The BarrettHand grasper

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This paper details the design and operation of the BarrettHandBH8-250, an intelligent, highly flexible eight-axis gripper that reconfigures itself in real time to conform securely to a wide variety of part shapes without tool-change interruptions.The relevance of this topic is that now the robots are able to replace a human in a variety of environments, be it industrial, military, medical industry, etc. Robots can perform various kinds of human work, in whole or in part replace human labor. Object grasping by robot hands is challenging due to the hand and object modeling uncertainties, unknown contact type and object stiffness properties. To overcome these challenges, the essential purpose is to achieve the mathematical model of the robot hand, model the object and the contact between the object and the hand. In this paper, an intelligent hand-object contact model is developed for a coupled system assuming that the object properties are known.These machines are unpretentious to the conditions of work, they do not have to pay wages, they can work without breaks and holidays, as well able to perform routine work.According to Barrett CEO, William Townsend, "Conventional [non-programmable]grippers are the #1 bottleneck to the effectiveness and productivity potential ofprogrammable robots. Barrett's Grasper unlocks profound cost savings in factoryautomation compared to conventional ‘cheap' gripper solutions. This article backs up that claim by highlighting the dollars and cents arithmetic." The grasper brings enormous value to factory automation because it: reduces the required number and size of robotic workcells, while boosting factory throughput; consolidates the hodgepodge proliferation of customized gripper-jaw shapes onto a common programmable platform; and enables incremental process improvement and accommodates frequent new-product introductions, capabilities deployed instantly via software across international networks of factories.

This paper introduces a new approach to material handling, part sorting, and component assembly called “grasping”, in which a single reconfigurable grasper with embedded intelligence replaces an entire bank of unique, fixed-shape grippers and tool changers. The BH8-series BarrettHandis a self-contained and compacted multi-fingered programmable grasper with the dexterity to secure target objects of different sizes, shapes, and orientations. It houses a CPU, software, communications electronics, servocontrollers and 4 brushless motors. Of its three multi-jointed fingers, two have an extra degree of freedom with 180 degrees of synchronous lateral mobility. The BarrettHandis designed to overcome the alternative grippers' major limitation: adaptability. Each gripper must be custom designed for each shape and orientation which, unless the host arm will perpetually perform the same task, would need a variable supply of grippers and the ability to switch between them accordingly to targets' shapes and orientations. To appreciate the motivations that guided the design of Barrett's grasper, we must explore what is wrong with robotics today, the enormous potential for robotics in the future, and the dead-end legacy of gripper solutions. For the benefits of a robotic solution to be realized, programmable flexibility is required along the entire length of the robot, from its base, all the way to the target workpiece. A robot arm enables programmable flexibility from the base only up to thetoolplate, a few centimeters short of the target workpiece. But these last few centimeters of a robot must adapt to the complexities of securing a new object on each robot cycle, capabilities where embedded intelligence and software excel. Like the weakest link in a serial chain, an inflexible gripper limits the productivity of the entire robot workcell. Grippers have individually-customized, but fixed jaw shapes. The trial-and-error customization process is design intensive, generally drives cost and schedule, and is difficult to scope in advance. In general, each anticipated variation in shape, orientation, and robot approach angle requires another custom-but-fixed gripper, a place to store the additional gripper, and a mechanism to exchange grippers. An unanticipated variation or incremental improvement is simply not allowable.By contrast, the mechanical structure of Barrett's patented grasperis automatically reconfigurable and highly programmable, matching the functionality of virtually any gripper shape or fixture function in less than a second without pausing the workcell throughput to exchange grippers. For tasks requiring a high degree of flexibility such as handling variably shaped payloads presented in multiple orientations, a grasper is more secure, quicker to install, and more cost effective than an entire bank of custom-machined grippers with tool changers and storage racks. For uninterrupted operation, just one or two spare graspers can serve as emergency backups for several workcells, whereas one or two spare grippers are required for each gripper variation – potentially dozens per workcell. And, it's catastrophic if both gripper backups fail in a gripper system, since it may be days before replacements can be identified, custom shaped from scratch, shipped, and physically replaced to bring the affected line back into operation. By contrast, since graspers are physically identical, they are always available in unlimited quantity, with all customization provided instantly in software.

The flexibility of the BarrettHand is based on the articulation of the eight joint axes.Clive Laughlin writes, "However developments such as the BarrettHand featured in this issue show very positive movements towards flexible grippers that are capable of industrial application and [programmability]...". Only four brushless

DC servomotors are needed to control all eight joints, augmented by intelligent mechanical coupling. The resulting 1.18kg grasper is completely self-contained with only an 8mm diameter umbilical cable supplying DC power and establishing a two-way serial communication link to the main robot controller of the workcell. The grasper's communications electronics, five microprocessors, sensors, signal processing electronics, electronic commutation, current amplifiers, and brushless servomotors are all packed neatly inside the palm body of the grasper.The BarrettHand has three articulated fingers and a palmwhich act in concert to trap the target object firmly and securely within a grasp consistingof seven coordinated contact vectors — one from the palm plate and one from each link of each finger.

Each of the BarrettHand's three fingers is independently controlled by one of three servomotors. Except for the spread action of fingers Fl and F2, which is driven by the fourth and last servomotor, the three fingers, Fl, F2, and F3, have inner and outer articulated links with identical mechanical structure.Each of the three finger motors must drive two joint axes. The torque is channeled to these joints through a patented, TorqueSwitch mechanism, whose function is optimized for maximum grasp security. When a fingertip, not the inner link, makes first contact with an object, it simply reaches its required torque, locks both joints, switches off motor currents, and awaits further instructions from the microprocessors inside the hand or a command arriving across the communications link.But when the inner link, makes first contact with an object for a secure grasp, the TorqueSwitch, reaches a preset threshold torque, locks that joint against the object with a shallow-pitch worm, and redirects all torque to the fingertip to make a second, enclosing contact against the object within milliseconds of the first contact. The sequence of contacts is so rapid that you cannot visualize the process without the aid of high-speed photography. After the grasper releases the object, it sets the TorqueSwitch threshold torque for each finger in anticipation of the next grasp by opening each finger against its mechanical stop with a controlled torque. The higher the opening torque, the higher the subsequent threshold torque. In this way, the grasper can accommodate a wide range of objects from delicate, to compliant, to heavy.

The finger articulations, not available on conventional grippers, allow each digit to conform uniquely and securely to the shape of the object surface with two independent contact points per finger. The position, velocity, acceleration, and even torque can all beprocessor controlled over the full range of 17,500 encoder positions. At maximum velocity and acceleration settings, each finger can travel full range in either direction in less than one second. The maximum force that can be actively produced is 2kg, measured at the tip of each finger. Once the grasp is secure, the links automatically lock in place allowing the motor currents to be switched off to conserve power until commanded to readjust or release their grasp.While the inner and outer finger-link motions curl anthropomorphically, the spread motion of Figure 10 is distinctly non-anthropomorphic. The spread motion is closest in function to a primate's opposable (thumb) finger, but instead of one opposable finger, the BarrettHand has twin, symmetrically opposable fingers centered on parallel joint axes rotating 180 degrees around the entire palm to form a limitless variety of gripper-shapes and fixture functions.The spread can be controlled to any of [3,000] positions over its full range in either direction within 1/2 second. Unlike the mechanically lockable finger-curl motions, the spread motion is fully backdrivable, allowing its servos to provide active stiffness control in addition to control over position, velocity, acceleration, and torque. By allowing the spread motion to be compliant while the fingers close around an object, the grasper seeks maximum grasp stability as the spread accommodates its position, permitting the fingers to find their lowest energy states in the most concave surface features.

Although the BarrettHand BH8-250 was only introduced commercially in 1999, 30 units have been put into service around the globe at a price of US$30,000 each. The largest concentration of graspers is among automotive manufacturers and suppliers in Japan, including Honda, Yamaha Motorcycles, and NGK (ceramic substrates for catalytic converters). At this time, these manufacturers are only beginning to explore the capabilities of this versatile device, while some customers, such as Fanuc Robotics and the US and Japanese space programs have become repeat customers.

Resources

1.http://www.mcbup.com/research_registers/aa.asp2.http://www.barrett.com/robot/
3.http://www.emerald-library.com
4.http://www.sciencedirect.com/
5.http://www.iri.upc.edu/
6.http://www.plantautomation.com/7.http://www.parkflyer.ru