White Paper

Continuous Motion Automation –
The Factory of the Future

By

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Executive Summary

A new paradigm of automation has been established that creates a continuous motion of incoming components morphing into finished products in the shortest amount of time. By keeping the flow of items constantly moving, significantly higher throughput rates can be achieved without pushing traditional robots and automation devices beyond the practical laws of physics. This barrier of practical traditional motions has limited the standard recommendations of automation consultants and the offerings of automation designers.

Several designs developed by the Pack Flow Concept team will be briefly discussed in this white paper as a means of achieving the benefits of Continuous Motion Automation. Recommendations on how one could proceed with a phased plan over a 5 year time frame will be presented. This disruptive patented and patent pending technology would create a marketing advantage beyond what the competition can offer for the foreseeable future, based on the current limited incremental trends.

Automation – State of the Art

Much of today's automation is based on stopping and starting. Inventory sits and waits for its "15 seconds of fame" before it waits again. Components and finished goods are "work in progress" but very little progress is made. The challenge in a factory is to speed up the process of goods out the door.

Automation found in today's factory has not significantly evolved in the past 30 years. After the first programmable robot was constructed 50 years ago, and the subsequent establishing of what geometry, power source and controller design was the most versatile, only incremental improvements have occurred. Traditional approaches based on this linear thinking of simply trying to get a particular robot or assembly station to perform its dedicated operation faster has reached its limit. It is time for a fresh approach.

Continuous Motion Automation

The first step in achieving Continuous Motion Automation (CMA) is to recognize the need to view all incoming components and outgoing finished goods as a Logistics problem. View the motion within the factory walls similar to viewing the interstate highway network found in the USA. Yes there are rest stops along the highway, but the greater majority of time the shipment is in motion. So also in the factory the components should be moving a majority of the time. This implies conveyors, both linear and pallet style, and other transfer devices such as mobile robots plus other new alternatives.

The next step is to review the operational steps and modify them to be performed while the components are in motion. Can multiple parts be assembled while in motion rather than at rest. Or if it needs to be at rest, use a Net Zero Motion approach (defined later) that the resting timeframe is a fraction of a second.

Lastly, look at the combination of automation solutions and human operator tasks make economic sense for the near future with the viewpoint of phasing in additional automation as a plug compatible replacement of the human. But this can only reach the full benefit if the overall framework is designed for CMA.

No longer can a factory replace a human with a traditional robot simply tuned to go faster than before. The practical accelerations of a single head robot have been reach several years ago yet very few automation "experts" or salesmen want to publically say so. Removing the return stroke of robot head motion is critical to factors of 2x, 3x and even 4x of output production. Using other parameter measurements, overall increases of 10x may be achievable.

Timing of the factory floor will be critical to make the CMA factory flow well, but the resulting operations will truly be Next Generation.

The Principles of Continuous Motion Automation

The Pack Flow Concepts Automation Team has developed what is referred to as the Principles of Continuous Motion Automation. Some of these are existing common sense but others are novel developments away from traditional thinking. They are:

1] Keep products in motion wherever possible
2] Remove any return stroke of automation/robotic gripper or transfer head
3] Avoid the use of a high speed single automation/robotic gripper or transfer head
4] Process a product while in motion wherever possible
5] If continuous motion will not accommodate a process step use Net Zero Motion
6] Keep product linked wherever possible to stream into the next workcell
7] Use continuous flexible buffer to accommodate consecutive workcell timing differences
8] Only locate high precision actuation where needed.
9] Flow product in straight line wherever possible
10] Design to Simplicity

Each of these will be briefly discussed, and where possible, a novel automation embodiment of the concept will be shown. There are additional white papers already developed on each of these concepts if more information is desired.

1] Keep products in motion wherever possible

A product at rest does not generate any increased value unless it is being processed while at rest. And for most factories, the processing time at rest is dwarfed by the time sitting as work in progress. Keeping product in motion, in combination with other of these principles, can lead to better profits. But this comes with the concern of how to handle product when some portion of the factory is not functioning. Buffers and accumulators are required.

Example – Roll Accumulator

One type of factory that is an example of keeping product in motion is a cookie or cracker line. Here the overall process has long startup times, the significant work in progress in the oven and a rate of 200 slugs or wrapped stacks of cookies per minute is not uncommon. The product is in motion wherever and whenever possible, so much so that, when the cartoner jams, the flow though the oven cannot be stopped. The extra slugs of cookies are dumped onto trays and moved away manually until the jam is fixed. Then the captured slugs are re-entered into the line manually.

Shown in Figure 1 is a high speed roll accumulator (Patent Pending) that takes the diverted stream of products and fills a row on the wide green conveyor belt. The slats on the conveyor belt constrain the row of slugs when the belt is wound up on the take up spool.

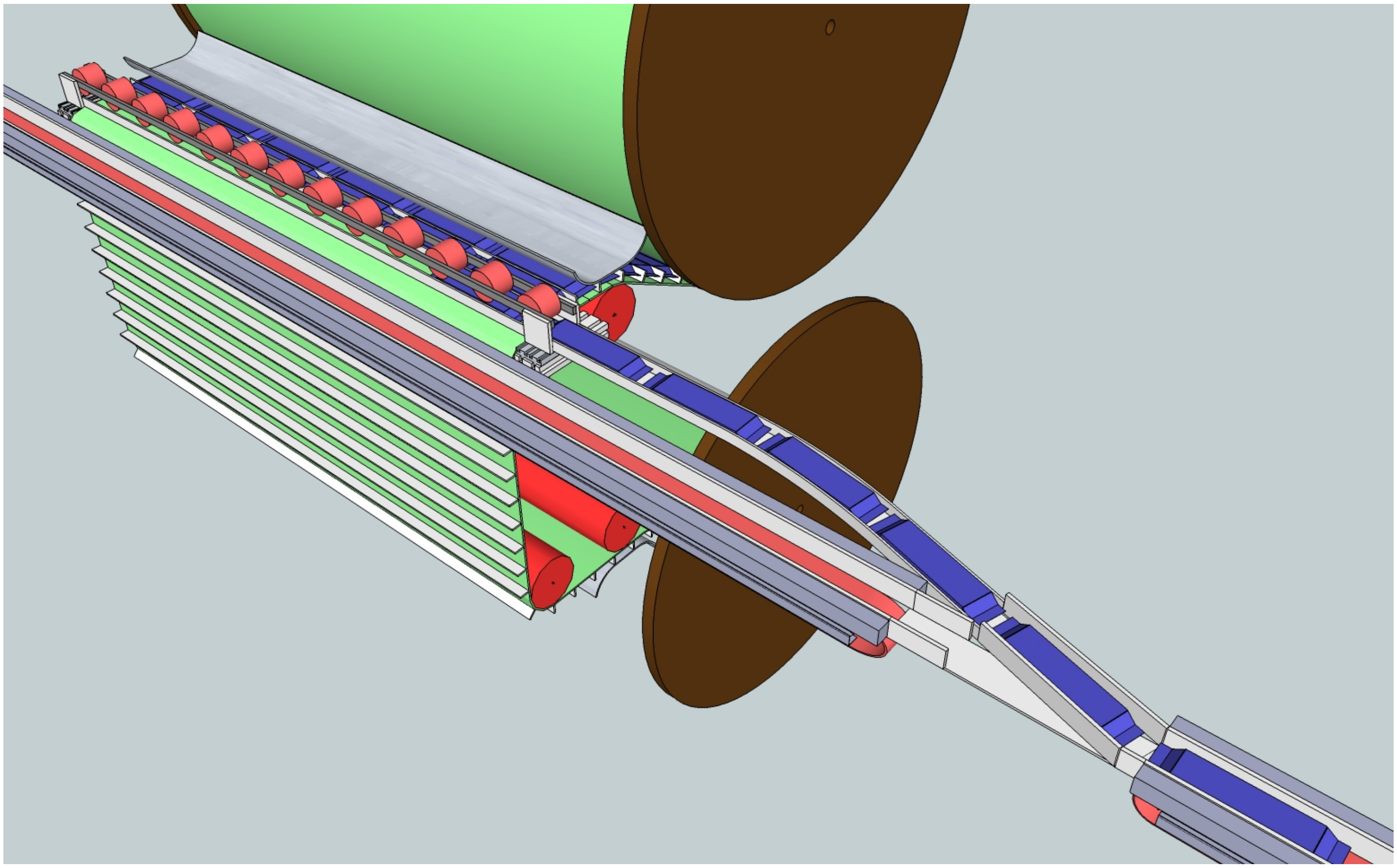


Figure 1 – Roll Accumulator – Patent Pending

2] Remove any return stroke of automation/robotic gripper or transfer head

One can double the speed of any automation/robotic gripper or transfer head by removing the return stroke (Figure 2). This goes against the style and approach to almost every industrial robot developed today. Heads need to recirculate and march like a series of ants carrying food back to the nest.

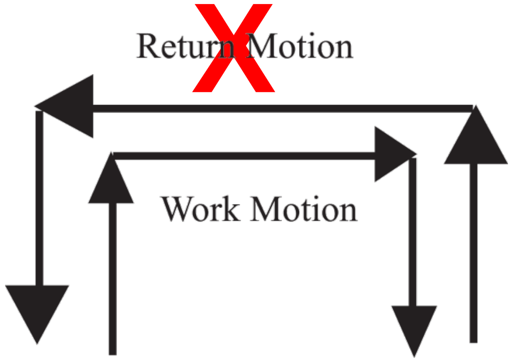


Figure 2 – Removing the Return Stroke

Example – Trackbot

The Trackbot (Figure 3) was design and build by Distributed Robotics LLC (sister company to Pack Flow Concepts LLC) and Cambridge Valley Machining Inc. in the year 2000. It was shown working at Pack Expo in 2000. It has a US Patent 6,688,451. It was developed to handle filled pouches. It is limited to pick product from a line, but when additional marketing showed the need to pick product distributed on wider conveyors, the project was placed on hold.

Figure 3 – Trackbot Multi-Head Robot – US Patent 6,688,451

3] Avoid the use of a high speed single automation/robotic gripper or transfer head

High Speed single automation/robotic gripper or transfer heads can reach 15g, 20g and higher rates. The trouble is that it is nearly impossible to accurately pick or place the gripped item. The practical limit of acceleration has been reached several years ago, and some visionaries have started to state this fact.

Example – Compact FlowBot

The Compact FlowBot is shown in Figure 4. This working prototype was built using Rapid Prototype plastic components. It is a multi-head robot that expands and contracts (Figure 5) to cover the required pick and place areas, plus also has the ability to hold extra product as a dynamic buffer to accommodate timing mismatches.

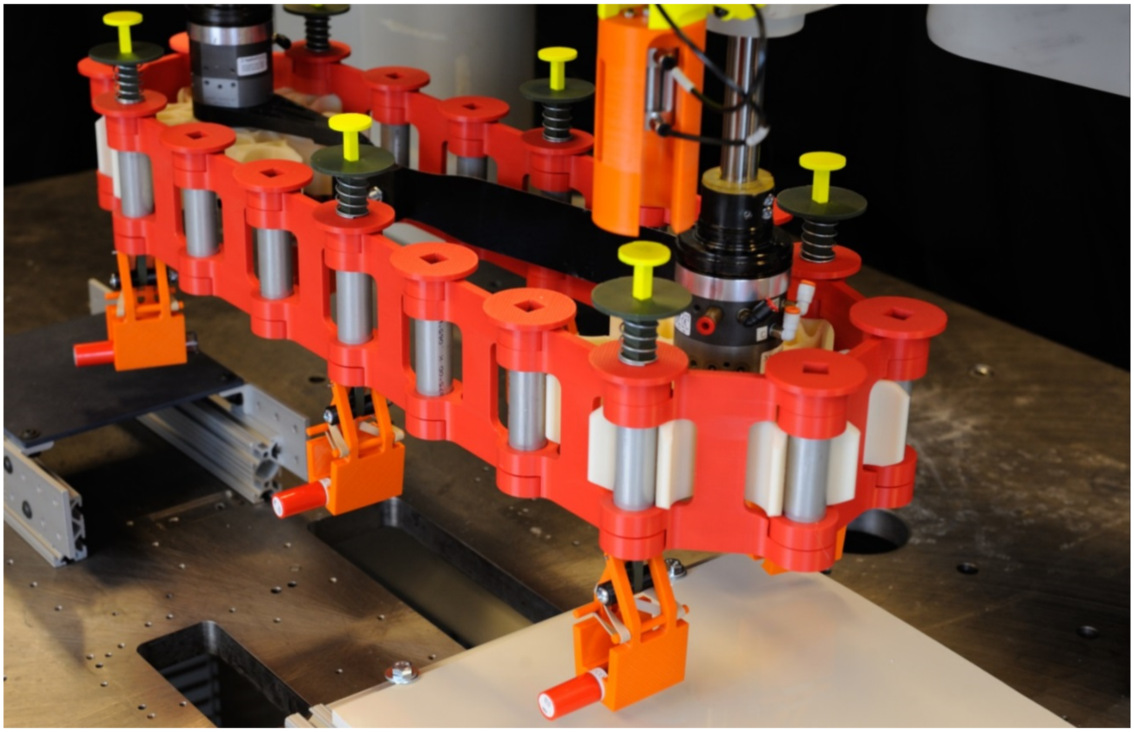
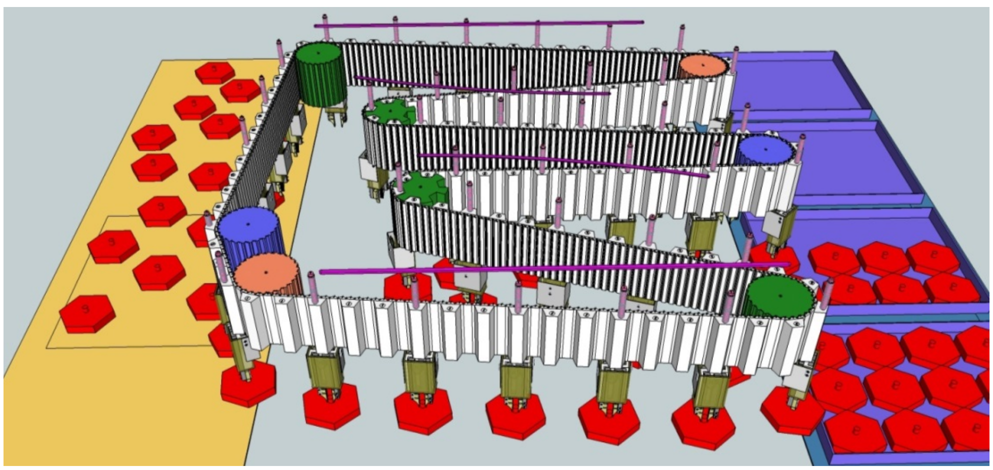


Figure 4 Compact FlowBot Multi-Head Robot Prototype – Patent Pending



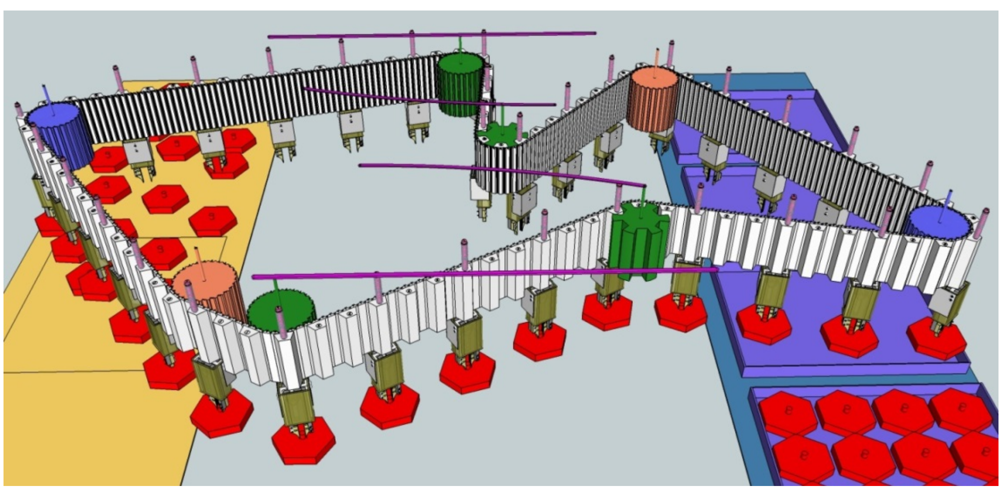


Figure 5 – Compact FlowBot – Top Shows Contracted System – Bottom Shows Expanded System

4] Process a product while in motion wherever possible

Automobile assembly lines have used systems that keep the car body moving, albeit slowly. Workers scurry from one body to the next to install a steering wheel or an air conditioner. Food processing lines wash and inspect vegetables and fruits while in motion.

This can be extended to an assembly station that uses the same motion to transfer the components into the assembly area, perform the assembly, and then transfer the resulting product to the next station. Specifics on this concept are under development and in Confidential presently. This is referred to as the Assembly Work Table.

5] If continuous motion will not accommodate a process step use Net Zero Motion

A novel design to have a continuous motion transfer device is shown in Figure 6. Here the segmented conveyor is moving counter clockwise. The red heads or Bots are each powered by small XYZ gantry systems and the heads are moved backwards to the conveyor motion at the same rate so that the net effect is a short duration at rest to pick the part. The head then moves forward to catch up and is reset to allow a similar motion profile to place the part.

Example – Treadbot

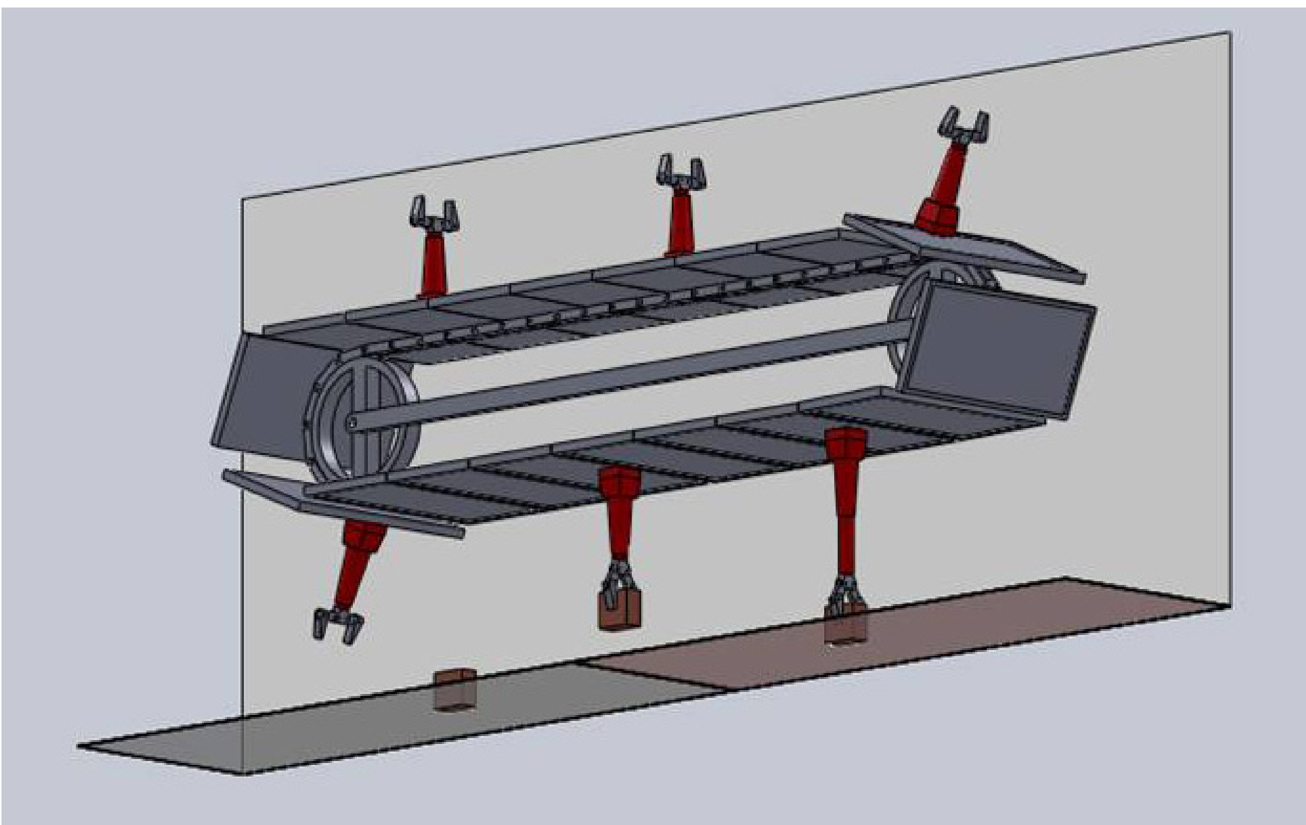


Figure 6 – Treadbot Multi-Head Robot with Net Zero Motion – US Patent 7,712,598

6] Keep product linked wherever possible to stream into the next workcell

Some products are naturally connected, such as what is found in the packaging field. Bags of snack food are deposited and sealed in a tube of packaging material and then cut at the seams. Then a conveyor moves the bags up to a table where they are manually packed. If one does not cut the bags and feeds the bag stream to the packing station, the stream can function as an accumulator to handle the timing mismatching. This can replace a significant amount of vision based robotic automation equipment by keeping control of the product longer.

Example – Chip Bag Case Packer

Figure 7 shows the snack forming machine on the left and the case packing robot on the right.

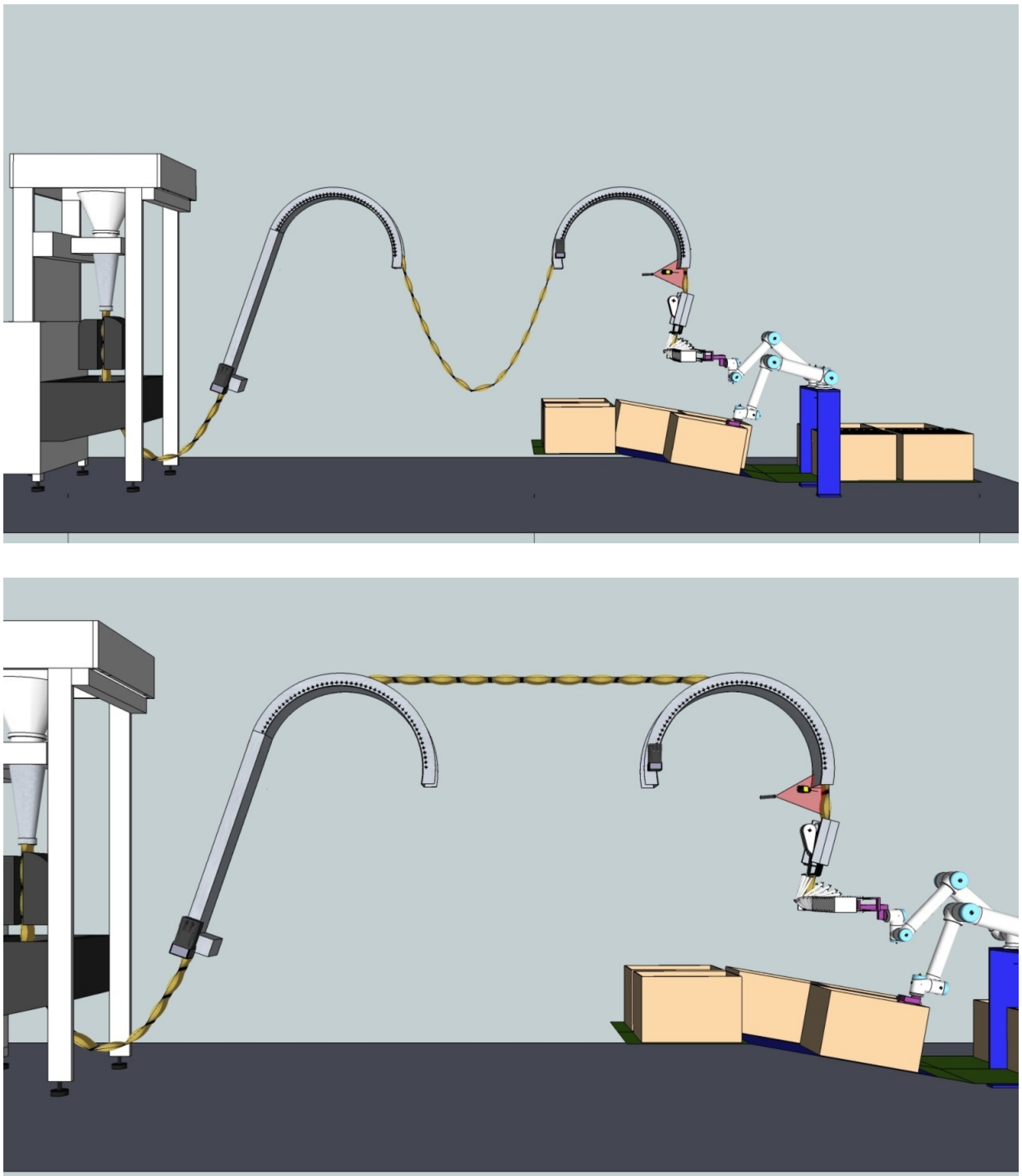


Figure 7 – Stream of Chip Bags – Top Shows Accumulation – Bottom No Accumulation – Patent Pending

7] Use continuous flexible buffer to accommodate consecutive workcell timing differences

Cookies packaged for vending machines can be produced at a rate of 300 per minute. That speed is excessive to many material handling techniques. But if the 300 rate is pulsed onto a processing table (Figure 8) and cut in groups, the rate of the unit of 6 can now be 50 per minute. Then the rows of 6 can be moved to the side and grouped so as to cut rows of 4 as they are case packed. The net results of changing the time base and the fixed input rate to a pulsed slower rate creates a tractable problem and therefore a solution.

Example – High Speed Product Case Packer

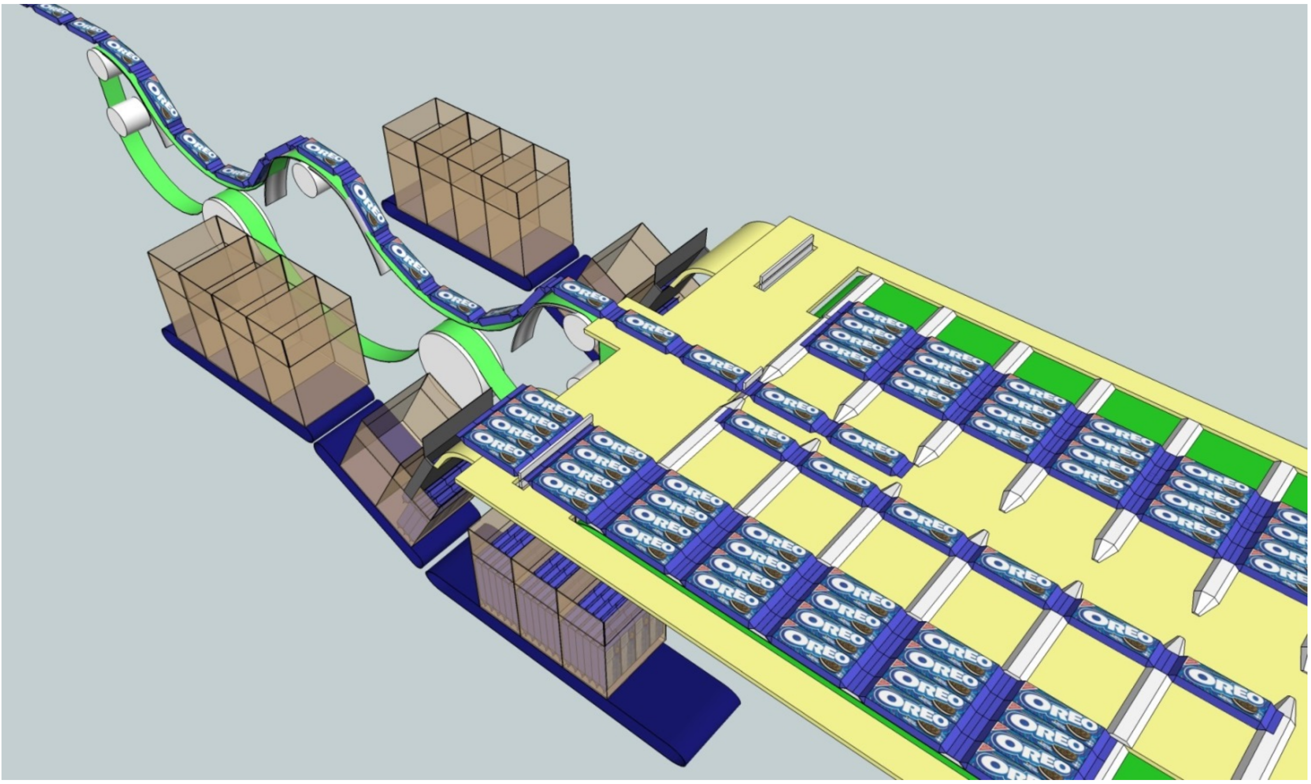


Figure 8 – High Speed Product Case Packer – Product Packed by Rows – Patent Pending

8] Only locate high precision actuation where needed.

Much of the motion of a traditional robot arm does not have to be very accurate. Only at the end points where the item is picked or the end point where the item is placed or assembled is accuracy required. Therefore a lightweight lower cost robot can move a smaller precise end effector and dock or register the end effector when needed. This end effector has smaller range of motion actuation to perform the tasks.

Example – GRASP Docking End Effector

GRASP Inc. developed such a docking end effector (Figure 9) in 1988. The precision available at that time, using low cost technology was 0.0001 inches. Greater accuracy was possible if needed.

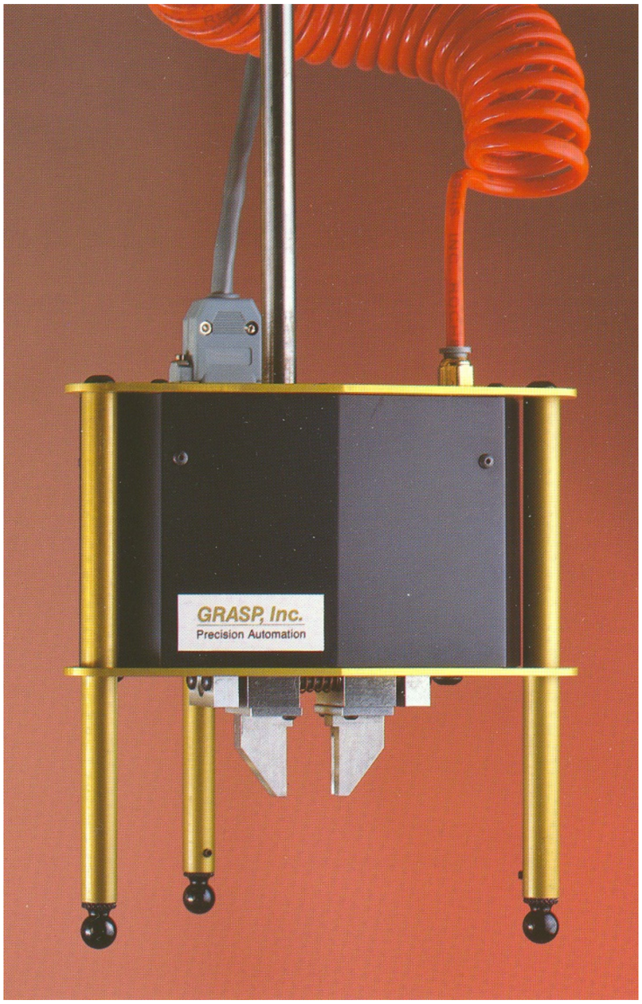


Figure 9 – Grasp Docking End Effector – US Patent 4,919,586

9] Flow product in straight line wherever possible

Standard robotic or automation motion is to go up, over and down. Often the standard workcell environment gave little choice. But if one looks to a novel approach to moving products from supply totes to shipping totes, and allows the totes' side wall to fold downward, then the motion path can be a straight line. Heavier products can be lifted by a roller thumb which acts like a hand truck to carry most of the weight on the roller than with the robot.

Robotic Order Picking

This workcell demonstration (Figure 10) was shown at Automate 2013 in January 2013. The Universal Robot UR-5 was used to move product from one open tote to the other. Work is currently being extended in conjunction with several companies presently.

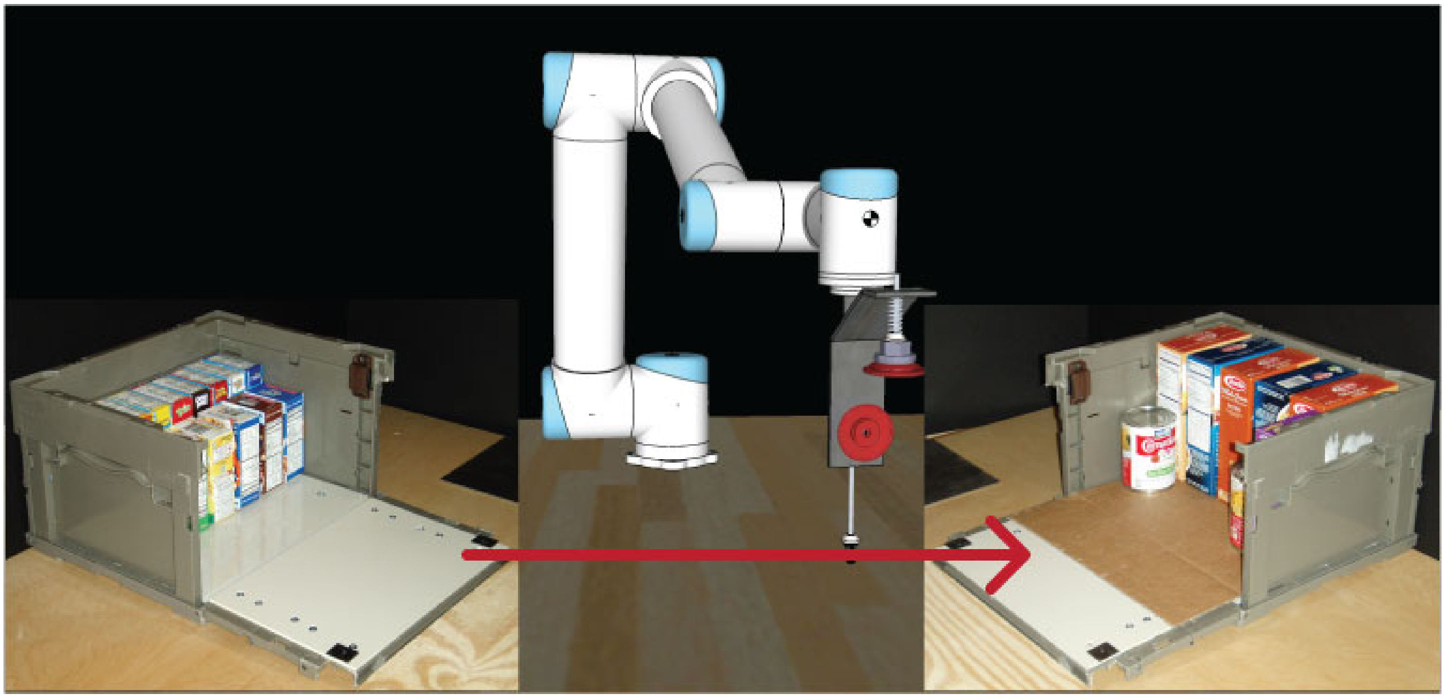


Figure 10 – Robotic Order Picking With Folding Side Wall Totes – Patent Pending

10] Design to Simplicity

The basic reasoning for continuous motion is simplicity of design, fewer parts, and much higher efficiency, which equals less wasted time. The simplicity of design is the single fault with most current automation systems. So though this principle is number 10 it could easily be principle number 1. The difficulty of starting a design process with the number 1 principle task of simplicity and not focusing on improving the core task in implementing one of the other principles is that is often too difficult to burden the design process with too many requirements at the same time.

Suggested Phases for Development

Phase 1

- Develop the Compact FlowBot for moderate speed flexible parts feeding and assembly
- Start developing Robotic Order Picking for bulk parts feeding

Phase 2

- Develop the Treadbot for high throughput assembly
- Develop the Roll Accumulator to handle motion stoppages

Phase 3

- Develop variations of the Chip Bag Case Packer/High Speed Product Case Packer for line balancing
- Develop updated Docking End Effector such that the feet do not have to dock into features

Phase 4

- Develop Assembly Work Table that is currently Confidential

Phase 5

- Integration