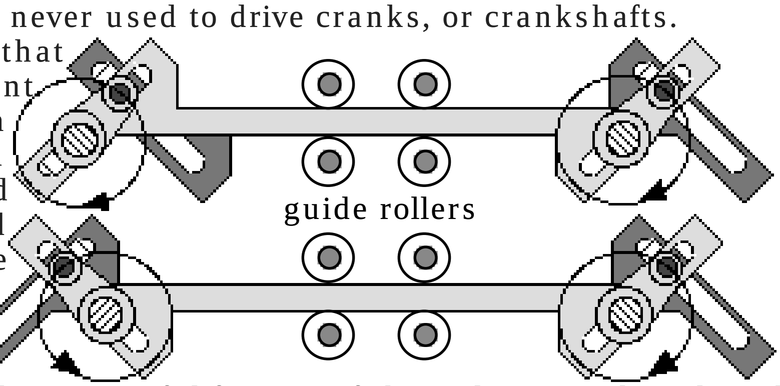
Mechanisms of this kind could be driven by variations of the “scotch yoke,” or crank and slotted crosshead. Normally it is a crank that drives a crosshead, rather than a crosshead that drives a crank but I wanted a method for transmitting rotation between the shafts of kit toys without using gears, pulleys, sprockets, belts, chains things kids might have trouble with and came up with a variation of the scotch yoke. Scotch yokes are used mostly for converting the rotary motion of a crank into sinusoidal reciprocating motion that can’t be provided by using a connecting rod to couple a crank to a reciprocating component such as a piston. They haven’t been used much for converting reciprocating motion into rotary motion, possibly because of the “dead center” problem indicated by this sketch.

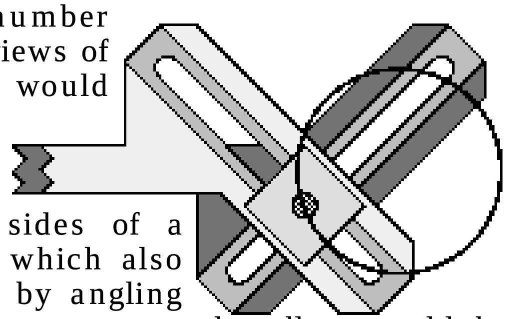




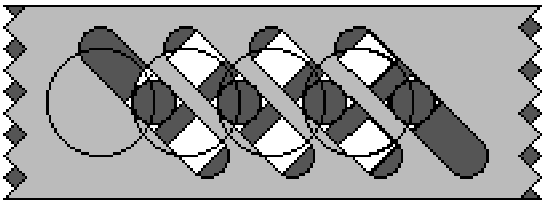
This problem could be solved by using crankshafts with two throws phased some angular distance apart, but since most applications involve couplings for parallel crankshafts which can be driven by connecting rods, slotted crossheads are almost never used to drive cranks, or crankshafts.

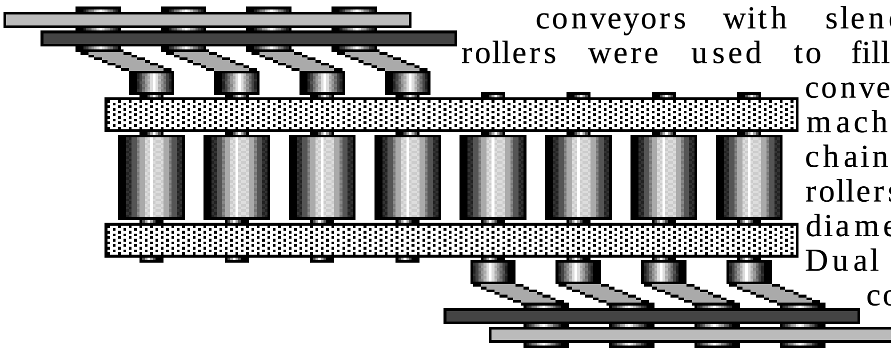
I wanted something that could drive cranks in different planes of rotation which would be hard to do with connecting rods, so I decided to use two diagonally slotted crossheads that could be driven by a single crank pin to transmit motion to a driven crank pin, as shown in some of these sketches. A useful feature of these drives is that slotted crossheads coupled with slots parallel to one another would drive cranks in the same directions, while crossheads with their slots perpendicular to one another would rotate in opposite directions. Applications that required greater degrees of precision or durability than the rubbing contacts of crank pins and slots provide might use ball bearing bushings, as indicated in the next sketch.



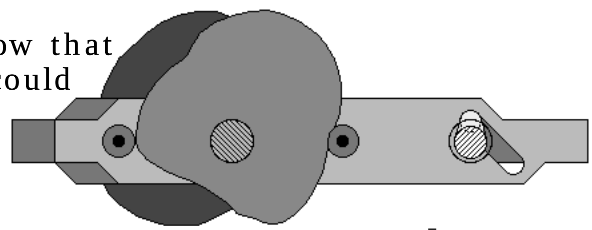


Either arrangement might be used to drive a number of shafts as indicated by these side and plan views of a drive for conveyor rollers The slotted plates would be phased ninety degrees apart and might generate vibrations that would be objectionable, so this might be prevented by using cranks and slotted plates on both sides of a conveyor line, as indicated in the plan view, which also shows that by angling the crank arms outward, rollers could be positioned closer to one another. I did contract machine design in the Chicago, Illinois area for nearly twenty years and remember that in several places “bridging” conveyors with slender, closely spaced rollers were used to fill the gaps between conveyor based process machines with belts or chains that required end rollers with very large diameters.

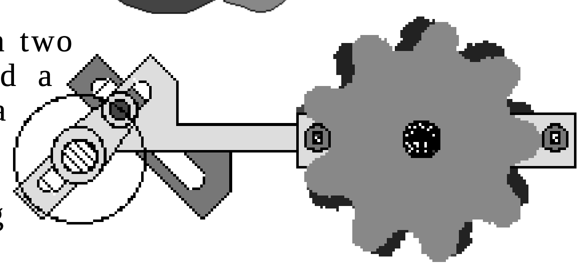




Dual slotted cross heads could also be used with cams as shown by these sketches:

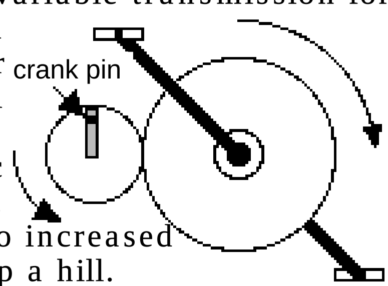


The first sketch is intended to show that two plate cams driven by the same shaft could be used to drive a crank with either nonuniform motion, or dwell periods for an indexing drive.

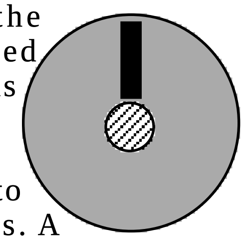


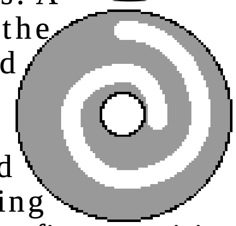
The second sketch is intended to show that a crank could be combined with two of the diagonally slotted cross heads and a pair of constant diameter plate cams as a gearless speed reducer. Some details are omitted, such as bushings or rollers for guiding reciprocating components along straight lines of travel.

Crank and diagonally slotted cross head combinations could also be combined with racks and pinions for various applications. One of these applications might be as an automatic, continuously variable transmission for bicycles. This sketch shows how a large gear on a pedal shaft might be used to drive a a smaller gear with a variable throw crank pin. There are several mechanisms that could change the throw distance while the gears were rotating. Some require electric motors, so it might be better to use a mechanism that could be actuated manually, or perhaps in response to increased loading of the type that occurs when a bicycle starts up a hill.

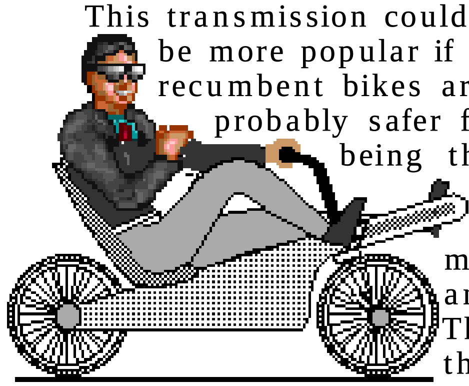


Several mechanisms could reduce the distance between the center of the gear and the crank pin in response to increased loading. What I have tried to indicate with these sketches is that one, or perhaps both sides of the gear with the variable throw crank pin could have straight slots to guide a crank pin. Between the two sides there would be a disk with a spiral slot to control the position of the crank pin guided by the straight slots. A spiral spring would couple this disk to the inner perimeter of the gear in question so that increased resistance to rotation would load the spring and cause the disk to rotate in relation to the gear to reduce the distance between the center of the gear and the crank pin so that shorter strokes of two diagonally slotted cross heads would be generated. When the resistance to loading returned to normal, the spring would restore the disk to its first position, increase the distance between the distance between the center of the gear and the crank pin and generate longer strokes of the diagonally slotted cross heads. If you are familiar with the operation of lathes, you will have seen how spiral slots are used to open and close the jaws of a three-jaw lathe chuck.



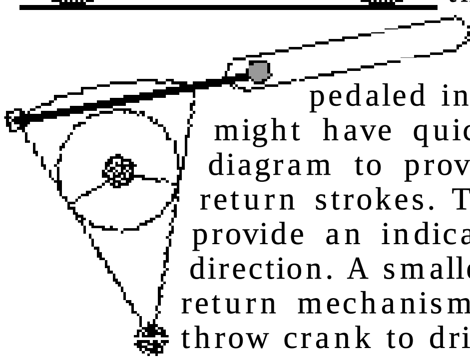


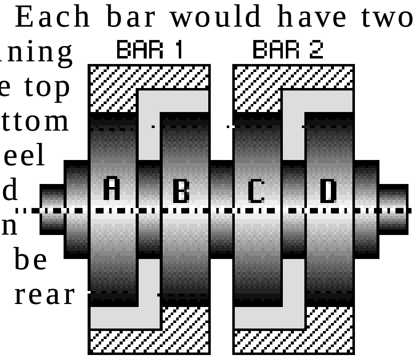
This transmission could be used in semi-recumbent bicycles that might be more popular if they were compact and had cleaner lines. Semi-recumbent bikes are reported to be less tiring for touring and are probably safer for riders because of the reduced likelihood for being thrown headfirst against anything they collide with. I am not an industrial designer, but this sketch shows what a semi-recumbent bicycle might look like with a linear pedaling mechanism and internal drive components.



The problem with a linear pedaling mechanism is that a rider might not know whether he was pedaling forwards or backwards.

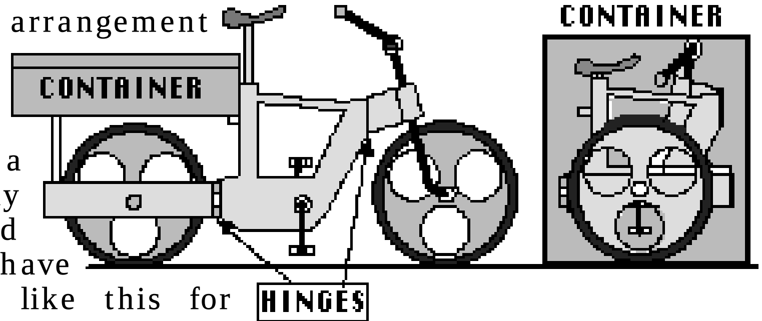
The transmission would not work if a rider pedaled in the wrong direction so semi-recumbent bicycles might have quick return cranking mechanisms similar to this diagram to provide forward strokes that were slower than the return strokes. This would increase pedaling efficiency a bit and provide an indication that pedaling was in the right, or wrong, direction. A smaller gear would be driven by the gear for the quick return mechanism and the smaller gear would include a variable throw crank to drive two diagonally slotted cross heads that would be coupled to two two bars, one for each cross head. Each bar would have two gear racks to engage two gears mounted on overrunning bearings. One gear rack on each bar would engage the top side of a gear and one gear rack would engage the bottom side of a gear so that rotation of the bicycle's rear wheel would be generated on both the forward and rearward motions of both bars. as indicated by this section view of two bars with integral gear racks. It might be better for the reciprocating bars to straddle the rear wheel, rather than being on the same side.



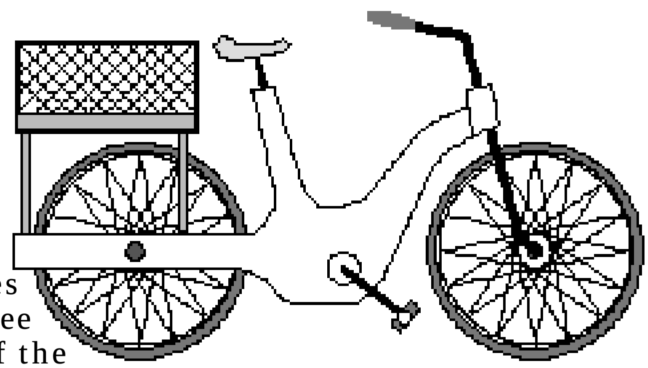


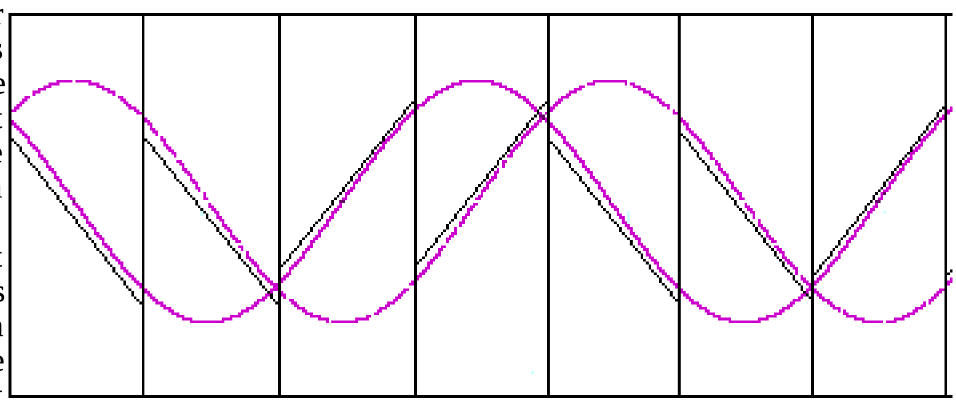
This might be combined with a mechanism that would make it easier to remove the rear wheel by releasing a detent that would hold a square or splined shaft to support the wheel and couple it to drive assembles contained by hollow frame members that straddle the rear wheel.

A similar mounting arrangement might be used in a folding commuter bike that could be concealed in a container that would ordinarily be used as a luggage carrier. I have already mentioned that I worked in and around Chicago and might have been able to use a bicycle like this for commuting to some of the places that were too far from any of the stops for commuter trains to reach by walking. The problem is that the rail lines were built when people commuted to jobs in the city, By the time I moved there about thirty years ago, more people commuted between suburbs than between suburbs and the downtown part of the city, so a network of rail lines that converged downtown were not as useful as they might have been at the time they were constructed.

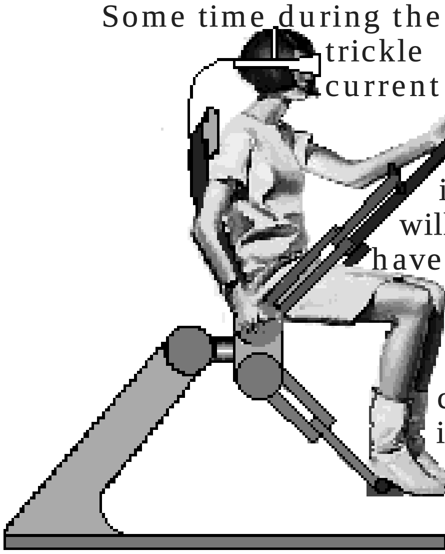


The next sketch shows a utility model for old folks like me that might have trouble getting on and off regular bikes or handling shift and brake levers. It might be a good idea to include a chart of acceleration curves for two diagonally slotted cross heads phased ninety degrees apart. Vertical lines mark ninety degree intervals and show that during two of the four intervals for one rotation, cross heads would move at almost constant velocities when the pedaling was at a constant rate.





At the point where one cross head slows down and reverses before resuming constant velocity, the second cross head would overtake its partner, whether the partner was moving in the same direction or not. At this time, the shaft that supported and drove the rear wheel would overrun its combination clutch/bearing; I thought that this might be worth including, in the event that you might wonder how two reciprocating bars could provide <u>almost constant</u> rotation and a relatively uniform velocity.

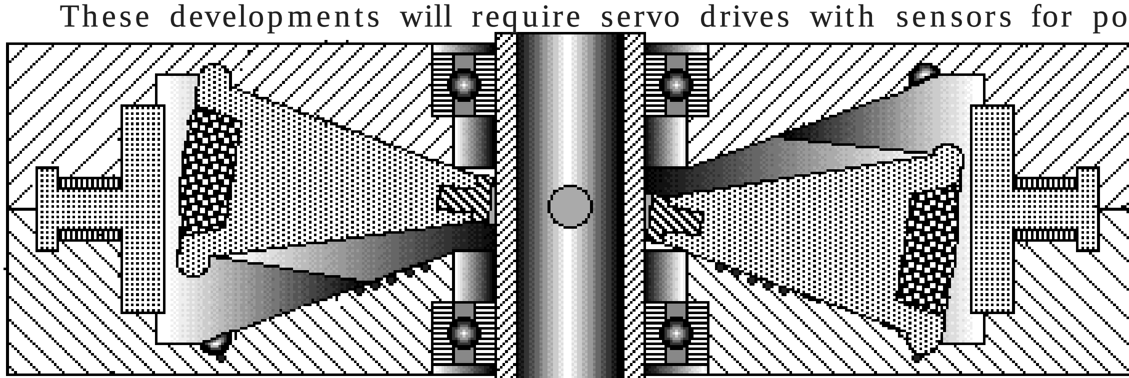


Some time during the next decade or so, virtual reality technology might trickle down to the home entertainment level from its current big-ticket applications in virtual surgery and engineering to create a need for control devices that can enhance the enjoyment of adventures in cyberspace. It has been predicted that people will use wired body suits for this. Families would have to buy these things in different sizes for family members of different sizes so I think there may also be various kinds of “one-size-fits-all” controllers that could evolve from force feedback controllers for video and computer games or from interactive exercise machines that should be designed around the human body, rather than the single activities like jogging, cycling, etc. that most exercise machines provide.

It has already been shown that virtual reality and telerobotics can be used together synergistically, and since they require similar force-feedback controllers and displays it is likely that the volume production of virtual reality systems will stimulate the development of telerobotics applications that might make it possible for more people to become telecommuters who phone their work in from home.

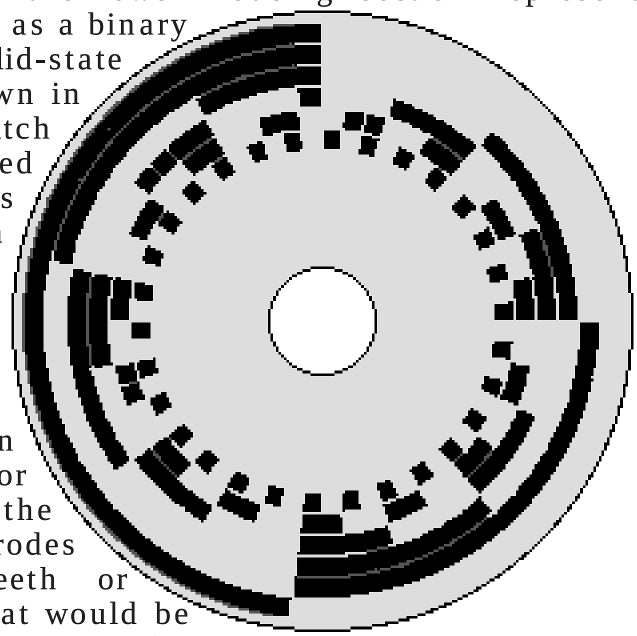
Most telecommuters are “white-collar” workers who probably worked in offices before technological developments made it possible for them to work at home. Before long there might also be a lot of “blue-collar” workers that don’t use computers now, but could do so when new technology makes it possible for people to control various kinds of work surrogates from their homes or service centers with special equipment for monitoring and controlling distant machines. Most of NASA’s technologies return to earth in one way or another, so the technology for controlling rovers on Mars will probably be used by little old ladies in retirement homes for controlling partially autonomous rovers that might resemble garbage trucks, farm machines, small army tanks with big “attitudes,” or flying windmills that will be touched on later.

These developments will require servo drives with sensors for position

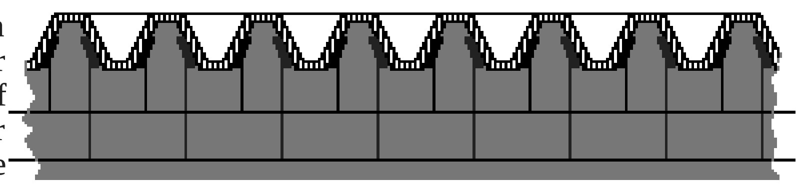


and torque that could be incorporated in gear motors that used wobble gears and housings with conical surfaces that would provide rolling contacts of the wobble gears on the internal surfaces of the housings. This would make it possible to use sensors based on the use of piezoelectric polymers, or FSRs (Force Sensing Resistors) similar to those in graphics tablets, rather than proximity sensors for sensing the positions of wobble gears and the positions and degrees of force exerted by, or against, the output components.

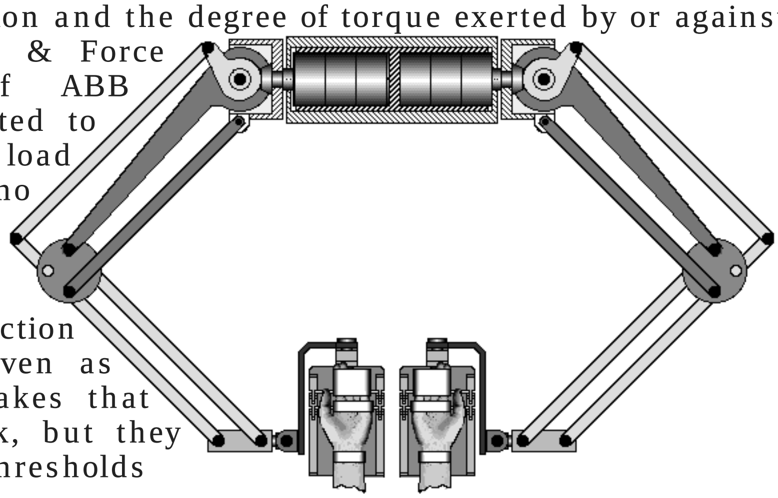
The dots shown embedded in the lower housing section represent concentric ring sections that could act as a binary number generator of signals for solid-state commutation, and the black dot shown in this sketch indicates a contact switch that would be actuated when a raised portion of a wobble gear reached this position during each rotation of an output shaft, to reset the shaft's "benchmark" position and to add to, or subtract from, a count of rotations made after a move command was given.



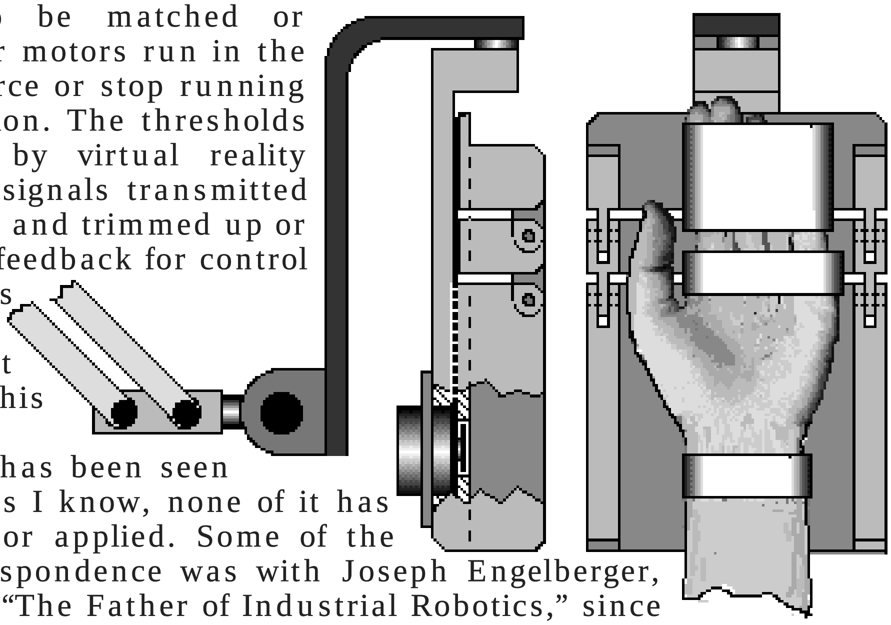
The next sketch shows an "unrolled" sectional view of gear teeth or indentations above a shielded FSR in the lower housing section. Sets of electrodes under opposite sides of gear teeth or indentations would provide signals that would be used to indicate the direction and amplitude of torque exerted by, or against the shaft.



FSRs have two thin substrate layers. One layer supports a pattern of electrodes and the other layer is a semi conductive polymer that acts like an open circuit until pressure is applied to the FSR's surface. Increased pressure causes increased shunting by the semi conductive layer, so FSRs can interpret both the positions and magnitudes of applied forces. FSRs are used mostly in touch pads and pressure sensitive graphics tablets that can sense up to 1,024 degrees of pressure that computers can interpret as different line widths and shades of gray for display on monitors, and could probably be used to provide some gear motors with integral sensors for commutation, shaft position and the degree of torque exerted by or against their shafts. The Weighing & Force Measurement Division of ABB Industrial Systems is reported to have developed magnetic load cells that require no movement, but has not responded to any of my requests for information.



.Gear motors with high reduction ratios couldn't be back driven as dynamic or regenerative brakes that could provide force feedback, but they could be controlled by force thresholds that would have to be matched or exceeded to make gear motors run in the direction of applied force or stop running in the opposite direction. The thresholds might be generated by virtual reality programs, or by load signals transmitted from slave gear motors and trimmed up or down to provide force feedback for control by articulated booms with stirrups for the feet and devices that might look a bit like this for the hands.



All of this stuff has been seen by others but as far as I know, none of it has been taken seriously or applied. Some of the most interesting correspondence was with Joseph Engelberger, who is also known as “The Father of Industrial Robotics,” since he and a partner started it all quite a while back with their Unimate robot and a company of the same name. Domestic manufacturers weren’t interested so Engelberger took his robot to Japan. The rest is history— Japan became the robotics capital of the world and the Unimate company became the “history.”

Later on Engelberger organized another company to manufacture robotic HelpMate couriers that were purchased and used by a few large hospitals. Under a contract with NASA, Emgelberger added articulated arms, cameras and other stuff to a courier platform that became the prototype for NASA’s robotic torso, the Robonaut, which was intended to do a lot of the extravehicular chores on the International Space Station under control by a human astronaut inside the space station.

Engelberger retained the right to develop a mobile version to be sold as a robotic caretaker for elderly folks that live alone. At least one of these things was built using two cameras for binocular machine vision, two articulated arms with grippers a variety of ranging and proximity sensors, a lot of motors and actuation and at least four computers. It weighed about seven-hundred pounds and had a telescoping torso that could extend to a height of six and a half feet. I tried to suggest something more like an electric wheel chair with extensible arms for handling things and doing light chores and that ended our correspondence. Mr. Engleberger is, or perhaps was, a dedicated roboticist of the type that believes mere humans should be kept out of the control loop. A manufacturer of hospital supplies acquired Engelberger’s company and retained him as a consultant, so we might have to wait a while for robotic servants like Rosie to go on sale in Walmart stores.

Best wishes, Frank McNeill

Frank McNeill