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INTRODUCTION TO A FORCE CONTROLLED BEER POURING ROBOT

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Abstract: Industrial robots are one of the most important components of modern automation and are used in various applications. Whereas in many applications it is sufficient with static programming to fulfill the process requirements, there are also many applications where static programming does not suffice or is too impractical. Examples of tasks with these characteristics include deburring, grinding and handling. Without information regarding the forces effecting the robots end-effector, use of industrial robots in the aforementioned can be impractical as there is often variations between workpieces. To remedy this, one can introduce a feedback loop containing the forces applied to the robots end-effector into the robots control system, thus, force control. The purpose of this project is to demonstrate the application of force control in an untraditional application, beer pouring, and thus, widen up the traditional scope of force control. By combining force feedback with force feedback, it's achieved a beer pouring robot system which can handle both to serve a certain amount of beer, however, taken into account the control of the flow of beer from the bottle to avoid unstable pouring situations due to vacuum and foam. With this, the robot cell can provide delicious glasses of beer! The implementation is currently under development, on a NACHI SC15 industrial robot with a special high speed real time interface developed in collaboration with NACHI Fujikoshi. The paper shows the concept and the introductory promising results from the implementation in PPM's laboratory in Norway.
Keywords: robotics, force control, beer

1. INTRODUCTION

Purpose of robotics is to advance and progress human work to a new level, thru higher reliability, longer working hours, better precision and repeatability, flexibility and much more. In later years we have seen that robots are used not only in industrial applications, but also in service applications, where robots job is to directly serve customers (Thomessen et al, 2000 i; Thomessen et al, 2000 ii, Mueller et al 2008, DeSchuter 1986, Paul 1982, Siciliano et al 2008). With these applications we are forwarding new technological advancements to common people, and in some way hoping that while also helping them with their daily tasks and routines we are encouraging them not to be afraid of new technologies, but giving them assurance that automation is helping in their everyday lives.

While some jobs are hard and, we can automate these jobs using robot workers, which will do the same work as human workers but with high productivity and quality. However, there is a challenge to obtain the same high flexibility for a robot compared to a human worker. This has put the research on intelligent sensor systems to try to give the robot partly the same senses as a human worker. Examples are vision, tactile sensor or force control.

In this paper we are focusing on an untraditional robot application from an industrial point of view, beer pouring. The intention is through this very challenging application, to demonstrate the capability of the stat-of-the-art force feedback systems, and through this to give valuable ideas and knowledge to more industrial applications. The pouring process is implemented through flow feedback using force control, supported by model based feed forward. Thus, this application extends the perspective of force control in addition to demonstrating the smooth and high performance implementation to a standard NACHI robot controller, thus, showing the short industrialization time with state-of-the-art industrial robot technology.

2. DEVELOPMENT OF A GRIPPER FOR ROBOT POURING APPLICATION

A crucial part of the beer pouring application is the gripper, which has to be able to lift the bottle out of a crate, or from a shelf, and after that gripper should be able to open it and proceed to pour a drink in to the glass. It has to handle various types of bottles to become fully functional seen from a beer drinker point of view. Another important challenge, is the position of the bottle within the main fingers of a gripper, where bottle should remain as still as possible, so the forces that are affecting flow can be measured and controlled appropriately, and in the end that this gripping force is not to big so that it doesn't break parts that are used and also still give us right control over opening and handling the bottles. Because there was a need to construct glass and bottle fixtures, need occurred to also take that in account while working on a gripper design.

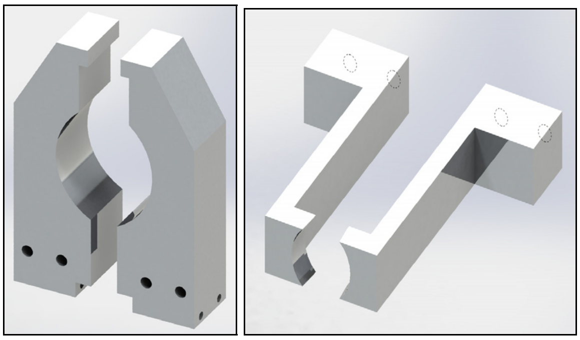

Figure 1. Main and extraction gripper fingers

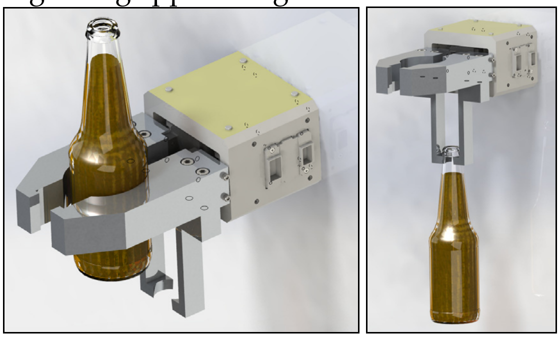

Figure 2. Gripper fingers in their working positions

With this in mind construction of the gripper fingers was made to suit all of the aforementioned problems. Gripper was constructed as an assembly of two kinds of fingers, first were the main fingers that would be gripping the bottles and doing the pouring process, and fingers that were designed for the gripping and manipulating bottle extraction from a crate or a shelf.

A standard industrial gripper was used as the base for the fingers. However, it's important to have a modular design of the fingers to adapt to various industrial robots.

3. DEVELOPMENT OF BOTTLE AND GLASS FIXTURES

Fixtures are going to hold the bottles and glasses, and are going to enable manipulation of the aforementioned objects. Their role here is to position the bottles and glasses.

A round table solution is chosen to optimize the robot motions. In addition, there is a turning mechanism to give beater usage of our limited space. This provides a fixture that will be able to position glasses on predefined surface. It will also simplify the pouring process because the position of the glasses is going to be defined in robot working space.

Figure 3. Glass fixture

Bottle fixture is predominantly used for storing the bottles after they have been opened, this is mainly due to settling of the foam, and thus reduce the foam's effect on the pouring process.

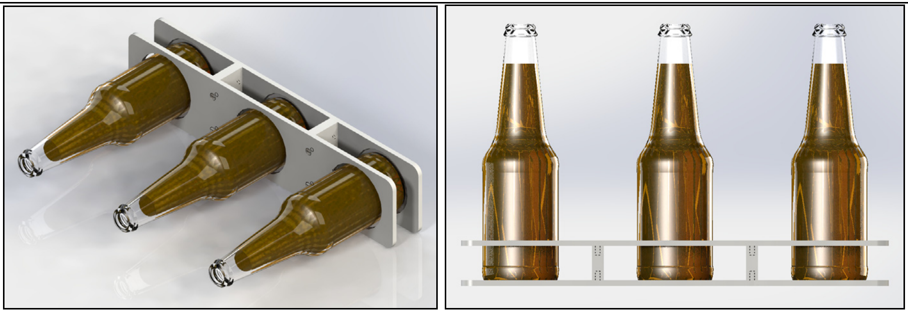

Figure 4. Bottle fixtures

4. FORCE CONTROLED POURING PROCESS

To control the contact force between the robot's end effector and environment, the robot controller needs to have a feedback loop containing the forces applied to the robots end-effector into the robots control system. The control of a system based on force as an input is called force control. The implementation will be done on a NACHI MR20 industrial robot using an Olimex as a real-time interface to a NACHI AX20 robot controller.

In traditional industrial robot controllers, however, there is no feedback containing the forces applied to the robots end-effector.

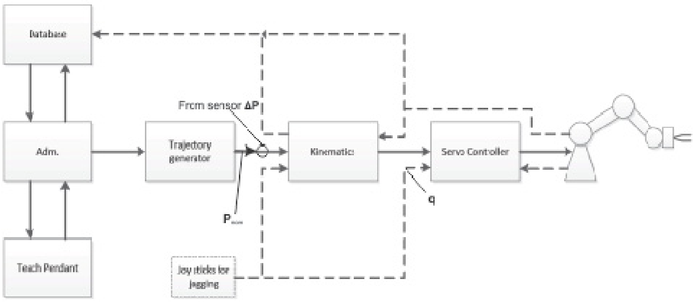

Figure 5. General structure of an industrial robot controller

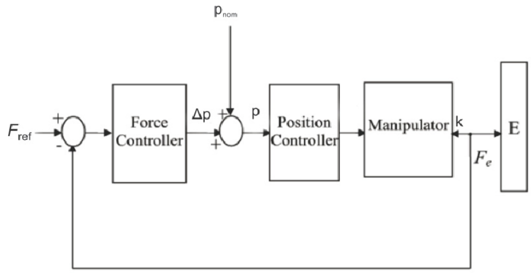

Figure 6. External force feedback loop structure

To include force control, it has to be introduced an out force feedback loop, close around the conventional controller. This control strategy is called "External force control.

And can be extended to include feed forward from reference to improve step response. However, this requires that the dynamics of the interaction between robot's end effector/gripper and the environment is known.

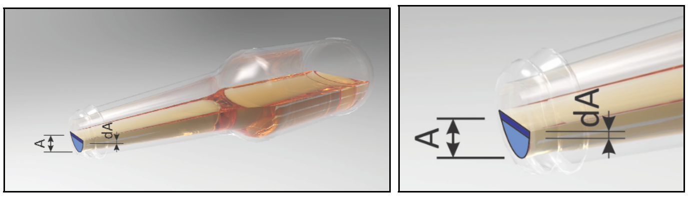

Figure 7. Change of flow affecting the force

In the beer pouring, standard force control is derived from outflow of water from the bottle with constant change of area fluid is flowing out. Force change will be governed by the mass flow which is dependent with the volume change.

$$dV = -dzA_r(z) = Q(t)dt = C_d A_{or}\sqrt{2gz(t)}dt$$

This basic force control principle is.

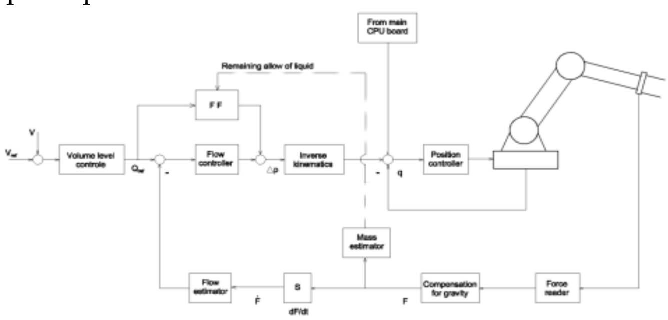

Figure 8. Implementation of force control on an industrial robot controller

Volume level controller receives the information on the quantity of beer we want to pour into the glass and forward that information to the next block.

Flow controller block performs the control of a beer flow. It receives the information on the quantity of beer that needs to be poured and how much has been poured and compiles these two information. Force reader block receives the information. It than forwards the information about the change of force/momentum in time.

Compensation for gravity block receives the information on change of force/momentum due to beer pouring and performs the compensation. Change of center of gravity occurs in the gripper as well as change of mass, and it must be compensated.

Mass estimator of liquid block calculates the remaining mass of beer remaining in the bottle.

Block S calculates the change of force in time, dF/dt, which in turn, represents the flow out of the bottle.

This information about the change of force in time goes further to the Flow estimator block, which calculates how much more the force needs to be changed in order to pour the required quantity of beer. This return information (feedback) is "compiled" with the input information related to the required quantity of beer in the glass.

The FF block (feed forward) estimates the angle of the bottle to provide a given flow. This is based upon the remaining quantity of beer into the bottle, and the desired flow out of the bottle.

Inverse kinematics block calculates the kinematics of robot arm motion based on the calculated force required on the gripper.

Position controller block receives information from the main CPU board and returning information from the sensors following the motion of every joint of a robot, and based on this information sends instructions about the further motion of the robot.

Figure 9. Side view of the robot cell layout

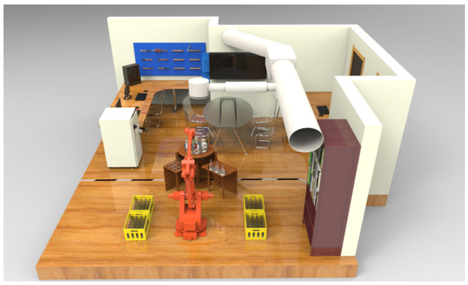

Figure 10. Back view of the robot cell layout

5. CONCLUSION

The paper shows the design and initial results for developing a force controlled beer pouring robot. The concept is currently under laboratory implementation, and practical results will be presented on the DEMI conference.

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