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Because Motion Matters™

Closed Loop Control Matches Imaging Improvements in CT Scan Technology

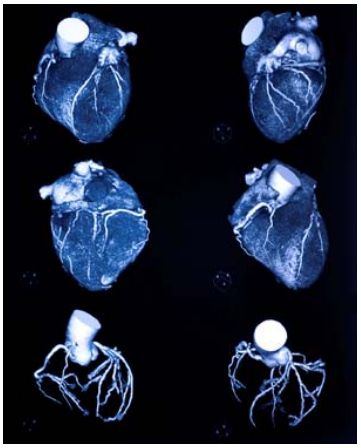
Lee Stephens, Senior Motion Control Engineer
Kollmorgen
Radford, VA
540-633-3545
contactus@kollmorgen.com
www.kollmorgen.com

Significant advancements in imaging capabilities have occurred recently in CT (Computed Tomography) scan technology. Improved image resolution, larger image process receivers, along with the data capability of computers and control systems, enables CT scans to be more detailed and thus more useful for accurate diagnosis. But capitalizing on these improvements also demands more precise control of the imaging process.

The evolution of control

CT scans are a method of imaging using a mobile X-Ray methodology to acquire a complete 3D image used to diagnose various anomalies of the body.

Early CT designs used motors that allowed the machines to rotate during the imaging process. This was a very slow and tedious process that required the patient to remain still for extended amounts of time. As image capability improved, the addition of segmented receivers (slices) allowed for increasing the area of imaging but taxed the control system with the larger mass and finer resolution.



Obtaining timed clocking of the images at faster rates would allow for a piece-wise reconstruction of the set into a 3D image of the internal workings of the body, and some improvements have been realized in that regard. In some cases a motor system with a position sensor on the rotational axis was used, while other solutions used velocity controllers operating at an approximate velocity within the analog tolerances. This semi-closed loop was adequate for many image processors of the time, but further improvements were still needed.

The need for more precise control

Internal organs move with the respiration of the human body. Capturing larger areas with the new imagers can successfully account for such movement, but getting a high-resolution picture of the wrong area or at the wrong time isn't useful. So to obtain the most helpful images one needs to position the imager at the right place and at the right time. The image reception is done in segments (called slices) and has seen increases from 4 to 16 and up to 128 slices. This 4-fold increase each time yields smaller more detailed data, but what does this mean for the control system? Image technology increases will require the control to be more precise. When the imaging components were limited to 4 slices, previous control was likely to have been completely adequate but blurring became evident as the picture data was more detailed, limiting the advancement. In order to take advantage of a 16 time increase in data, the control system has to improve. Without control improvements, no net gain would occur. Advancements in image resolution are continuing to improve and resolution is increasing. The servo technology behind Kollmorgen's AKD™ control schemes will be irreplaceable for these advancements.

Reconstructing multiple images into a complete scan is best done when consistency of the position relative to time is consistent. But as rotational speeds increase the precision timing and velocity requirements of the control system also increase. Improvements of position-time closed loops in digital controls make this possible.

Velocity control vs. position control
Historically speaking, AC induction motors operating in velocity mode were adequate for imaging, with positioning mathematically determined from the velocity data. But with velocity control comes deterministic errors in the equations, and this method is simply not as accurate as having the position loop closed around a velocity loop. Adding position feedback help, but closing the loop around the position is the most reliable.

With a digitally sampled position control, the position-time relationship is not totally subject to the tolerances of the velocity loop and related parameters. The additional loop can correct on each sample for velocity and position error. The result is a tightly coupled loop between position and time that can be used for data acquisition at the required position-time interval.

As the technology advanced, the need for even more accurate determination of position during the scan operation was needed. More slices equated to more detail, but blurring of this data would yield no improvements. As a result, velocity stability is more important with the higher resolution requirements.

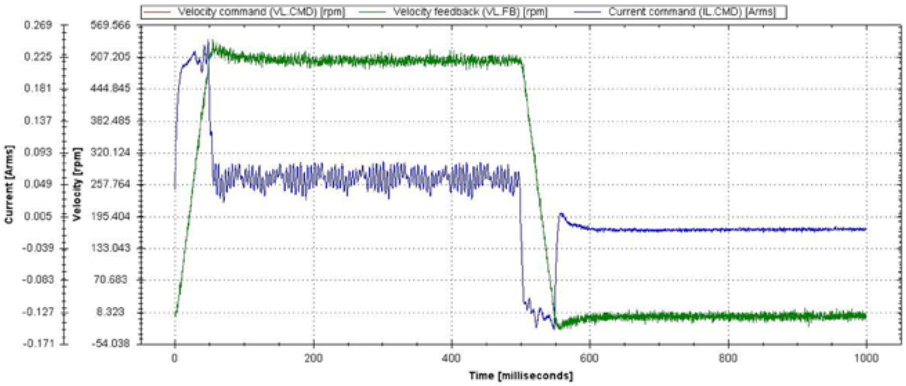
Control loops contained within a drive
An efficient and compact method of control is to have the position, velocity and current loops within the drive. Fieldbus protocols using CANopen® or EtherCAT® can be used for communication to the drive negating the need for a separate motion controller in many applications. One such drive, Kollmorgen's AKD servo drive, has options including these protocols. Using the drive in fieldbus and indexing mode will allow a move to be generated within the drive and triggered by a CANopen® or EtherCAT® command. Multiple moves can be downloaded or stored to the drive and either triggered by a data bit or a Field bus command. This centralized control eases manufacture by reducing the required area, increasing ease of assembly and reducing cable count.

Given the control, there are known position-time references along the trajectory allowing for precise operation of events during the move. The reporting structure can be through the bus communications, or if high-speed events are to be captured, it may be done digitally with the inputs. This optional structure within a drive simplifies external controls and centralizes a significant portion of the variables associated with imaging technology.

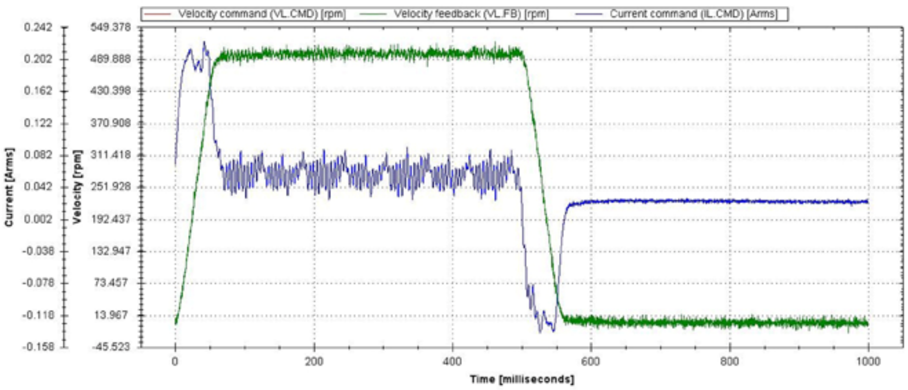
Utilizing drives with integrated control loops also enables higher rotating speeds to capture a complete image in a shorter amount of time, effectively reducing the amount of radiation a patient is exposed to during a given procedure. Additionally, by providing a higher quality image the physician is able to make an accurate diagnosis more quickly. This motion control strategy may also reduce or even prevent image artifact problems.

What is position-time closed loop?

A velocity controller has a control scheme that contains the current loop and velocity loops. With the tolerances of the velocity loop, it is quite possible that a system would overshoot or undershoot the commanded trajectory due to the tolerances of the system or compliance. Closing a position loop around the velocity loop will resolve this due to the position-time relationship. Even an insufficiently tuned velocity loop is improved with position loop closure. Reducing the tolerances will allow for more imaging in less time, with significantly improved images and less post processing requirements.



Scope plot showing velocity command and velocity with a velocity closed loop system.



Position time closed loop with identical velocity gains.

The challenges of controlling medical imaging

The medical imaging equipment controls are only extraordinary in terms of their size and precision. In the standard controls market, large size and precision are not the norm - far more common would be small size and high precision, or large size and low precision control.

The large inertia of a rotating gantry and the need for precision control results in high gains. High gains, however, typically equate to troubles when the mass or inertia ratios are larger than 5:1. With inertia ratios of up to 100 times this ratio, keeping the system under control poses a unique set of challenges that can be counterintuitive. If the gain is too high, tuned resonance issues occur, meaning that the gain of the system is too large to support the application. Decoupling of the load can occur around the desired control bandwidth which results in overshoot of velocity and/or position. If any gains are beyond the compliance of the system, the gantry will overshoot or resonate out of the control limits. Resultant jerk forces could also damage the image tube, sensors or other sensitive equipment. Obviously stressing the compliance limits is not something that should be taken lightly.

By utilizing digital filters for precision tuning, getting clear, well defined pictures is the new imaging reality. Without improved control schemes, however, the net result of image improvements would not be maximized leaving the analysis at a point of diminishing returns. Advanced drives, like the AKD servo drive from Kollmorgen, provide advanced filtering, digital current, velocity and position loops in a single package, and allow for full return on the improvement of the imaging technology.

ABOUT KOLLMORGEN

Kollmorgen is a leading provider of motion systems and components for machine builders around the globe, with over 60 years of motion control design and application expertise.

Through world-class knowledge in motion, industry-leading quality and deep expertise in linking and integrating standard and custom products, Kollmorgen delivers breakthrough solutions unmatched in performance, reliability and ease-of-use, giving machine builders an irrefutable marketplace advantage.

For more information visit www.kollmorgen.com, email support@kollmorgen.com or call 1-540-633-3545.