BifCo Panel Repair

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Abstract

BifCo repairs two-dimensional structural panels. Mr. Bif has hired you to design the motion control subsystem (MCS) for his proprietary repair process. A robotic arm assembly performs the repairs in an environmental chamber. The repairs can be done without totally disassembling the panel. So in addition to defining the section to be repaired, exclusion zones must be defined and observed for features that protrude from the assembled portion of the panel. Further, the robotic arms must stay within the walls of the repair chamber. You must design a motion control subsystem that supports all robotic motion: "Manual" moves commanded by the operator, and automatic motion that moves the tool back and forth across the repair zone a segment at a time, from the starting edge to the end of the repair zone. Your subsystem must also update a graphical display that shows the zones of work, exclusion zones, the real-time position of the robot's arms, as well as the end position for each move of the robot's arms.

Panel Repair Overview

This overview is provided to familiarize the engineer with the overall process. Elements of the overview that are in scope are highlighted in the next section.

Typical Operation

Initially the traverse is stowed in its parked position so it is out of the way.Workers transport and attach the panel to be repaired to a fixture in the chamber.

The machinist then powers up the repair robot and begins the job setup. The machinist uses a hand held remote control pendant located in the processing chamber to digitize, or outline, the defective section, an irregular polygon that may contain voids, and also digitizes any exclusion zones that are in the path of motion from the tool magazine to the repair site. The zones may also be built and edited with the mouse on the real time display.

After defining the zones of work and motion exclusion the repair process begins. The machinist's display graphically shows zones of work and exclusion. The display also shows the tool holder's current position and the positions of the robot's arms (important for radial/radial case).

Using a series of mouse drags of the traverse drawn on the real time display, the machinist positions the robot's tool holder to a starting point just inside an edge of the repair zone. Any portion of a repair zone that intersects an exclusion zone is considered an exclusion zone. The machinist then verifies the direction of secondary axis motion so that each subsequent segment procedes across the repair zone and then issues a command that initiates the multi-step repair process.

The MCS moves the tool back and forth across the repair zone a segment at a time, from the starting edge to the end of the repair zone. Automatic motion is not permitted if positioned outside of a repair zone. The graphical display shows the real-time position and end position during each move of the robots arms.

In the case of the X/Y traverse, the motion is linear. In the case of the rotary/rotary the repair motion is a series of arcs. Straight-line motion is not expected or required in the rotary case.

Your software is not expected to solve for an optimal or full coverage path. The machinist may have to set the position for several start points to complete the repairs. Automating this is considered phase 2 work.

Below is an example of how work and exclusion zones could be shaped and positioned on a panel. Note: the real-time display does not show the features or damage, just the zones.

Work Area, Damaged Area, Exclusion Zones, Features, Panel
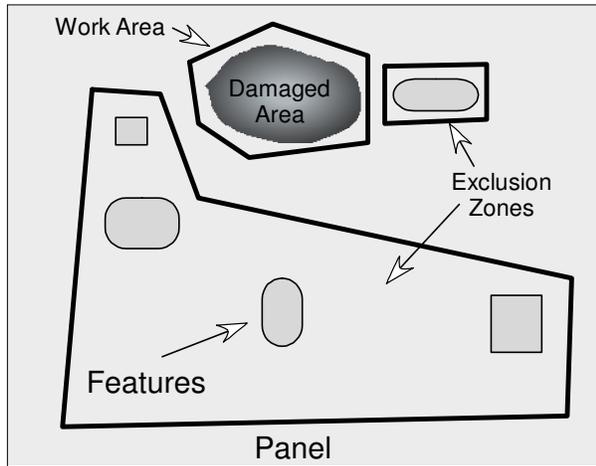
Motion Control System Scope

In Scope:

1) Management of all motion of the robot in the plane of the panel.
   a. Automatic motion in a repair zone
      i. The MCS moves the tool back and forth across the repair zone a segment at a time, from the starting edge to the end of the repair zone. Given a repair zone, the tool will manage motion within that zone.
      ii. Automatic motion is not permitted if positioned outside of a repair zone. The MCS must detect this state and prevent automatic motion. Manual moves are permitted outside of the repair zone.
   b. Remote control motion given as a speed and direction by switches on the remote control.
   c. Manual motion in the form of absolute position. For instance move X to 102" or move axis 1 to 35°
   d. Mouse motion initiated by dragging an axis on the realtime display. For example the user drags the X axis to a position –5" from its current position.

2) Alignment of the traverse to its position in space. Traverse position is unknown at initial power up or after a power failure.
3) The MCS must draw its state on the realtime display. A device context (or system equivalent) will be passed by the caller to the display update functions.
4) The MCS code must support the linear or rotary traverse. Methods will be required to define the traverse geometry.

In Scope - System Interface:

1) The MCS must accept zone definitions from this the remote control and digitizing subsystem. A zone definition is an irregular polygon that may contain voids. All zones are defined as vertices of a polygon.
2) The MCS must provide data to the display system to support the display of the tool holder's current position and the positions of the robot's arms (important for radial/radial case).
3) Using a series of mouse drags, the machinist positions the robot's tool holder to a starting point just inside an edge of the repair zone. The MCS must provide an interface for accepting these movement requests, and managing the tool movement.

Out of Scope:

1) Straight-line motion is not expected or required in the rotary case. In the case of the X/Y traverse, the motion is linear. In the case of the rotary/rotary the repair motion is a series of arcs.

2) Your software is not expected to solve for an optimal or full coverage path. The machinist may have to set the position for several start points to complete the repairs. Automating this is considered phase 2 work.
3) The working head of the tool can be engaged or retracted. Management of tool head position is out-of-scope.
4) Remote controller is out of scope. The remote control code will call into the MCS with velocity move commands.
5) The digitizer is out of scope. The digitizer will call into the MCS to request the current position.

System Components

Robot Assembly

Currently BifCo uses two types of robots in their repair chambers, a simple X/Y traverse and a radial/radial form. Mr. Bif would like your design to be extensible to other combinations of traverses. For instance, a linear and rotary could be combined.

Below are examples of the repair chambers currently in use.

Linear/Linear Axis Top and Front Views
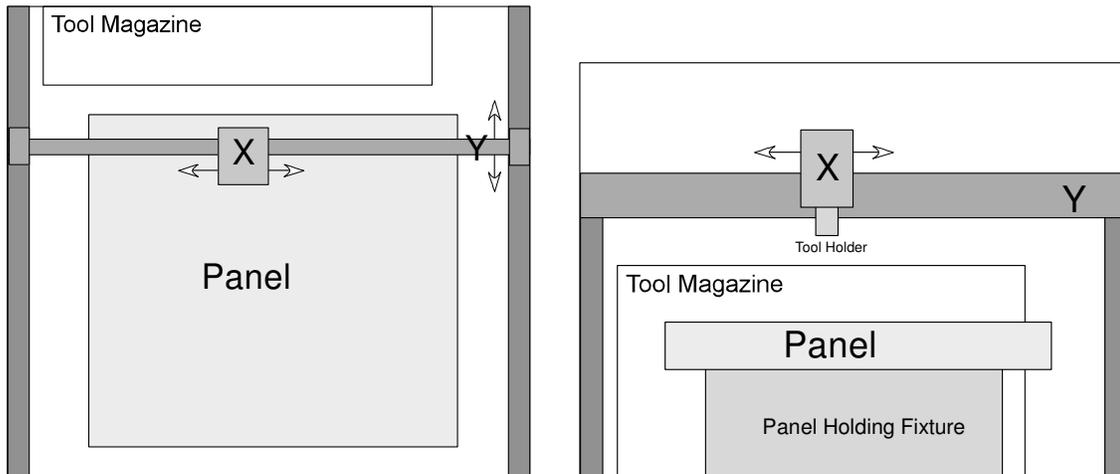
Radial/Radial Axis Top and Front Views
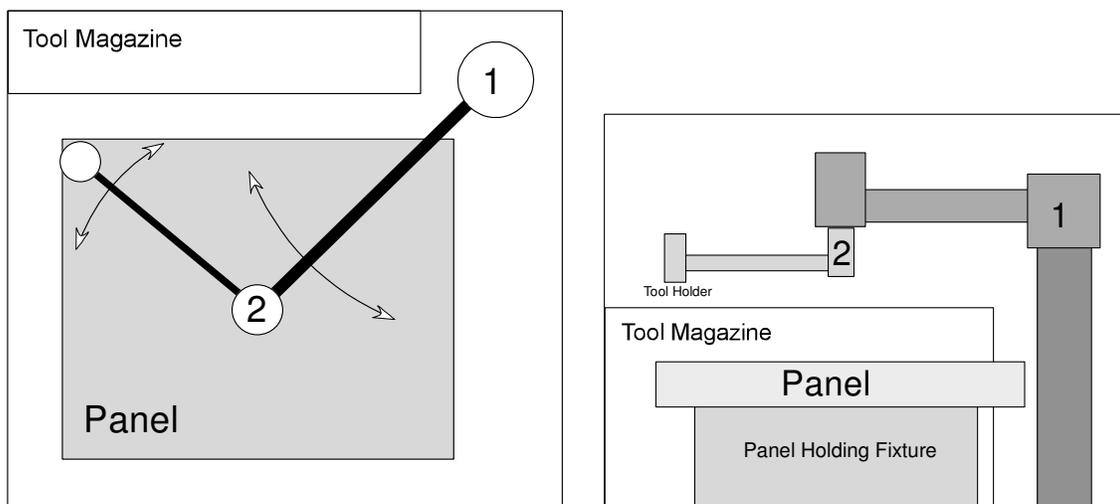
The radial/radial assembly's axes of rotation are parallel to each other and perpendicular to the plane of the panel.

The working head of the robot has two positions, engaged and retracted. This will be controlled by the tool software (outside of the problem domain).

Remote Controller

A remote control pendant for moving the traverse is attached to the computer. The remote control software will use methods in the motion control software to move the traverse axis. Remote control moves are done in velocity mode: move at a speed X until told by the remote to stop. The remote control moves the traverse like a mouse moves a mouse pointer. It is also used to digitize vertices of the work and exclusion zones. Digitization records the position of the traverse. Your motion control software will receive these positions to define the zones.

Motion Controllers

Currently BifCo uses BrandX and BrandY motion control cards in the computers, but we are thinking of updating to the SuperDuper card. Your design must support multiple motion controllers. The controllers are multi-axis, and only one type is used in a repair station. (Hint: Abstract the motion control card interface)

Position Sensing

Position is sensed by encoders attached to the output of the gearboxes. These are relative position encoders, not absolute. These encoders provide feed back to the motion controllers. This feedback is required for closed loop control and to update the real-time display. Each axis has a home switch and two limit switches at each end of travel. These limits switches are set outside of the software limits. If a limit switch closes, electronics in the traverse hardware stops all motion and retracts the tool head.

Real-time Display

A real-time display shows the current position of the traverse and tool head at all times. Below are examples of the real time display with the traverse position shown for linear and rotary cases.
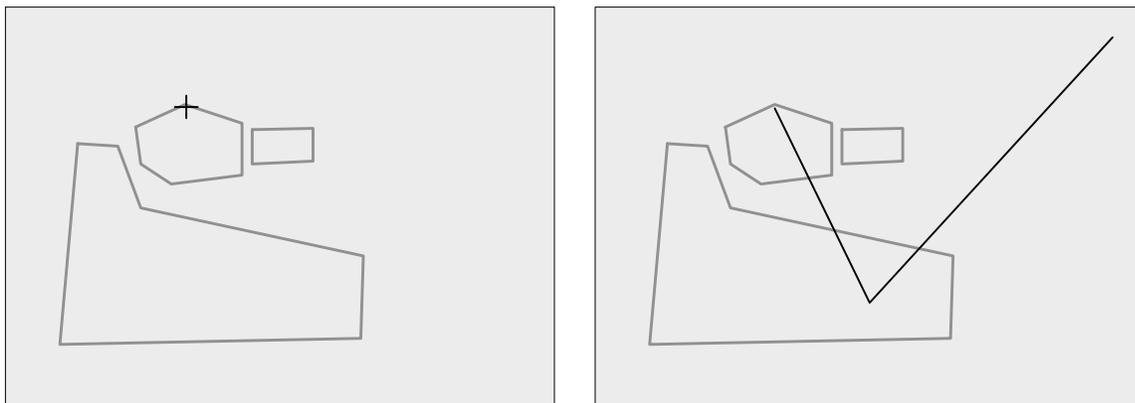
You must provide methods to configure the drawing coordinate system and set the drawing colors for the real time display window. The real time display will call into your code to update the positions at least 10 times per second. All drawing requests will come with a device context.

For each motion, your code must calculate and display the traverse's end position on the real-time display before the motion is started. This allows the machinist to abort the operation in case a software bug or setup error sends the tool holder to the wrong place.

Methods must also support mouse drag initiated moves that show the trajectory the tool head will take. You are not expected to support this for dual axes moves because of the complexity added when considering motor accelerations.

System Behavior

Traverse Alignment

Alignment defines the traverse's position in space. The motion controller does not know where the traverse is positioned until it is aligned. If alignment of the traverse is lost, it must be realigned before any work. Alignment is lost on initial power up, by reset of the controllers, or by loss of power to the encoders.

The real-time display should indicate that alignment is not complete. When unaligned, the position of the head and arms must not be drawn on the real time display.

The only way to move an unaligned traverse is with the remote control.

To align the traverse, the remote control is used to move an axis to a known position and then enter that position. Alignment may also be automated by driving the traverse near a home switch position with the remote control and then command the motion controller to find home.This assumes the home position is known. The home position generally, but not always, will be at or near the parked position.

Motion Types

Methods are required for two kinds of motion: absolute moves to a position and velocity moves when using the remote control. Methods are also required to set the speed for absolute moves.

Exclusion and Work Zones

During automatic motion throughout the repair process, exclusion zones must be avoided and the work zones boundaries must be observed.

Axis 2 arcs to process one pass of work area

Axis 1 arc while sweeping axis 2
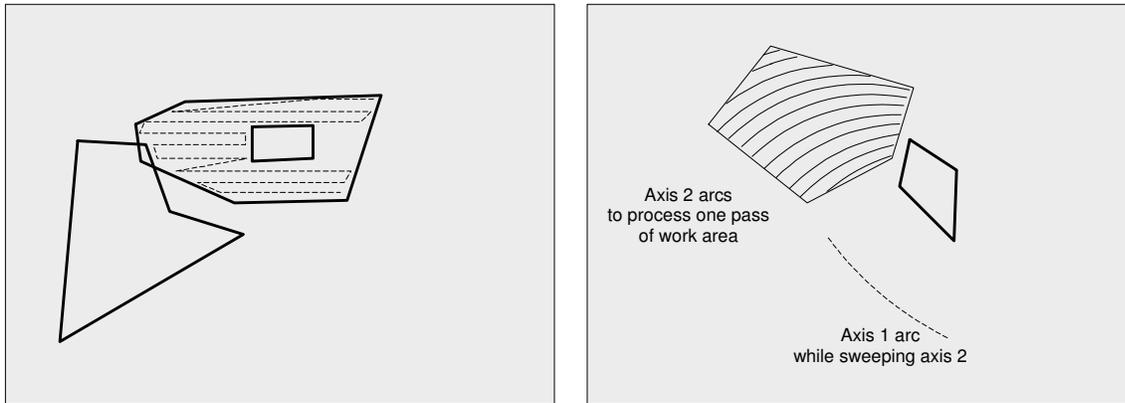
During mouse drag moves, exclusion zones must also be avoided. Allow motion up to the edge of the exclusion zone or software limit, but not entry into the zone or motion past the limit.

In the rotary case an exclusion zone protecting the chamber walls will always be in effect. This is to protect the tool, the traverse, and the walls.

Exclusion zones must be observed for fixed angle or distance moves. For instance, if a request to move the X position +10 inches would run into an exclusion zone or software limit 8 inches away, an error message must indicate that the maximum allowed would be +8 inches.

Motion Completion

Methods are required to test for motion completion during remote control moves, absolute moves, and end of segment moves during automatic processing. Note that during the processing, the automatic motion is a step-by-step process so the tool can be commanded for the two types of moves: a processing segment, and moving to the next segment start point.

Other Issues

Configuration

Other configuration information must be accessible:
- Changing the axis lengths.
- Encoder counts per unit of travel – the distance in linear or angular travel per count of encoder feedback. For instance 1024 count per revolution encoder would result in 360/1024 degrees per count. On a linear screw drive with a pitch of ¼" this would be 1/4096" per count.
- Limit of motion – software limits are typically set inside the hardware limit switches.
- Changing motion speeds when processing, moving, and digitizing.
- Step size during processing – the distance between each sweep of an automatic move.

Assumptions

Motion Control Card

The fundamental unit of measurement used by a motion control card is an encoder count. For this system assume that the range of counts will be a 32 bit signed integer value.

Motion control cards are assumed to have the following minimum capabilites:
- Set current position (in counts).
- Test if axis alignment has been set and maintained by the hardware.
- Set an axis maximum running speed (counts/sec) and acceleration (counts/sec²). This pertains to all motion. This does not cause movement.
- Enable/disable servo – turn motion control hardware on and off.
- Read current position as an n-tuple (x, y)
- Absolute moves – single and multiple axis at once to an n-tuple of positions. For instance two axis to position (x,y).
- Relative moves - single and multiple axis. For instance move the X axis –x" and the Y axis +y".
- Velocity moves – single and multiple axis. Example: move X axis at velocity xVel results in X axis motion at the specified velocity until stopped or velocity set to zero.
- Test for motion complete (stopped) by axis
- Stop motion – decellerate to 0 speed.
- Abort motion – immediately stop motion, infinite decelleration.
- Find the home switch transition of an axis and stop on transition.

Glossary

Term	Definition
Closed-loop Control	In a position control system the current position is continuously fed back and compared with the commanded position so that position can be held or motion tracked.
Home Switch	A switch that transitions from open to closed at a known position. On one side of home the switch will be closed, on the other side it will be open.
Limit Switch	A switch that has indicates a physical travel limit has been exceeded. This is typically set in a way to prevent physical damage of the traverse mechanism. For instance, before you run into a wall or the end of travel on a rail.