MX Robot SPEL function documentation

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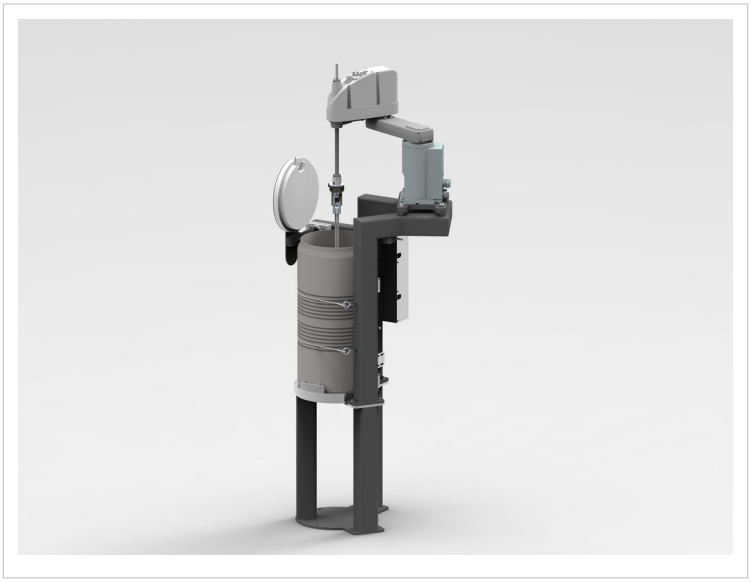

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QuickReference

API

To run the probing mechanism, start the robot from P0 or from any position inside the dewar (except dumbbell inside the cassette ports), then call any of the following functions

- Call **ResetCassettes** - with **g_RunArgs$** = "[LMR]{1,3}"
  - i.e. **g_RunArgs$** = <cassette_position(s)>
- Call **ResetCassettePorts** - with **g_PortsRequestString$(cassette_position)** = "1111100...111000"
  - 1 = Reset the port
  - 0 = do not Reset the port
- Call **ProbeCassettes** - with **g_PortsRequestString$(cassette_position)** = "1111100...111000"
  - 1 = Probe the port
  - 0 = do not Probe the port
- Call **MountSamplePort** - with **g_RunArgs$** = "[LMR] [ABCDEFGHIJKL] [1-16] "
  - i.e. **g_RunArgs$** = <cassette_position> <column/puck Name> <row/ puckPort Index>
- Call **DismountSample** - with **g_RunArgs$** = "[LMR] [ABCDEFGHIJKL] [1-16] "
  - i.e. **g_RunArgs$** = <cassette_position> <column/puck Name> <row/ puckPort Index>
- Call **JSONDataRequest** - with **g_RunArgs$** = "[ASDTFPCM]{1,7} [LMR]{0,3}"
  - A = PUCK_STATES, P = PORTS_STATES, D = SAMPLE_DISTANCES, C = CASSETTE_TYPE, T = TRIGGER_PORT_FORCES, F = FINAL_PORT_FORCES, S = SAMPLE_STATE, M = MAGNET_STATE
  - L = Left Cassette, M = Middle Cassette, R = Right Cassette (Note: For S & M, we do not have to supply cassette position)
- Call **FindPortCenters** - with **g_PortsRequestString$(cassette_position)** = "1111100...111000"
- Call **SetPortState** - with **g_RunArgs$** = "[LMR] [ABCDEFGHIJKL] [1-16] [0,2]"
  - i.e. **g_RunArgs$** = <cassette_position> <column/puck Name> <row/ puckPort Index> <PORT_ERROR=2/PORT_UNKNOWN=0>

Include files

cassettedefs.inc contains the Properties of Normal and Calibration Cassettes

superpuckdefs.inc contains the Properties of Super Puck Adaptor Cassettes

genericdefs.inc contains the cassette positions, cassette types, toolset names, sample port properties, shrink factor and probing thresholds

mountingdefs.inc contains standby distances and tolerances during mounting and dismounting routines, and sample state definitions.

robotspeed.inc contains all the acceleration, speed tuning parameters for robot go (jump) and move motions in probing, insideLN2 and outsideLN2 (and superslowspeed used in portjamrecheck) maneuvers.

jsondefs.inc contains definitions used in json requests (these definitions are used in client updates)

Global Variables

To identify the **Cassette Type** at a position,

Global Variable	Parameters	Value Contained
g_CassetteType(cassette_position)	cassette_position: 0 = Left, 1 = Middle, 2 = Right	0 = unknown 1 = calibration cassette, 2 = cassette, 3 = adaptor

```
Print Str$(g_CassetteType(0)) '' left   position
```

For SuperPuck Adaptor

Global Variable	Parameters	Value Contained
g_PuckStatus(cassette_position, puckIndex)	cassette_position: 0 = Left, 1 = Middle, 2 = Right	-1 = PUCK_PRESENT 0 = PUCK_UNKNOWN 1 = PUCK_ABSENT 2 = PUCK_JAM
g_SPSampleDistanceError(cassette_position, puckIndex, portIndex)	puckIndex: 0 = A, 1 = B, 2 = C, 3 = D,	Real value
g_SP_PortStatus(cassette_position, puckIndex, portIndex)	portIndex 0-15 = 1-16	-1 = Present 0 = Unknown 1 = Empty 2 = Error
g_SP_TriggerPortForce(cassette_position, puckIndex, portIndex)		Real Value
g_SP_FinalPortForce(cassette_position, puckIndex, portIndex)		Real Value

```
Print Str$(g_PuckStatus(2,3)) '' right, D   position, puckIndex
Print Str$(g_SPSampleDistanceError(2,1,0)) '' right, B, 1 position, puck index, port index
Print Str$(g_SP_PortStatus(2, 1, 0))
Print Str$(g_SP_TriggerPortForce(2, 1, 0))
```

For Normal/Calibration cassettes

Global Variable	Parameters	Value Contained
	cassette_position: 0 = Left, 1 = Middle, 2 = Right	
g_CASSampleDistanceError(cassette_position, rowIndex, columnIndex)	rowIndex: 0-7 = 1-8	Real value
g_CAS_PortStatus(cassette_position, rowIndex, columnIndex)	columnIndex 0-11 = A-L	-1 = Present 0 = Unknown 1 = Empty 2 = Error
g_CAS_TriggerPortForce(cassette_position, rowIndex, columnIndex)		Real Value
g_CAS_FinalPortForce(cassette_position, rowIndex, columnIndex)		Real Value

```
Print Str$(g_SPSampleDistanceError(2,1,0)) '' right, B, 1 position, puck index, port index
Print Str$(g_CAS_PortStatus(2, 1, 0)) ''Value of -1 to 2
Print Str$(g_CAS_TriggerPortForce(2, 1, 0))
Print Str$(g_CAS_FinalPortForce(2, 1, 0))
```

For Sample Properties

Global Variable	Value Contained
g_InterestedCassettePosition	0 = Left, 1 = Middle, 2 = Right
g_InterestedPuckColumnIndex	0-11 = A-L
g_InterestedRowPuckPortIndex	0-15 = 1-16
g_InterestedSampleStatus	0 = SAMPLE_STATUS_UNKNOWN 1 = SAMPLE_IN_CASSETTE 2 = SAMPLE_IN_PICKER 3 = SAMPLE_IN_PLACER 4 = SAMPLE_IN_CAVITY 5 = SAMPLE_IN_GONIO

```
Print Str$(g_InterestedCassettePosition) '' Value of 0 to 2
Print Str$(g_InterestedPuckColumnIndex) ''Value of 0 to 11
Print Str$(g_InterestedRowPuckPortIndex) '' Value of 0 to 15
Print Str$(g_InterestedSampleStatus) ''Value of 0 to 6
```

GTJSONstringFormat

Value Definitions

The following tables are noted for parsing port_status and puck_status from the JSON strings:

PortStatusString$

PortStatus	Value
PORT_OCCUPIED	-1
PORT_VACANT	1
PORT_ERROR	2
None of the above (PORT_UNKNOWN)	0

PuckStatusString$

PuckStatus	Value
PUCK_PRESENT	-1
PUCK_ABSENT	1
PUCK_JAM	2
None of the above (PUCK_UNKNOWN)	0

Probing

Cassette Type

```
{'set':'cassette_type', 'position':'left', 'min_height_error':0.123, 'value':'calibration'}
```

Cassette Port Properties

```
{'set':'port_states', 'position':'middle', 'start':6, 'value':[-1,]}
{'set':'sample_distances', 'position':'middle', 'start':6, 'value':[0.123,]}
{'set':'trigger_port_forces', 'position':'middle', 'start':6, 'value':[0.456,]}
{'set':'final_port_forces', 'position':'middle', 'start':6, 'value':[0.654,]}
```

Comprehensive Data Packet

```
{'set':'port_states','position':'middle','type':'normal','start':0,'value':[-1,1,...,2,0,]}
{'set':'sample_distances','position':'middle','type':'normal','start':0,'value':[-0.12,1.45,...,0.78,0.00,]}
{'set':'trigger_port_forces','position':'middle','type':'normal','start':0,'value':[-0.12,1.45,...,0.78,0.00,]}
{'set':'final_port_forces','position':'middle','type':'normal','start':0,'value':[-0.21,1.54,...,0.87,0.00,]}
```

SuperPuck Port Properties

```
{'set':'puck_states', 'position':'right', 'start':0, 'value':[-1,]}
{'set':'port_states', 'position':'right', 'start':16,'value':[1,]}
{'set':'sample_distances', 'position':'right', 'start':16,'value':[0.123,]}
{'set':'trigger_port_forces', 'position':'right', 'start':16,'value':[0.456,]}
```

```
{'set':'final_port_forces', 'position':'right', 'start':16,'value':[0.654,]}
```

Comprehensive Data Packet

```
{'set':'puck_states','position':'right','type':'superpuck','value':[-1,2,1,0,]}
{'set':'ports_states','position':'right','type':'superpuck','start':0,'value':[-1,1,...,2,0,]}
{'set':'sample_distances','position':'right','type':'superpuck','start':0,'value':[-0.12,1.45,...,0.78,0.00,]}
{'set':'trigger_ports_forces','position':'right','type':'superpuck','start':0,'value':[-0.12,1.45,...,0.78,0.00,]}
{'set':'final_ports_forces','position':'right','type':'superpuck','start':0,'value':[-0.12,1.45,...,0.78,0.00,]}
```

Mounting/Dismounting

```
{'set': 'sample_locations', 'value': {'picker': ('left', 0), 'placer': (), 'goniometer': (), 'cavity': (),}}
{'set':'mount_distance','position':'right','type':'superpuck','start':0,'value':[1.45,]}
{'set':'dismount_distance','position':'right','type':'superpuck','start':0,'value':[-0.12,]}
```

```
# 0 = DUMBBELL_UNKNOWN
# 1 = DUMBBELL_IN_CRADLE
# 2 = DUMBBELL_IN_GRIPPERS
# 3 = DUMBBELL_MISSING

{'set': 'magnet_state', 'value': 2}
```

GTRobotTests

debugTests.prg

The debugTests.prg file contains functions to test different parts of the robot code. You can call the following functions which are defined in this module to perform the corresponding tasks:

- Call **testTong** from P0 to check the force sensor. This function uses the force sensor to forcetouch the same point on the post 20 times and lists the distances the robot travelled to sense enough force each time.

This function was originally intended to check the straightness of the tong, but they are commented out now. To check the straightness of the tong by this method remove the comment in the line: P(standbyPoint) = P453 *:Z(zIndex * -10.0).*

- Call **debugProbeAllCassettes** to probe all the cassettes
- Call **StressTestAllCassettes** to mount first and then dismount all the ports (which are occupied) in all cassette positions.
- Call **debugAllPucksFindCenters**(cassette_position As Integer) to find the exact location of each port center in the cassette_position supplied. Valid cassette_positions: 0 - Left, 1 - Middle and 2 - Right Cassette.

GTPythonScripts

Additional files are present in the Documents folder of the MXSampleMounting Project. These are additional tools for reference on the project.

- **grep_commands.txt** to list different functions in the program
- **spel_code_dotfile.ipynb** creates dot files which can later be used to create graphs using graphviz tools
- **spel_code_graph.ipynb** displays graphs of function calls inline in jupyter notebook (requires graphviz, pandas modules)
- **MX Robot SPEL function documentation.pdf** contains a local copy of the wiki related to project
- **RobotFunctionPoints.pdf** contains the starting and end points of different functions as on 7/4/2016

GTSetupPoints

Description

Contains functions for checking points and toolsets and to derive basic points, magnet points, cassette points and goniometer points from the points obtained from executing the calibration process.

GTCheckPoint

GTCheckPoint takes 1 Pointnum as Integer parameter and no output parameters

If the Point is not defined or if its X or Y co-ordinate is set to zero, GTCheckPoint returns false

Otherwise GTCheckPoint returns true

GTCheckTool

GTCheckTool takes 1 Toolnum as Integer parameter and no output parameters

If the Tool's X or Y co-ordinate is set to zero, GTCheckTool returns false

Otherwise GTCheckTool returns true

GTInitBasicPoints

Calls GTCheckPoint to check the following points:

- P0
- P1
- P18

If GTCheckPoint returns True for all these points, then GTInitBasicPoints returns True

Otherwise GTInitBasicPoints returns false

GTInitMagnetPoints

Calls GTCheckPoint to check the following points:

- P6
- P16
- P26
- P10
- P11
- P12

And calls GTCheckTool to check the following Tools:

- Tool(1) - picker Toolset
- Tool(2) - placer Toolset

Then derives angled placer toolset [Tool(4)] from placer Toolset

GTInitMagnetPoints exits by returning false if any of the above checks fail.

Then GTInitMagnetPoints sets the global variables, g_dumbbell_Perfect_Angle, g_dumbbell_Perfect_cosValue, and g_dumbbell_Perfect_sinValue based from the point P6

Then GTInitMagnetPoints derives the following points in order

- P3
- P2
- P4
- P17
- P27
- P93
- P94
- P15
- P25
- P5

GTInitCassettePoints

Calls GTCheckPoint to check the following points

- P6
- Left Cassette Points - P34, P41, P44
- Middle Cassette Points - P35, P42, P45
- Right Cassette Points - P36, P43, P46

GTInitCassettePoints exits by returning false if any of the above checks fail.

Then calls GTSetupCassetteAllProperties for left, middle and right cassette. If it fails then GTInitCassettePoints exits by returning false.

GTInitGoniometerPoints

Calls GTCheckPoint to check P20 and if it is a valid point, the function then extracts the g_goniometer_Angle variable from P20

GTInitAllPoints

This function calls the above functions in the following order

1. GTInitBasicPoints
2. GTInitMagnetPoints
3. GTInitCassettePoints
4. GTInitGoniometerPoints

It returns true if all the functions called complete successfully otherwise it returns false.

Global Variables

Note: All angle values in GT domain are in degrees

- Global Real **g_dumbbell_Perfect_Angle**
- Global Real **g_dumbbell_Perfect_cosValue**
- Global Real **g_dumbbell_Perfect_sinValue**
- Global Real **g_goniometer_Angle**
- Global Real **g_goniometer_cosValue**
- Global Real **g_goniometer_sinValue**

GTSetupCassette

Description

Contains functions for setting up actual position, actual orientation angle, and tilt information for each cassette. The following functions are defined in this module:

- GTSetupDirection(cassette_position As Integer, column_A_Angle As Real, standbyU As Real, secondaryStandbyU As Real)
- GTSetupCoordinates(cassette_position As Integer, pointNum As Integer)
- GTSetupTilt(cassette_position As Integer, topPointNum As Integer, bottomPointNum As Integer) As Boolean
- GTSetupCassetteAllProperties(cassette_position As Integer) As Boolean

Global Variables

The following global variables (arrays) are set by the functions in GTSetupPoints

Angle of First Column in Cassette and U value for each cassette

- Global Real **g_AngleOfFirstColumn(NUM_CASSETTES)**
- Global Real **g_UForNormalStandby(NUM_CASSETTES)**
- Global Real **g_UForSecondaryStandby(NUM_CASSETTES)**
- Global Real **g_UForPuckStandby(NUM_CASSETTES)**

Tilt Information for Each Cassette

- Global Real **g_tiltDX(NUM_CASSETTES)**
- Global Real **g_tiltDY(NUM_CASSETTES)**

*Cassette Bottom Center's X,Y, Z Coordi*nates

- Global Real **g_CenterX(NUM_CASSETTES)**
- Global Real **g_CenterY(NUM_CASSETTES)**
- Global Real **g_BottomZ(NUM_CASSETTES)**

Angle offset of cassette from theoretical cassette orientation angle

- Global Real **g_AngleOffset(NUM_CASSETTES)**

GTCassetteUtilities

Description

Contains functions for setting tilt offsets, getting a point on the circumference centered around the cassette center based on u and for probing individual ports on calibration and normal cassette. The following functions are defined in this module:

- GTParseCassettePosition(cassetteChar$ As String, ByRef cassette_position As Integer) As Boolean
- GTCassetteName$(cassette_position As Integer) As String
- GTapplyTiltToOffsets(cassette_position As Integer, PerfectXoffset As Real, PerfectYoffset As Real, PerfectZoffset As Real, ByRef Actualoffsets() As Real)
- GTSetCircumferencePointFromU(cassette_position As Integer, U As Real, radius As Real, ZoffsetFromBottom As Real, pointNum As Integer)
- GTadjustUAngle(cassette_position As Integer, UAngle As Real) As Real

GTCassetteType

Description

Contains functions for finding the cassette top, function for classifying the cassette type based on height, and to find the average height of the cassette from different points on the cassette, and the helper functions to setup the standby point for the before mentioned functions. The following functions are defined in this module:

- GTCassetteType$(cassetteType As Integer) As String
- GTResetCassette(cassette_position As Integer)
- GTSetScanCassetteTopStandbyPoint(cassette_position As Integer, pointNum As Integer, uOffset As Real, ByRef scanZdistance As Real)
- GTScanCassetteTop(standbyPointNum As Integer, maxZdistanceToScan As Real, ByRef cassetteTopZvalue As Real) As Boolean
- GTCassetteTypeFromHeight(cassette_position As Integer, cassetteHeight As Real, ByRef guessedCassetteType As Integer, ByRef min_height_error As Real) As Boolean
- GTsetfindAvgHeightStandbyPoint(cassette_position As Integer, pointNum As Integer, index As Integer, guessedCassetteType As Integer, ByRef scanZdistance As Real)
- GTfindAverageCassetteHeight(cassette_position As Integer, cassetteFirstHeight As Real, guessedCassetteType As Integer, ByRef average_height As Real) As Boolean

Global Variables

The following global variables (arrays) are set by the functions in GTCassetteType

- Global Preserve Integer **g_CassetteType(NUM_CASSETTES)**

GTCassetteProbing

Description

Contains functions for probing a cassette to classify its type, function to probe all the sample ports in the cassette and to reset the probed information to absent. The following functions are defined in this module:

- **GTProbeCassetteType**(cassette_position As Integer) - Probes the cassette_position for detecting whether a cassette is present or absent. If a cassette is present, it identifies what type of cassette is present.
- **GTProbeSpecificPorts**(cassette_position As Integer) - Only after GTProbeCassetteType is successfully completed, this function should be called to run to the probe the specific sample ports in the cassette as requested in g_PortsRequestString$(cassette_position).
- **GTResetSpecificPorts**(cassette_position As Integer) - This function resets the status of specific pucks and the specific ports to unknown in the corresponding global variables as requested in g_PortsRequestString$(cassette_position).

GTSampleMounting

Description

Contains functions for finding whether the Goniometer can be reached, function for deriving the goniometer points from P20, and to set the ports of interest and mount these interesting ports. The following functions are defined in this module:

- GTGonioReachable() As Boolean
- GTSetGoniometerPoints(dx As Real, dy As Real, dz As Real, du As Real) As Boolean
- GTsetInterestPoint(cassette_position As Integer, puckColumnIndex As Integer, rowPuckPortIndex As Integer) As Boolean
- GTMoveToSPMountPortStandbyPoint(cassette_position As Integer, puckIndex As Integer, puckPortIndex As Integer)
- GTMoveToCASMountPortStandbyPoint(cassette_position As Integer, rowIndex As Integer, columnIndex As Integer)
- GTMountInterestedPort

Global Variables

The following global variables are set by the functions in GTSampleMounting

- Global Preserve Integer **g_InterestedCassettePosition**
- Global Preserve Integer **g_InterestedPuckColumnIndex**
- Global Preserve Integer **g_InterestedRowPuckPortIndex**
- Global Preserve Integer **g_InterestedSampleStatus**

GTNormalCassetteUtilities

Description

Contains functions for setting tilt offsets, getting a point on the circumference centered around the cassette center based on u and for probing individual ports on calibration and normal cassette. The following functions are defined in this module:

- GTParseColumnIndex(columnChar$ As String, ByRef columnIndex As Integer) As Boolean
- GTcolumnName$(columnIndex As Integer)
- GTprobeCassettePort(cassette_position As Integer, rowIndex As Integer, columnIndex As Integer, jumpToStandbyPoint As Boolean)
- GTProbeSpecificPortsInCassette(cassette_position As Integer) As Boolean
- GTResetSpecificPortsInCassette(cassette_position As Integer)
- GTsetCassetteMountStandbyPoints(cassette_position As Integer, rowIndex As Integer, columnIndex As Integer, standbyDistanceFromCASSurface As Real)

Global Variables

The following global variables (arrays) are set by the functions in GTCassetteUtilities

- Global Preserve Real **g_CASSampleDistanceError(NUM_CASSETTES, NUM_ROWS, NUM_COLUMNS)**
- Global Preserve Integer **g_CAS_PortStatus(NUM_CASSETTES, NUM_ROWS, NUM_COLUMNS)**
- Global Preserve Integer **g_CAS_TriggerPortForce(NUM_CASSETTES, NUM_ROWS, NUM_COLUMNS)**
- Global Preserve Integer **g_CAS_FinalPortForce(NUM_CASSETTES, NUM_ROWS, NUM_COLUMNS)**

GTSuperPuckUtilities

Description

Contains functions for probing super puck adaptor for angle correction, and to setup the correction angle, probing the presence of pucks and individual ports, and the helper functions to setup perfect point, standby and destination points for the before mentioned functions.

Global Variables

The following global variables (arrays) are set by the functions in GTSuperPuckUtilities

- **g_PuckPresent(NUM_CASSETTES, NUM_PUCKS)**
- **g_SampleDistancefromPuckSurface(NUM_CASSETTES, NUM_PUCKS, NUM_PUCK_PORTS)**
- **g_SP_PortStatus(NUM_CASSETTES, NUM_PUCKS, NUM_PUCK_PORTS)**
- **g_SP_TriggerPortForce(NUM_CASSETTES, NUM_PUCKS, NUM_PUCK_PORTS)**
- **g_SP_FinalPortStatus(NUM_CASSETTES, NUM_PUCKS, NUM_PUCK_PORTS)**

Function Details

The following functions are defined in this module:

initSuperPuckConstants

initSuperPuckConstants() sets the values for the constants which are declared as module variables such as

1. **m_SP_Alpha** - Angle between the line pointing the center of the Superpuck Adaptor and the rear face of the Puck
2. **m_SP_Puck_Radius** - Radius of each puck
3. **m_SP_Puck_Thickness** - Thickness of each puck
4. **m_SP_PuckCenter_Height** - Vertical distance between the puck center and the bottom of the SuperPuck Adaptor
5. **m_SP_Puck_RotationAngle** - The rotation of each puck with respect to PUCK_A
6. **m_SP_Ports_1_5_Circle_Radius** - Radius of the circle formed by the ports 1 to 5 in each puck
7. **m_SP_Ports_6_16_Circle_Radius** - Radius of the circle formed by the ports 6 to 16 in each puck

GTpuckName$

GTpuckName$(puckIndex As Integer) As String returns a string representing the human readable Puck Name according to the following table

puckIndex	returned String$
0	PUCK_A
1	PUCK_B
2	PUCK_C
3	PUCK_D

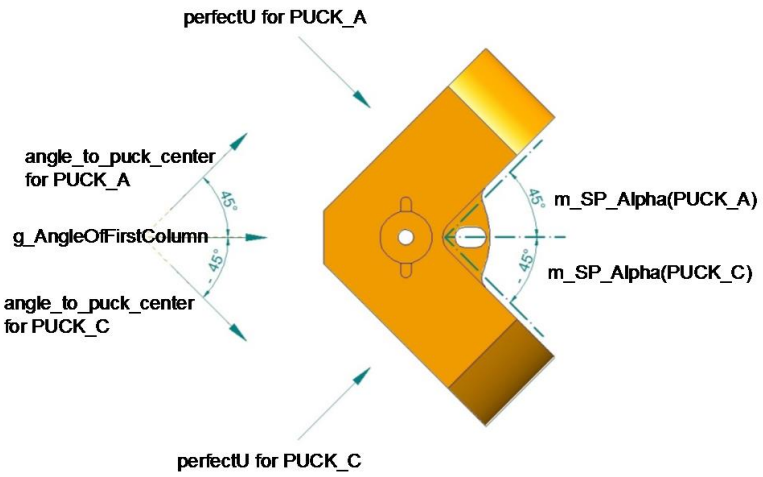

Figure1: Picture describing the angles involved in various functions of helper functions for SuperPuck Adaptor probing routines.

GTParsePuckIndex

GTParsePuckIndex(puckChar$ As String, ByRef puckIndex As Integer) As Boolean sets the corresponding puckIndex and returns True if puckChar$ is valid otherwise returns false

GTSPpositioningMove

GTSPpositioningMove(cassette_position As Integer, puckIndex As Integer) As Boolean

Before Adaptor Angle Correction probing mechanism is invoked, this function should be called to push the puck Adaptor once at the edge along the vertical center line of the Super Puck Adaptor. This is done to alleviate the errors in Adaptor Angle Correction probing due to improper orientation of the puck adaptor.

The angle variables used in this function are depicted in Figure1: MX_Robot_SuperPuck_Angles_Info.jpg

GTgetAdaptorAngleErrorProbePoint

GTgetAdaptorAngleErrorProbePoint(cassette_position As Integer, puckIndex As Integer, perfectPointNum As Integer, standbyPointNum As Integer, destinationPointNum As Integer) is a helper function to set the perfect, standby and destination points for the SuperPuck Adaptor Angle Correction

Here variables storing angles are as shown in Figure1

The probe for angle correction is done at the intersection of the SuperPuck Edge and the line joining the puckCenter and Port 11 for PUCK_A and PUCK_B whereas

The probe for angle correction is done at the intersection of the SuperPuck Edge and the line joining the puckCenter and Port 10 for PUCK_C and PUCK_D due to the rotation angle of 180 for pucks C and D.

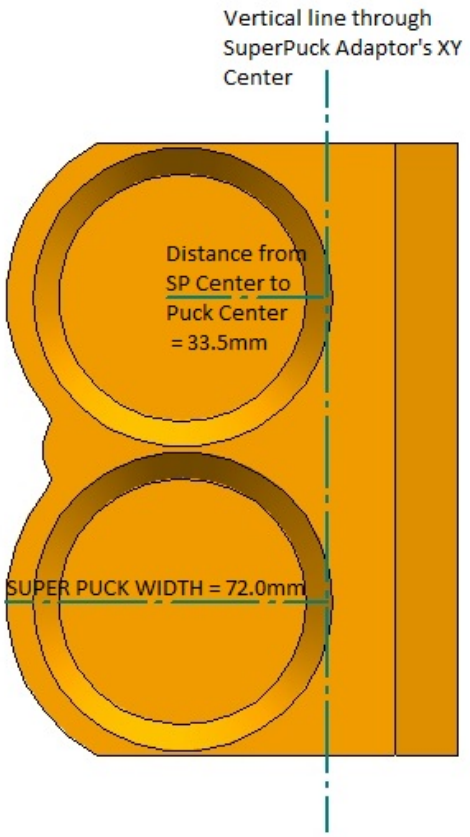

Figure2: Picture depicting the radii used in of helper functions of SuperPuck Adaptor Angle Correction routine.

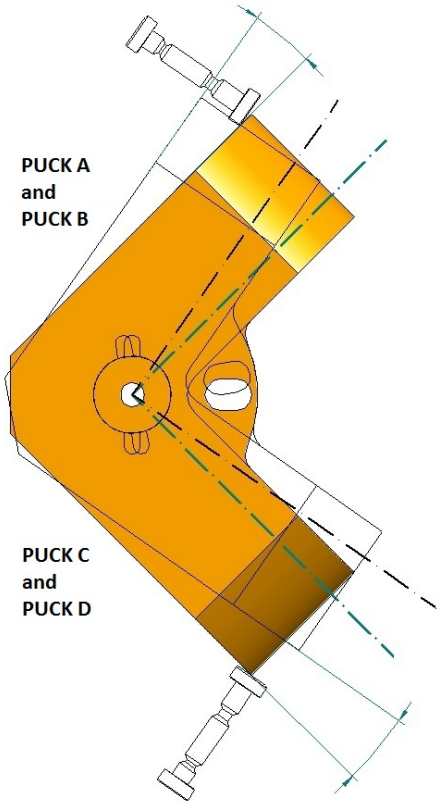

Figure3: Example scenario to determine the sign of the error_from_perfectPoint_in_mm and the magnet touching the SuperPuck Adaptor edge in the helper functions for SuperPuck Adaptor Angle Correction probing routine.

GTprobeAdaptorAngleCorrection

GTprobeAdaptorAngleCorrection(cassette_position As Integer, puckIndex As Integer) As Boolean This function calls the GTSPpositioningMove and GTgetAdaptorAngleErrorProbePoint. Then starts from the standby point and move towards the destination point. Once Forcetouch exceeds the threshold, the distance to the magnet's center is measured from the perfectPoint.

Look at Figure3, for an example scenario. In this figure the actual position is solid and the perfect position is transparent. Now in Figure 3 for PUCK_A and PUCK_B, the cassette is detected only after moving beyond the perfectPosition, this is considered positive (+) movement. But, for PUCK_C and PUCK_D, the cassette is detected before even reaching the perfectPosition, this is considered negative(-) movement. So the signs of error_from_perfectPoint_in_mm is set accordingly.

GTsetupAdaptorAngleCorrection

GTsetupAdaptorAngleCorrection(cassette_position As Integer, puckIndex As Integer, error_from_perfectPoint_in_mm As Real) As Boolean In the example shown in Figure3, when we look closely, we see that when the cassette is detected only after moving beyond the perfectPosition, such as for PUCK_A, we can observe that the magnet edge is touching the cassette at the moment when ForceTouch exceeds the threshold. But, when the cassette is detected before reaching the perfectPosition, such as for PUCK_C, we can observe that the magnet center is touching the cassette at the moment when ForceTouch exceeds the threshold. Hence, this is taken into account when calculating the angle error.

To view the angle errors from global coordinates and to follow easy conventions, sign of all angle errors are considered with respect to PUCK_A's angleError.

GTperfectSPPortOffset

GTperfectSPPortOffset(cassette_position As Integer, portIndex As Integer, puckIndex As Integer, distanceFromPuckSurface As Real, ByRef dx As Real, ByRef dy As Real, ByRef dz As Real, ByRef u As Real) sets **dx**, **dy**, and **dz** with the distances that have to be travelled to reach the port from the super puck adaptor center. **u** is set to the u angle for probing the puck.

The calculations involve calculating the puckCenter and then the Horizontal and Vertical distances from puck center to port center and then the distance from port's deepest end.

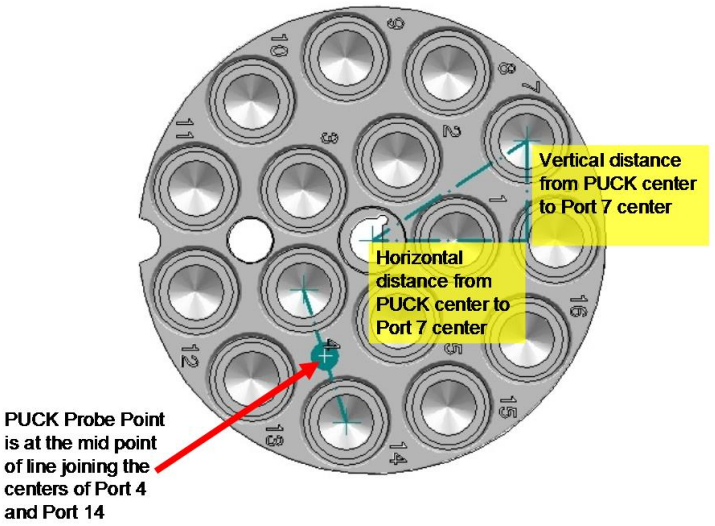

Figure4: Picture describing the puck probe point and the Horizontal and Vertical distances involved in calculating the distance from puck A center to the port 7 center.

- Figure1 is used as reference for the angles involved.
- Figure4 is used as reference to the Horizontal and Vertical distances from puck center to port center for Port 7.
- For calculating the distance from port's deepest end, the parameter **distanceFromPuckSurface** is used with the following rule:

1. **distanceFromPuckSurface** > 0 is the offset away from the puck
2. **distanceFromPuckSurface** < 0 is the offset into the puck (port)

GTsetSPPortPoint

GTsetSPPortPoint(cassette_position As Integer, portIndex As Integer, puckIndex As Integer, distanceFromPuckSurface As Real, pointNum As Integer)

GTsetSPPuckProbeStandbyPoint

GTsetSPPuckProbeStandbyPoint(cassette_position As Integer, puckIndex As Integer, standbyPointNum As Integer, ByRef scanDistance As Real)

GTprobeSPPuck

GTprobeSPPuck(cassette_position As Integer, puckIndex As Integer)

GTprobeSPPort

GTprobeSPPort(cassette_position As Integer, puckIndex As Integer, portIndex As Integer)

GTProbeSpecificPortsInSuperPuck

Function GTProbeSpecificPortsInSuperPuck(cassette_position As Integer) As Boolean

GTResetSpecificPortsInSuperPuck

Function GTResetSpecificPortsInSuperPuck(cassette_position As Integer)

GTsetSPMountStandbyPoints

Function GTsetSPMountStandbyPoints(cassette_position As Integer, puckIndex As Integer, puckPortIndex As Integer, standbyDistanceFromSPSurface As Real)

GTMagnetManeuvers

Description

Contains functions to jump from home to cooling point and wait, for checking whether the magnet is in the gripper, and to pick and return magnet from cradle. The following functions are defined in this module:

- GTJumpHomeToCoolingPointAndWait As Boolean
- GTIsMagnetInGripper As Boolean
- GTCheckAndPickMagnet As Boolean
- GTReturnMagnet As Boolean
- GTReturnMagnetAndGoHome As Boolean
- GTTwistOffMagnet

GTRobotSpeed

Description

Contains functions for saving current robot speed mode, setting new robot speed mode and to load previous robot speed mode. The following functions are defined in this module:

- GTSaveCurrentRobotSpeedMode
- SetProbeSpeed
- SetInsideLN2Speed
- SetOutsideLN2Speed
- GTsetRobotSpeedMode(speed_mode As Byte)
- GTLoadPreviousRobotSpeedMode

GTNumericManipulations

Description

Contains mathematical helper functions. The following functions are defined in this module:

- GTBoundAngle(lowerBound As Real, upperBound As Real, Angle As Real) As Real
- GTAngleToPerfectOrientationAngle(Angle As Real) As Real

GTPythonInterface

Python Interface Functions

To run the probing mechanism, start the robot from P0 or from any position inside the dewar (except dumbbell inside the cassette ports), then call any of the following functions

- Call **ResetCassettes** - with **g_RunArgs$** = "[LMR]{1,3}"
  - i.e. **g_RunArgs$** = <cassette_position(s)>
  - Resets the cassette type and all the cassette ports in that cassette position. It finally does a JSON CLIENT_UPDATE on CASSETTE_TYPE, PUCK_STATES, and PORT_STATES
- Call **ResetCassettePorts** - with **g_PortsRequestString$(cassette_position)** = "1111100...111000"
  - 1 = Reset the port
  - 0 = do not Reset the port
- Call **ProbeCassettes** - with **g_PortsRequestString$(cassette_position)** = "1111100...111000"
  - 1 = Probe the port
  - 0 = do not Probe the port
- Call **MountSamplePort** - with **g_RunArgs$** = "[LMR] [ABCDEFGHIJKL] [1-16] "
  - i.e. **g_RunArgs$** = <cassette_position> <column/puck Name> <row/ puckPort Index>
- Call **DismountSample** - with **g_RunArgs$** = "[LMR] [ABCDEFGHIJKL] [1-16] "
  - i.e. **g_RunArgs$** = <cassette_position> <column/puck Name> <row/ puckPort Index>
- Call **JSONDataRequest** - with **g_RunArgs$** = "[ASDTFPCM]{1,7} [LMR]{0,3}"

- A = PUCK_STATES, P = PORTS_STATES, D = SAMPLE_DISTANCES, C = CASSETTE_TYPE, T = TRIGGER_PORT_FORCES, F = FINAL_PORT_FORCES, S = SAMPLE_STATE, M = MAGNET_STATE
- L = Left Cassette, M = Middle Cassette, R = Right Cassette (Note: For S & M, we do not have to supply cassette position)

- Call **FindPortCenters** - with **g_PortsRequestString$(cassette_position)** = "1111100...111000"
- Call **SetPortState** - with **g_RunArgs$** = "[LMR] [ABCDEFGHIJKL] [1-16] [0,2]"
  - i.e. **g_RunArgs$** = <cassette_position> <column/puck Name> <row/ puckPort Index> <PORT_ERROR=2/PORT_UNKNOWN=0>

GTJSONUtilities

Description

Contains functions setting up JSON strings and send it to the client using UpdateClient(CLIENT_UPDATE, JSONString$, INFO_LEVEL) call. The following dataToSend argument (whereever required) can take the following (defined in jsondefs.inc) values

1. define PORT_STATES 0
2. define SAMPLE_DISTANCES 1
3. define PUCK_STATES 2
4. define CASSETTE_TYPE 3
5. define SAMPLE_STATE 4
6. define TRIGGER_PORT_FORCES 5
7. define FINAL_PORT_FORCES 6
8. define MAGNET_STATE 7

GTgetPortIndexFromCassetteVars

GTgetPortIndexFromCassetteVars(cassette_position As Integer, columnPuckIndex As Integer, rowPuckPortIndex As Integer) returns the Index of the port position in a Cassette

GTsendNormalCassetteData

GTsendNormalCassetteData(dataToSend As Integer, cassette_position As Integer) packs and sends JSON formatted strings of a Normal or Calibration Cassette located at cassette_position based on the supplied dataToSend Argument as mentioned above. If any of the arguments are invalid, the function just exits without sending anything.

```
{'set':'port_states','position':'middle','type':'normal','start':0,'value':[-1,1,...,2,0,]}
{'set':'sample_distances','position':'middle','type':'normal','start':0,'value':[-0.12,1.45,...,0.78,0.00,]}
{'set':'trigger_port_forces','position':'middle','type':'normal','start':0,'value':[-0.12,1.45,...,0.78,0.00,]}
{'set':'final_port_forces','position':'middle','type':'normal','start':0,'value':[-0.21,1.54,...,0.87,0.00,]}
```

GTsendSuperPuckData

GTsendSuperPuckData(dataToSend As Integer, cassette_position As Integer) packs and sends JSON formatted strings of a SuperPuck Cassette located at cassette_position based on the supplied dataToSend Argument as mentioned above. If any of the arguments are invalid, the function just exits without sending anything.

```
{'set':'puck_states','position':'right','type':'superpuck','value':[-1,2,1,0,]}
{'set':'ports_states','position':'right','type':'superpuck','start':0,'value':[-1,1,...,2,0,]}
{'set':'sample_distances','position':'right','type':'superpuck','start':0,'value':[-0.12,1.45,...,0.78,0.00,]}
{'set':'trigger_port_forces','position':'right','type':'superpuck','start':0,'value':[-0.21,1.54,...,0.87,0.00,]}
{'set':'final_port_forces','position':'right','type':'superpuck','start':0,'value':[-0.21,1.54,...,0.87,0.00,]}
```

GTsendPuckData

GTsendPuckData(cassette_position As Integer) packs and sends the Puck Presence information in JSON formatted strings of a SuperPuck Cassette located at cassette_position. If cassette_position is invalid, the function just exits without sending anything.

```
{'set':'puck_states','position':'right','type':'superpuck','value':[-1,2,1,0,]}
```

GTsendCassetteType

GTsendCassetteType(cassette_position As Integer) sends the cassette type in JSON formatted strings for a cassette located at cassette_position.

```
{'set':'cassette_type', 'position':'left', 'min_height_error':0.123, 'value':'calibration'}
```

GTsendCassetteData

GTsendCassetteData(dataToSend As Integer, cassette_position As Integer) packs and sends JSON formatted strings for any type of cassette located at cassette_position based on the supplied dataToSend Argument as mentioned above. If any of the arguments are invalid, the function just exits without sending anything.

GTsendSampleStateJSON

GTsendSampleStateJSON function takes no arguments. It packs and sends the state of the interested sample.

```
{'set':'sample_state', 'position':'left', 'start':0, 'value':2}"
```

GTsendMagnetStateJSON

GTsendMagnetStateJSON function takes no arguments. It packs and sends the location of magnet/dumbbell.

```
{'set':'magnet_state', 'position':'left', 'start':0, 'value':2}"
```

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