A High Precision Robotic Docking End Effector: The Dockbot$_{TM}$

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Abstract

Precision operations, including assembly, need an accurate platform as a base. The described robotic end effector can achieve 1 micron or smaller repeatability while being relocatable to the required task workspace.

Introduction

A new type of robotic end effector has been developed to assist with high precision operations, including assembly. This end effector allows for a single lower precision robot to transfer one or more higher precision end effector devices, with its internal micromanipulator, creating a cost effective automation system. This eliminates the overall system constraint of having to both reach large distances and to have precision motion.

This new device, called the Dockbot$_{TM}$, is a second-generation version of an earlier invention called the Closed Loop Assembly Micro Positioner (CLAMP) [Derby 1989, 1990, 1992]. So as to understand the differences and benefits of both devices, the CLAMP device will be explained first.

The Closed Loop Assembly Micro Positioner (CLAMP) Device

The CLAMP end effector uses a docking process of forcing its 3 legs into 3 hole features (the process is called "docking") found in the work table surface to achieve a very high precision with respect to the assembly work cell. The most common implementation is to use a conical hole, a conical slot and a flat plate as the 3 hole features The conical hole determines 3 degrees of freedom, the conical slot 2 degrees of freedom, and the flat plat the remaining degree of freedom, thus determining the total 6 degrees of freedom between the end effector and work table surface. This kinematic mount must be precise so as to allow the micro positioner to be as accurate as possible. The ends of the legs can either have a conical surface or preferably a spherical ball. Mating conical elements defines a set of line contact surfaces, and requires very tight machining tolerances. However the set of point contacts of a ball into a conical hole or slot is less demanding, and hardened metal ball components are commercially available. This use of spherical ball ends on the 3 legs is also useful in that the CLAMP device can be docked into the same set of docking features in 3 different orientations, 120 degrees from each other. This docking process for a high precision robotic end effector has been recently duplicated [Würsch et. al. 2001].

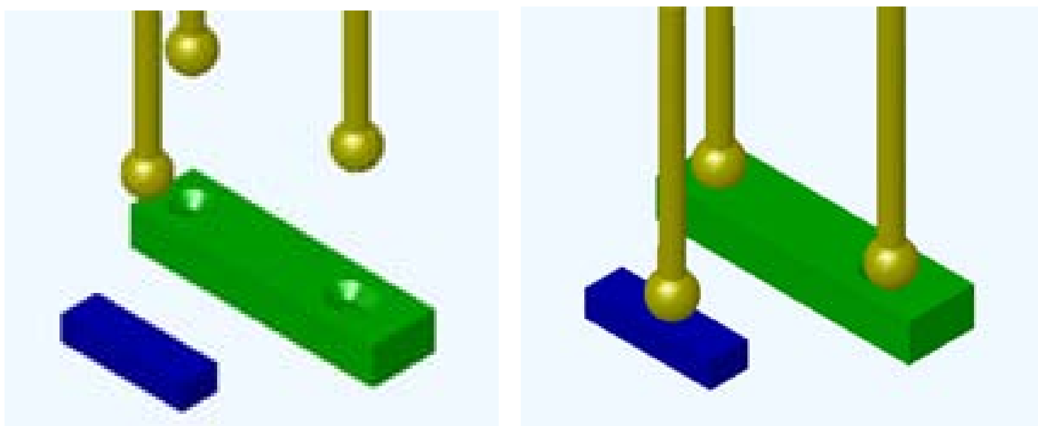

Fig 1 a) 3 legs above docking features   b) 3 legs in conical hole, slot and flat plate

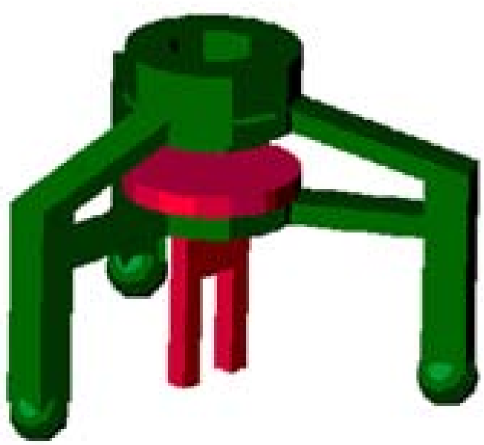

Fig 2 Conceptual CLAMP End Effector with 2 Finger Micro Gripper

Fig 3 Skeletal CLAMP Device Docked into Docking Features

When the 3 legs are docked, there is need for some freedom of motion or compliance between the larger low precision robot and the 3 docking features, otherwise there will be significant wear on the system. The CLAMP docking end effector incorporates the use of mechanical springs and several alignment features to assist with the docking and undocking process. Conical disks are held into conical holes on the top mounting plate by a series of compression springs. When the larger robot pushes down to properly seat or dock the CLAMP device, the springs are compressed and thus allow the lower CLAMP end effector to float freely into the docking features. When the CLAMP device is lifted from the docking features, the springs compress the CLAMP device back into registration to the top mounting plate. This assures that the CLAMP device will be able to successfully dock into the next set of features, and eliminates free vibrations if the coupling was to be simply a set of springs.

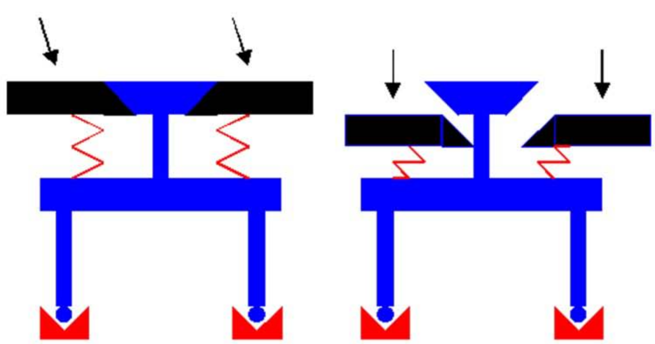

Fig 4 Conceptual Top Mounting Plate Compliance Device (2D Model)

Fig 5 Actual Top Mounting Plate Compliance Device

CLAMP End Effector Performance

The repeatability of the docking process was measured with a laser interferometer. Measurements were taken while docking with a range of misalignment of the larger robot, a range of docking force (and therefore compression of the springs in the top mounting plate), and a range of angular misalignment. (For detailed results, please contact the authors.) These results of less than 1 micron (0.000,04 inches) for repeatability give an excellent foundation for micro positioners and grippers to manipulate.

One limitation of the CLAMP system comes from needing to place a set of docking features around the place where one needs to perform the task. One option is to place the docking features on a XY table's moving surface created above the desired working surface [Derby 1989a]. With a hole in the moving surface of the XY table for the micro positioned and gripper to access the working surface, flexibility can be achieved.

Another precision implementation would be the coupling of 2 robot arms. With a CLAMP device on 1 arm and the docking features on the second arm, a relatively stable precision task can be done in free space [Ducoste and Derby 1990].

The Dockbot$_{TM}$

The CLAMP device is limited, however, in that a larger robot must hold it in place while the smaller micro positioner and gripper does its assembly task. Thus one large robot cannot service additional smaller robots (CLAMPs) simultaneously. It also becomes difficult to coordinate the larger robot to an incrementally moving work surface.

The novelty of the new docking and locking solution (Dockbot – patent pending) is the addition of:

- Method of locking the legs of the existing CLAMP device
- Requirement for the wrist exchange
- The ability for the larger lower precision robot or automation device to be able to reaquire the Dockbot, since the wrist interface may have shifted during the compliance motion while docking
- Possible handle for human operator transfer

- Device no longer obtains electrical control signals through the larger lower precision robot or automation device via the wrist
- Now uses connections from worktable for control signal/power or
- Uses wireless control means (i.e., IR, RF signal)
- Uses stored power
- Uses on board microprocessor for control

The docking process is very similar to the CLAMP device. Additionally, one of the methods of the locking process does assist in improving the docking process.

The locking process can use:

- Ball and detent methods
- Spring-loaded rollers similar to many kitchen cabinet latches
- Permanent magnets and steel plates
- Electromagnets and steel plates
- Physical latches - planar and non planar
- Threaded socket latches - rotary

The spring-loaded rollers also guide the spherical ball ends of the legs into the docking features, softening the docking process.

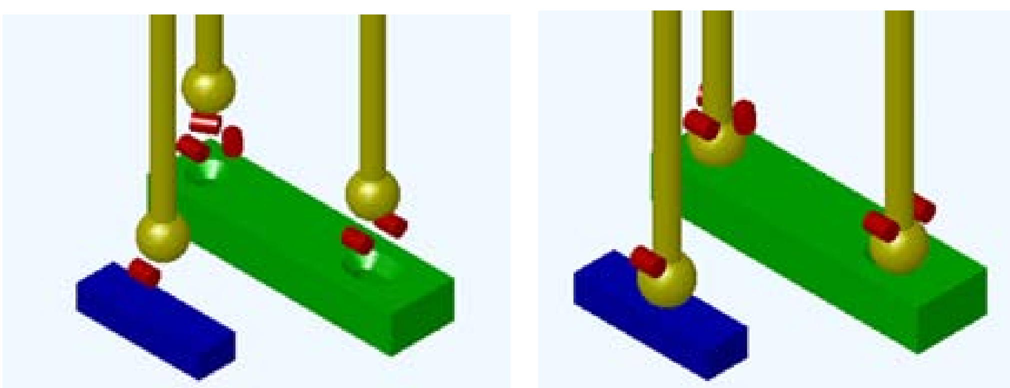

Fig 6 Spring-Loaded Rollers above Docking Features a) Legs above b) Locked in

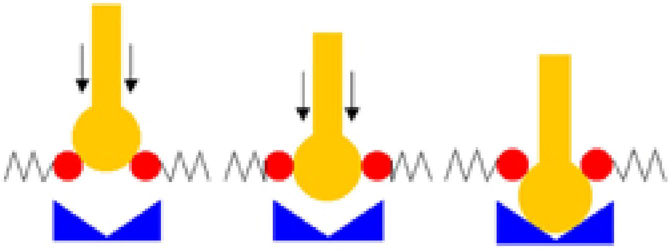

Fig 7 2D Version of Spring-Loaded Rollers and Docking/Locking Process

Fig 8 Spring-Loaded Rollers a) Above Conical Hole   b) Above Conical Slot

Various Dockbots Solution

Since the lower precision robot or automation device is not required to be connected to the Dockbot, the lower precision robot may service multiple similar or different devices. (Human operators may also move one device to another location for the device to operate.) This system may be configured as a single SCARA or 6 DOF robot moving multiple Dockbots within its reachable workspace. The Dockbots are not limited to having the docking features parallel to the floor. They could be at various angles, on a vertical surface, or even upside down.

The multiple Dockbots could each have different functions internally, with various micro grippers or operational processes. Each could get its own internal microprocessor program via RF or IR communication, for true distributed robotics. The Dockbots can be effectively parallel processing, where the SCARA or 6 DOF robot is the distribution and allocation device.

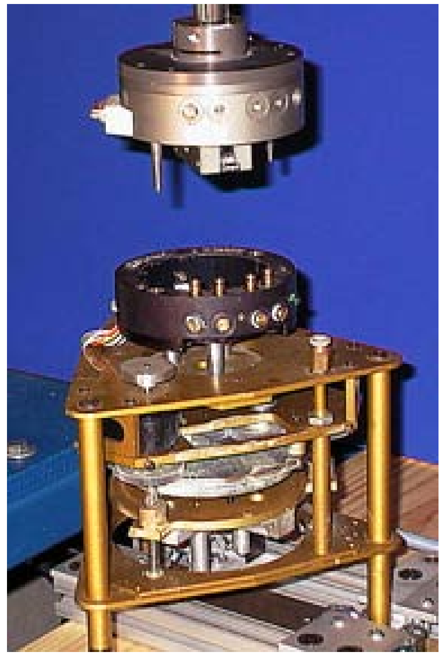

Fig 9 Dockbot Being Docked by SCARA Robot a) Above   b) In Docking Features

The Dockbot's docking features can also be located on multiple pallet surfaces, where the SCARA or 6 DOF robot essentially leap frogs 1 Dockbot over a series of other Dockbots to the next available pallet.

Applications include:

- Sensor / MEMS manufacturing
- Photonics
- Laboratory Automation

Conclusions

By creating a robotic system where a larger low precision robot moves a smaller high precision robot, or micro positioner, each part of the system can function well and cost effectively. It is possible to extend this approach to have the micro positioner of today's Dockbot move an even smaller Dockbot to its docking location to manipulate a nano positioner.

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