Treadbot Multi-head Robot For High Throughput Applications

By

Stephen Derby
Distributed Robotics LLC
172 Lockrow Rd
Troy, NY 12180
derbys@distributedrobotics.com
www.distributedrobotics.com
518-279-3419

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Introduction

A new type of robot has been created. It was designed for high speed pick and place operations that range from creating and packaging food items to order picking items at a warehouse. The overall concept of this new design was to both remove the return stroke found in most existing robots as well as to never require the overall robot system to come to rest. Neither the distance of the transfer motion nor the overall workspace size determines the cycle time with this new design. Extending the transfer motion range is simply a matter of configuring additional modular units. This design can be scaled to various sizes and speeds depending on the application.

Background

One of the robot types most widely used today is the SCARA (Selective Compliance Articulated Robot Arm) design (Figure 1a). The 3 primary motion axes are all vertical and the 2 moving arm members lie in a plane parallel to the floor. The second robot design choice for high speed pick and place is called the Delta configuration (Figure 1b) available by ABB Robotics and Do-Boy (formally Sig Robotics).

Figure 1a Standard SCARA robot (Courtesy Bosch)

Figure 1b Delta configuration robot (Courtesy ABB)

The standard pick and place operation requires the robot gripper to move through space and time such that the gripper makes the overall motion as seen in Figure 2. This gripper trajectory creates a cycle time that is only 50% efficient at best. So in order for the robot to be productive, this requires that the robot moves with high velocity and acceleration. Current SCARA robots and Delta configuration robots benchmark move is: up 1 inch, over 12 inches, down an inch and similarly return in 0.4 seconds. This produces accelerations of up to 13 G forces in order to achieve 150 picks per minute.

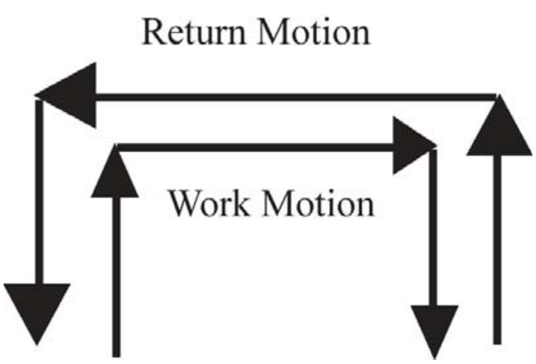

Figure 2 Traditional robot gripper trajectory

Trackbot Design – Related Technology

Distributed Robotics LLC first developed the patented Trackbot (Figure 3, US Pat No. 6688451) in order to reduce overall robot velocity and acceleration by removing the return stroke. This was achieved by creating a continuous looping motion along an oval track (Figure 4) where the Bots would arrive at the pick point, grab the object and continue the motion. The overall system would be more efficient if the Bots were programmed to work in waves (Figure 5).

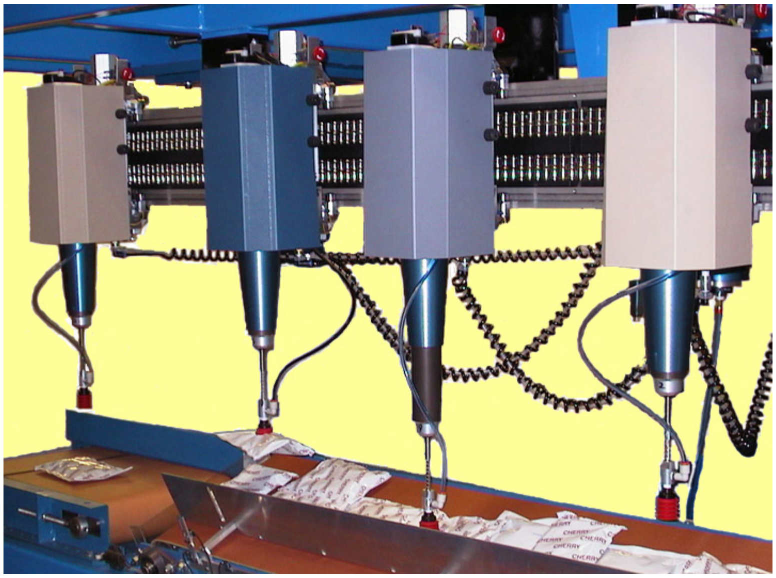

Figure 3 Trackbot machine with 4 Bots picking pouches

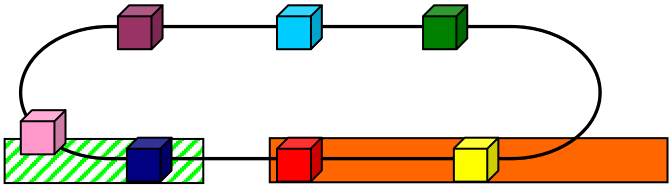

Figure 4 Trackbot track loop – Bots move clockwise

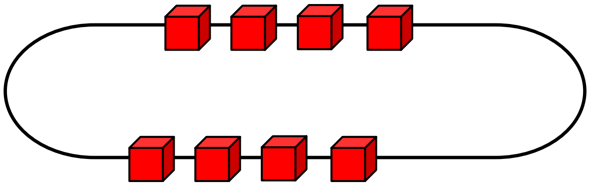

Figure 5   2 waves of 4 Bots on the same track – Bots move clockwise

This concept still required the Bots to come to rest for picking or placing, and thus each Bot occupies space and time that does slow the overall throughput rate. The spacing of each Bot's resting point must be determined ahead of the stopping sequence and any errors can produce collisions which are not desired. The Trackbot also is currently limited to pick locations along a straight line.

Treadbot Design

The Treadbot (Figure 6) removes both the return stroke and the need for an overall robot system to come to rest for a successful pick or place. The spacing of each tread (shown as rectangles in Figures 6-18) is fixed, so the majority of the moving mass is at an overall constant speed. The pick locations can be located anywhere in an X-Y space limited only the size of the Treadbot's design.

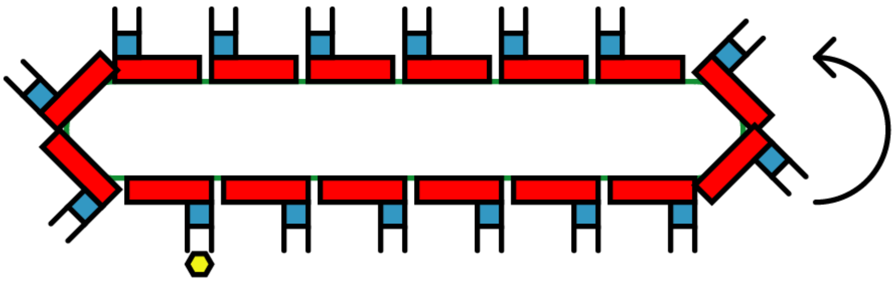

Figure 6 Gripper above hexagonal pick item

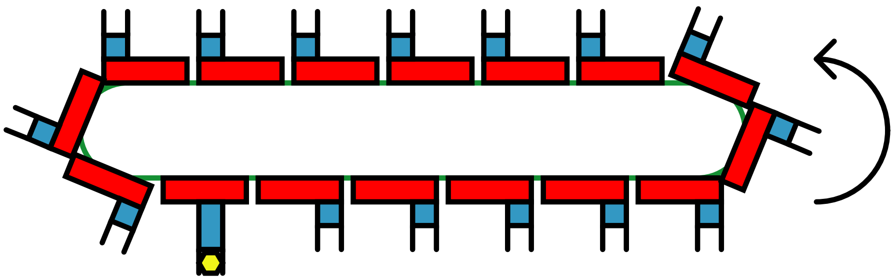

Figure 7 Grab hexagonal pick item while Bot stays at relative zero velocity

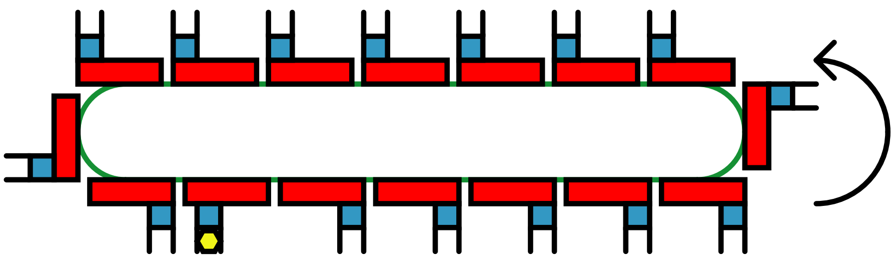

Figure 8 Lift hexagonal pick item while Bot stays at relative zero velocity

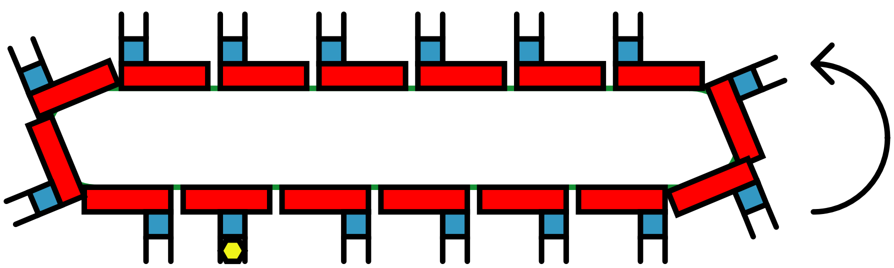

Figure 9 Bot catches up to front of tread

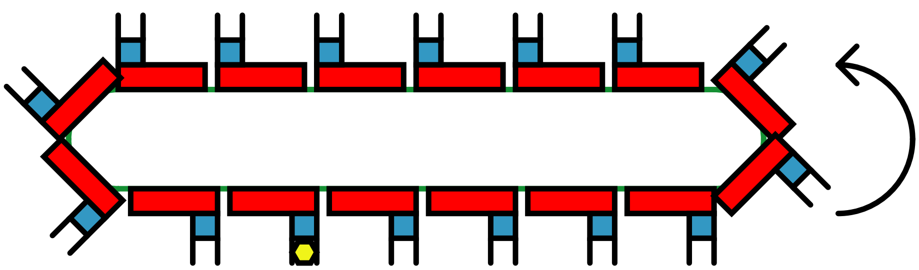

Figure 10 Bot pickup sequence complete

The design is based on a series of moving treads, similar to those found on a bulldozer or tank. Each tread nominally has a single Bot attached to it (shown as squares with gripper fingers in Figures 6-18), and the Bot is nominally able to move along the tread surface in X and Y. The principle is that while the tread is moving in one direction (the + X direction) at a constant speed, the Bot's local motion along the tread surface moves in the opposite direction (the – X direction) at a matching speed (Figures 6-8). The net effect is that the Bot is at rest relative to the world. The duration of this "relative rest" or "net zero motion" window is limited, but compared to standard robot trajectories' potential accelerations of 13 G force this is quite desirable. The Bot then catches up to the tread (Figure 9-10). This sequence (Figures 6-10) shows the picking of an object (hexagonal in Figures 6-18).

Placing is similar (Figures 11-15) to the picking process. Since the treads are always moving compared to the stopping and starting of the Trackbot Bots, picking and placing can be done at any time in the motion (Figure 16). The Treadbot is essentially a continuous motion transfer device.

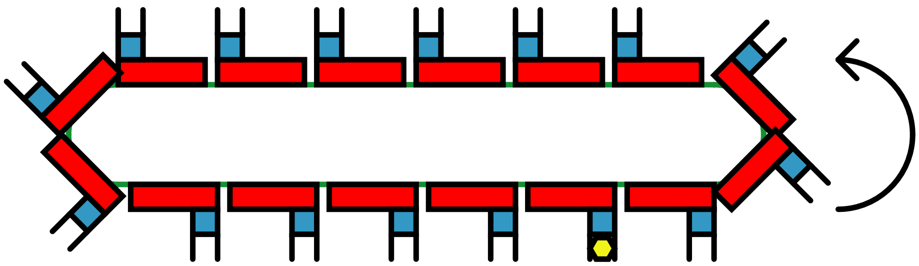

Figure 11 Gripper above place location

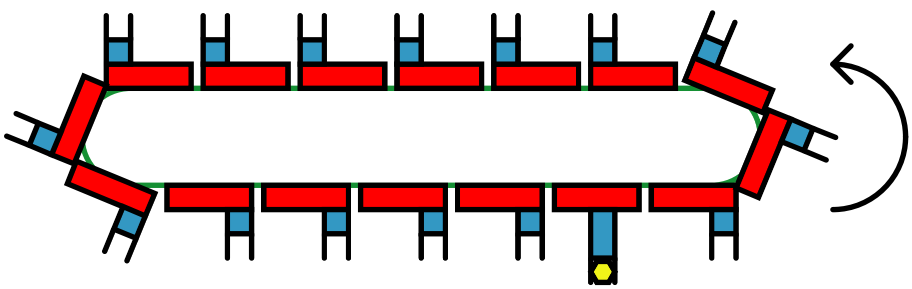

Figure 12 Place hexagonal pick item while Bot stays at relative zero velocity

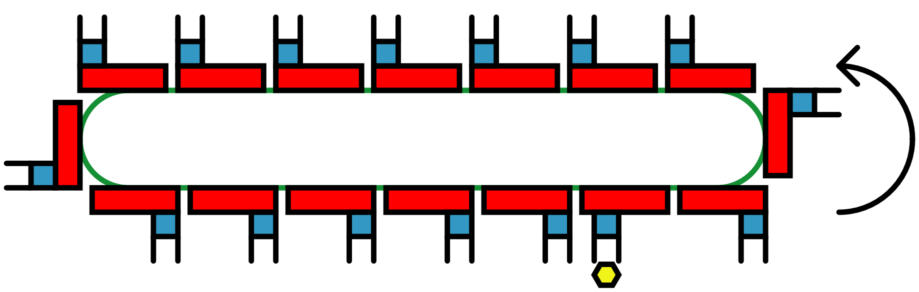

Figure 13 Lift Bot gripper while Bot stays at relative zero velocity

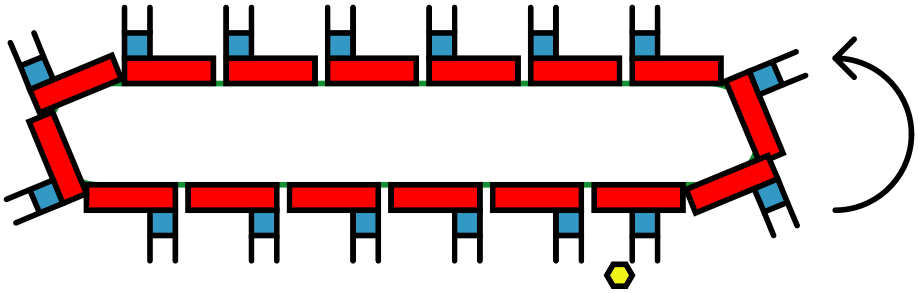

Figure 14 Bot catches up to front of tread

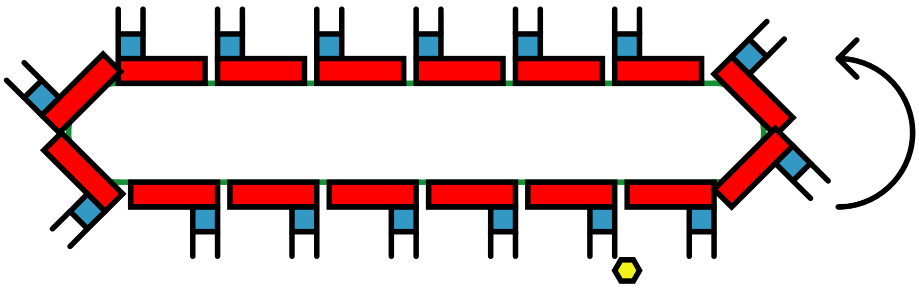

Figure 15 Bot place sequence complete

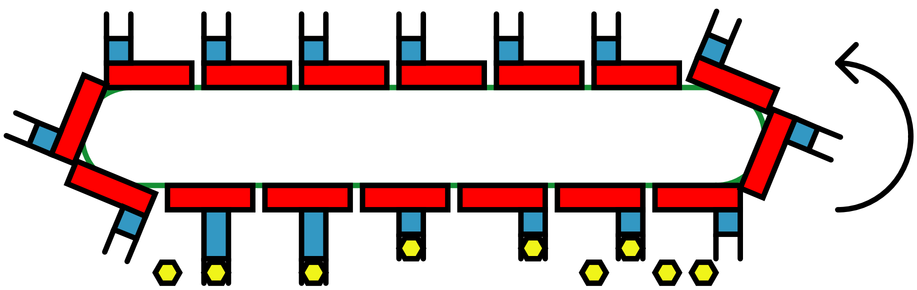

Figure 16 Concurrent pick and place by multiple Bots

The treads are actually 3 dimensional, connected to 2 parallel chain drives (Figure 17). The Bots nominally have the additional capability to move in the Y direction (parallel to the chain and tread motion) in order to pick and place anywhere under the tread. This is an additional improvement from the Trackbot design. The treads can each support multiple Bots if greater throughput is required, though the placing locations would likely be segmented into sections for each Bot.

The Bots would likely obtain the location for product to be picked by a series of vision systems. A possible strategy is to use an angled line produced by a laser and an area vision camera (Figure 18) to detect the products' location. The information from any particular Bot's vision system would likely be used by a Bot 1 or more locations trailing that Bot. Another strategy is when picking items from a conveyor slower than the tread motion, to use a vision system that captures images of the entire product to be picked.

Treadbot systems can be configured as per Figures 6-18 but be designed to pick on the upper return loop. This can be accomplished by pivoting the Z axis 180 degrees (Figure 19), thus doubling the throughput.

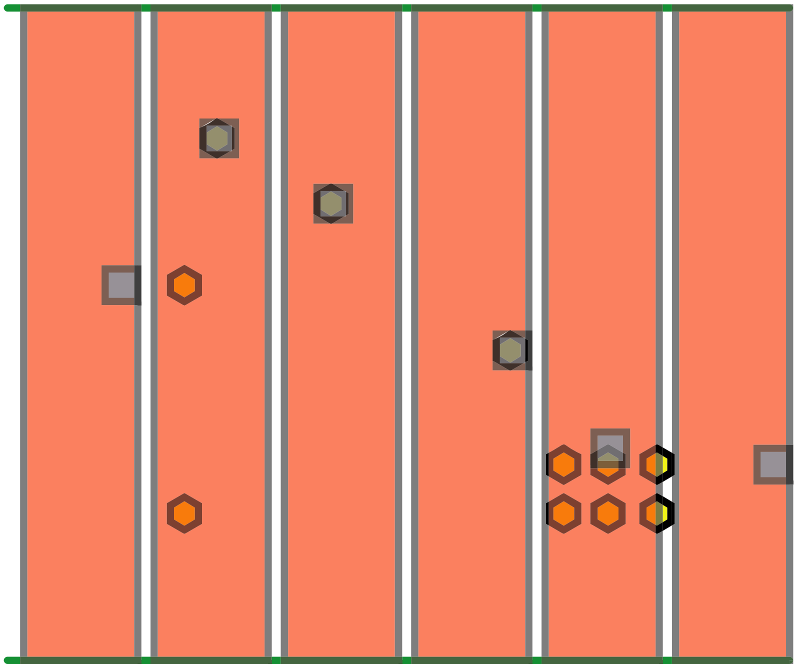

Figure 17 Top view – XY pick/place coverage – Treads move to the right

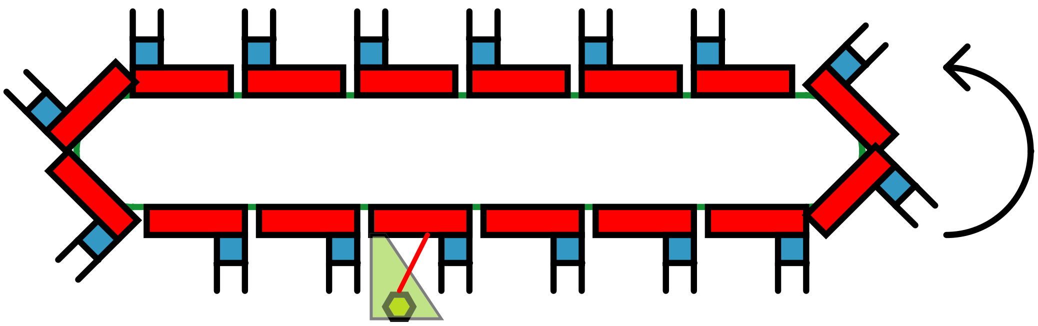

Figure 18 Laser line and area vision system

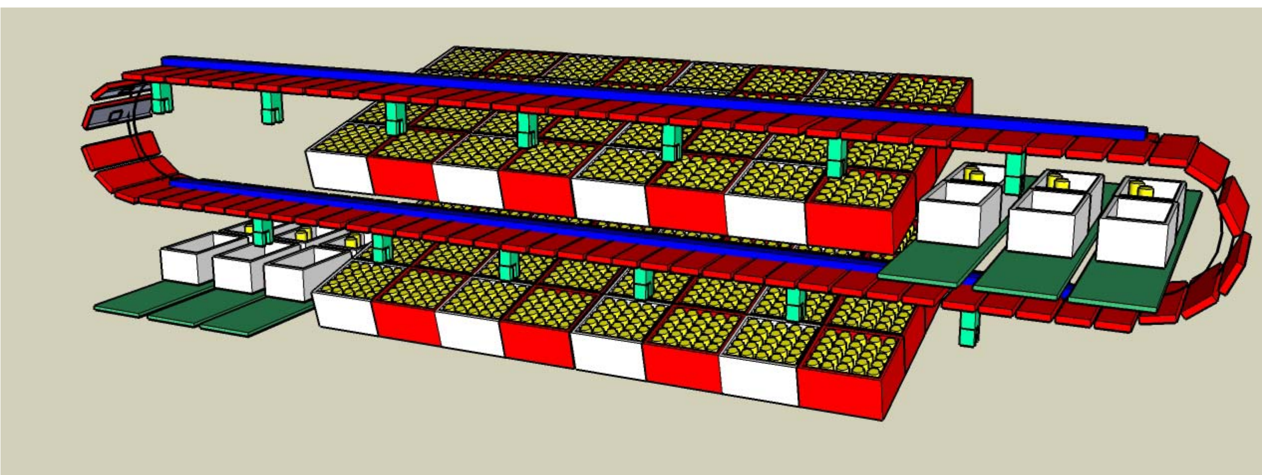

Figure 19 Treadbot system order selecting in Distribution Center – Bots pivot to tread bottom for upper loop picking

The Treadbot could be configured to loop parallel to the floor so as to pickup and transfer on both sides. Figure 20 shows a Treadbot configured to palletize using simpler Bot head motion for reduced complexity.

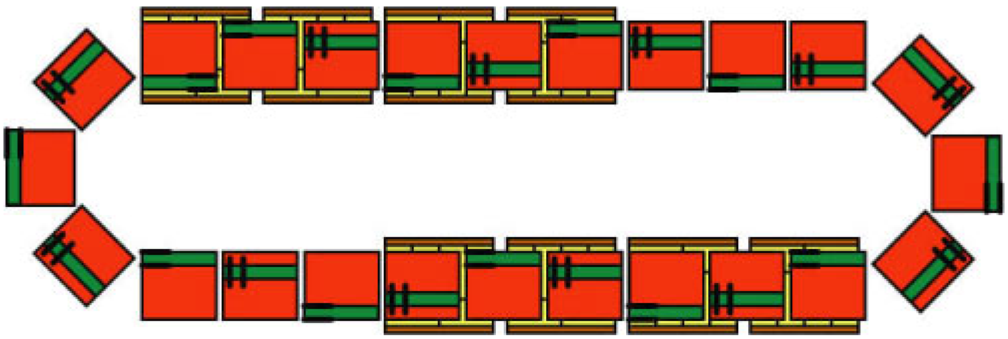

Figure 20 Overhead view of Treadbot configured for palletizing

Treadbot Throughput

The Treadbot's throughput will now be compared to standard SCARA and Delta configuration robots. Whereas SCARA and Delta robots have a current limit of 150-160 pick and places per minute over a fixed transfer range (12 inches or so), the Treadbot principle works differently. Since the Treadbot can be sized with several independent and dependant variables, the optimum configuration can depend on the application's throughput, product size and other concerns. But to understand how the Treadbot is different from traditional robots, it will now be compared using 3 different sets of assumptions:

1] Assume that a tread is 12 inches wide in the motion direction, and that the treads are moving 12 inches per second (this is quite slow compared to the approximately 80 inches per second required of the 150-160 picks per minute). This produces a rate of 60 pick per minute with a Bot "relative rest" time of approximately 0.8 seconds. In the 150-160 picks per minute motion of the SCARA and Delta robot the rest time is approximately 0.05 seconds. This scenario is not beneficial, so more tread speed is needed.

2] If the Treadbot moves at 48 inches per second, the rate jumps to 240 per minute with a "relative rest" time of 0.2 seconds. This is still just over half the speed of the SCARA and Delta robots with 4 times the rest time.

3] If the Treadbot's speed remains at 48 inches per second (still just over half of the others' 80 inches per second) and the treads are now reduced to 6 inches in the direction of tread motion, the rest time is now 0.1 seconds (twice the other 2 robot types) but the rate increases to 480 picks per minute (3 times their best rate, limited to 12 inches of motion).

Multiple pick heads can be placed on each Bot, etc. so configurations yielding a throughput rate of 1000 picks per minute are quite possible. The distance of the pick and place motion can be increased by adding more treads as modular units to the system. This will add to the costs, but does not increase the required speed or limit the cycle time. The motion's distance is now irrelevant to the equations.

Treadbot Applications

With a range of sizes, speeds and throughput rates, the possibilities for Treadbot applications are very large. These include:

- Unscrambling rolls for slicing at bakeries after cooling
- Custom chocolate and candy molding and assembly
- Sorting parcels for postal service
- Order picking for Distribution Centers (Figure 19)

Conclusions

The strategies of the Treadbot do not break the laws of Physics, but the shift in timing, accelerations and distances do seemingly adjust the space/time continuum to benefit pick and place motions unlike the standard practices of traditional robots. Increases in throughput rates will definitely benefit the market.