Optimised Dynamic Motion Control of Near Spherical Objects

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Abstract

This research investigates the development of an automated packing machine for a New Zealand Industrial Company (NZIC). NZIC is a leading international manufacturer that produces automated equipment for a labour intensive industry. The proposed system aims to solve the complex packing of near spherical objects (OBJ) which is currently the most labour intensive task.

A review of the existing full or partially autonomous systems has identified multiple units that have attempted to remove human labour from relevant or simplified versions of the task. Three areas are identified as requiring in-depth investigation and this research sets out to investigate these issues and propose possible solutions.

One failing aspect of the existing systems is the apparent lack of prior analysis on how such a machine would deliver on commercial requirements. This research made an in-depth motion analysis on possible automated solutions and laid the foundation for engineering development. The overall system topology was considered with various abstract layouts and this identified a sequential modular layout was best suited to the commercial interests. Physical consideration began with identifying the fundamental kinematic analysis of various end effector arrangements. The kinematics demonstrated the need to make the system tolerant to extended dwell periods and this means the system must pack a multiple of OBJs per cycle. Three robotic concepts where evaluated by simulations to investigate various means of practical implementation. A robotic gantry layout was chosen as the design that would best meet the requirements of the application. The gantry design is then further developed to make more efficient use of actuators and other beneficial attributes for development. The proposed design has been presented and the businesses case could be viable once the market for NZIC's industry recovers.

A second problem that all the existing systems have suffered from is the lack of fault correction or avoidance. A central component to the proposed design is the

introduction of grasp feedback for the control system. A low cost piezoelectric pressure sensor and means of measuring vertical load have been developed for a simple vacuum grasping unit. This grasp feedback unit has been integrated into a modular end effector (EE) unit that is intended to solve the specific OBJ handling requirements of the application. The EE unit development covers more than just the OBJ grasp by also considering OBJ manipulation and solutions for handling the industries uncontrolled environments. Low cost means of servo actuation are integrated into the EE as means of rotating the OBJ and translating its location along the robot's knuckle. A novel pneumatic system provides a solution capable of handling the working environment in addition to the main focus of intelligent grasp control. Where possible, without a full OBJ packing system being built, the grasp feedback has been simulated and subjected to limited testing. Various control system layouts have been developed for throughout the product life-cycle of the EE. The proposed EE unit demonstrates promise of solving all the OBJ handling issues identified during the review of existing commercial packing systems. The EE now needs to be prototyped to a standard capable of field trialling for the commercial application.

The third requirement is a means to manipulate all three rotational axis of the OBJs. No existing system can successfully complete this function with an acceptable production rate. Several concepts of such devices were prototyped, with one variant demonstrating a potential means of inducing variable and predictable rotation. This design was a mechatronic system that intends to manipulate the OBJ's three rotational degrees of freedom using an ultra low cost layout. The orientation system has been developed across all the mechatronic components including software, and takes into consideration several different designs for throughout the system's life cycle. A position based visual servo control system has been developed to provide a control feedback loop that traces the six degrees of freedom of OBJs. Explained is both the hardware layout for the inspection, plus the algorithms developed for motion tracking. The algorithms developed for motion tracking produce a series of inter-frame references 3D reconstructed from the captured images. A blob tracking search algorithm then matches the references across multiple images. Lastly an intersection of planes algorithm

estimates the OBJ motion. The completion of all elements for the manipulation unit has allowed motion studies of the proposed device. The motion study of the orientation device demonstrated predictable behaviour for steady motion, however the behaviour during transient motion proved too unstable to allow position control of the OBJs. It is concluded that the orientation unit was too low cost for the purpose and a direct acting servo unit should be further investigated.

The outcome of this research is an overall system proposal that should allow the successful commercial application of an automated organised packing of near spherical objects. The proposed end effector arrangement demonstrates promise of reliable OBJ grasping and should be field trialled in order to verify commercial use. The low cost orientation unit should not be progressed further as it seems unlikely to offer reliable positional control. Instead a means of direct rotational manipulation should be investigated.

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In reality it has been my upbringing around workshops, the farm and motor-sport has provided me with curiosity and understanding of machinery. Finally my beautiful Emma who locked me in my room until I finished this thing and who has been such a help in the final editing. Hopefully I'll now have more spare time to spend with you all.

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Glossary

BDC	Brushed DC motor
BLDC	Brushless DC motor
COG	Centre of gravity
EE	End Effector
FRST	Foundation for research, science and technology
GRDP	Grasp or release dwell period
LVDT	Linear variable differential transformer
NZIC	The name given to the New Zealand industrial company
OBJ	The objects handled by NZIC systems
OPM	OBJs per minute
PCB	Printed circuit board
SCADA	Selective compliance articulated robot arm
SCARA	Supervisory control and data acquisition
RTP	Rapid tray packer
ROI	Return on investment
SMA	Second moment of area
SROI	Special region of interest
VTR	Vacuum test rig