

```
>> compute_extrinsics(cad_model, 0, 0)
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```
T_ximea_tilt =
```

```
[ cos(pitch_ximea_tilt)*cos(yaw_ximea_tilt), cos(yaw_ximea_tilt)*sin(pitch_ximea_tilt)✓
*sin(roll_ximea_tilt) - cos(roll_ximea_tilt)*sin(yaw_ximea_tilt), sin(roll_ximea_tilt)✓
*sin(yaw_ximea_tilt) + cos(roll_ximea_tilt)*cos(yaw_ximea_tilt)*sin(pitch_ximea_tilt),✓
x_ximea_tilt]
[ cos(pitch_ximea_tilt)*sin(yaw_ximea_tilt), cos(roll_ximea_tilt)*cos(yaw_ximea_tilt) +✓
sin(pitch_ximea_tilt)*sin(roll_ximea_tilt)*sin(yaw_ximea_tilt), cos(roll_ximea_tilt)*sin✓
(pitch_ximea_tilt)*sin(yaw_ximea_tilt) - cos(yaw_ximea_tilt)*sin(roll_ximea_tilt),✓
y_ximea_tilt]
[          -sin(pitch_ximea_tilt),✓
cos(pitch_ximea_tilt)*sin(roll_ximea_tilt),✓
cos(pitch_ximea_tilt)*cos(roll_ximea_tilt), z_ximea_tilt]
[          0,✓
0,✓
0,          1]
```

```
T_tilt_pan =
```

```
[ cos(pitch_tilt_pan), 0, sin(pitch_tilt_pan), x_tilt_pan]
[          0, 1,          0, y_tilt_pan]
[ -sin(pitch_tilt_pan), 0, cos(pitch_tilt_pan), z_tilt_pan]
[          0, 0,          0,          1]
```

```
T_pan_base =
```

```
[ cos(yaw_pan_base), -sin(yaw_pan_base), 0, 0]
[ sin(yaw_pan_base),  cos(yaw_pan_base), 0, 0]
[          0,          0, 1, 0]
[          0,          0, 0, 1]
```

```
T_base_imperx =
```

```
[ cos(pitch_base_imperx)*cos(yaw_base_imperx), cos(yaw_base_imperx)*sin✓
(pitch_base_imperx)*sin(roll_base_imperx) - cos(roll_base_imperx)*sin(yaw_base_imperx),✓
sin(roll_base_imperx)*sin(yaw_base_imperx) + cos(roll_base_imperx)*cos(yaw_base_imperx)✓
*sin(pitch_base_imperx), x_base_imperx]
[ cos(pitch_base_imperx)*sin(yaw_base_imperx), cos(roll_base_imperx)*cos(yaw_base_imperx)✓
+ sin(pitch_base_imperx)*sin(roll_base_imperx)*sin(yaw_base_imperx), cos✓
(roll_base_imperx)*sin(pitch_base_imperx)*sin(yaw_base_imperx) - cos(yaw_base_imperx)*sin✓
(roll_base_imperx), y_base_imperx]
[          -sin(pitch_base_imperx),✓
cos(pitch_base_imperx)*sin(roll_base_imperx),✓
cos(pitch_base_imperx)*cos(roll_base_imperx), z_base_imperx]
[          0,✓
0,✓
```

```
0,          1]
```

```
T_ximea_imperx =
```

```
[ cos(pitch_base_imperx)*sin(yaw_base_imperx)*(sin(yaw_pan_base)*(sin(pitch_tilt_pan)*
(sin(roll_ximea_tilt)*sin(yaw_ximea_tilt) + cos(roll_ximea_tilt)*cos(yaw_ximea_tilt)*sin
(pitch_ximea_tilt)) - cos(pitch_tilt_pan)*cos(pitch_ximea_tilt)*cos(yaw_ximea_tilt)) -
cos(yaw_pan_base)*(cos(roll_ximea_tilt)*sin(yaw_ximea_tilt) - cos(yaw_ximea_tilt)*sin
(pitch_ximea_tilt)*sin(roll_ximea_tilt))) - cos(pitch_base_imperx)*cos(yaw_base_imperx)*
(cos(yaw_pan_base)*(sin(pitch_tilt_pan)*(sin(roll_ximea_tilt)*sin(yaw_ximea_tilt) + cos
(roll_ximea_tilt)*cos(yaw_ximea_tilt)*sin(pitch_ximea_tilt)) - cos(pitch_tilt_pan)*cos
(pitch_ximea_tilt)*cos(yaw_ximea_tilt)) + sin(yaw_pan_base)*(cos(roll_ximea_tilt)*sin
(yaw_ximea_tilt) - cos(yaw_ximea_tilt)*sin(pitch_ximea_tilt)*sin(roll_ximea_tilt))) - sin
(pitch_base_imperx)*(cos(pitch_tilt_pan)*(sin(roll_ximea_tilt)*sin(yaw_ximea_tilt) + cos
(roll_ximea_tilt)*cos(yaw_ximea_tilt)*sin(pitch_ximea_tilt)) + cos(pitch_ximea_tilt)*cos
(yaw_ximea_tilt)*sin(pitch_tilt_pan)), (cos(yaw_pan_base)*(sin(pitch_tilt_pan)*(sin
(roll_ximea_tilt)*sin(yaw_ximea_tilt) + cos(roll_ximea_tilt)*cos(yaw_ximea_tilt)*sin
(pitch_ximea_tilt)) - cos(pitch_tilt_pan)*cos(pitch_ximea_tilt)*cos(yaw_ximea_tilt)) +
sin(yaw_pan_base)*(cos(roll_ximea_tilt)*sin(yaw_ximea_tilt) - cos(yaw_ximea_tilt)*sin
(pitch_ximea_tilt)*sin(roll_ximea_tilt)))*(cos(roll_base_imperx)*sin(yaw_base_imperx) -
cos(yaw_base_imperx)*sin(pitch_base_imperx)*sin(roll_base_imperx)) + (sin(yaw_pan_base)*
(sin(pitch_tilt_pan)*(sin(roll_ximea_tilt)*sin(yaw_ximea_tilt) + cos(roll_ximea_tilt)*cos
(yaw_ximea_tilt)*sin(pitch_ximea_tilt)) - cos(pitch_tilt_pan)*cos(pitch_ximea_tilt)*cos
(yaw_ximea_tilt)) - cos(yaw_pan_base)*(cos(roll_ximea_tilt)*sin(yaw_ximea_tilt) - cos
(yaw_ximea_tilt)*sin(pitch_ximea_tilt)*sin(roll_ximea_tilt)))*(cos(roll_base_imperx)*cos
(yaw_base_imperx) + sin(pitch_base_imperx)*sin(roll_base_imperx)*sin(yaw_base_imperx)) +
cos(pitch_base_imperx)*sin(roll_base_imperx)*(cos(pitch_tilt_pan)*(sin(roll_ximea_tilt)
*sin(yaw_ximea_tilt) + cos(roll_ximea_tilt)*cos(yaw_ximea_tilt)*sin(pitch_ximea_tilt)) +
cos(pitch_ximea_tilt)*cos(yaw_ximea_tilt)*sin(pitch_tilt_pan)), cos(pitch_base_imperx)
*cos(roll_base_imperx)*(cos(pitch_tilt_pan)*(sin(roll_ximea_tilt)*sin(yaw_ximea_tilt) +
cos(roll_ximea_tilt)*cos(yaw_ximea_tilt)*sin(pitch_ximea_tilt)) + cos(pitch_ximea_tilt)
*cos(yaw_ximea_tilt)*sin(pitch_tilt_pan)) - (sin(yaw_pan_base)*(sin(pitch_tilt_pan)*(sin
(roll_ximea_tilt)*sin(yaw_ximea_tilt) + cos(roll_ximea_tilt)*cos(yaw_ximea_tilt)*sin
(pitch_ximea_tilt)) - cos(pitch_tilt_pan)*cos(pitch_ximea_tilt)*cos(yaw_ximea_tilt)) -
cos(yaw_pan_base)*(cos(roll_ximea_tilt)*sin(yaw_ximea_tilt) - cos(yaw_ximea_tilt)*sin
(pitch_ximea_tilt)*sin(roll_ximea_tilt)))*(cos(yaw_base_imperx)*sin(roll_base_imperx) -
cos(roll_base_imperx)*sin(pitch_base_imperx)*sin(yaw_base_imperx)) - (cos(yaw_pan_base)*
(sin(pitch_tilt_pan)*(sin(roll_ximea_tilt)*sin(yaw_ximea_tilt) + cos(roll_ximea_tilt)*cos
(yaw_ximea_tilt)*sin(pitch_ximea_tilt)) - cos(pitch_tilt_pan)*cos(pitch_ximea_tilt)*cos
(yaw_ximea_tilt)) + sin(yaw_pan_base)*(cos(roll_ximea_tilt)*sin(yaw_ximea_tilt) - cos
(yaw_ximea_tilt)*sin(pitch_ximea_tilt)*sin(roll_ximea_tilt)))*(sin(roll_base_imperx)*sin
(yaw_base_imperx) + cos(roll_base_imperx)*cos(yaw_base_imperx)*sin(pitch_base_imperx)),
x_ximea_tilt - x_base_imperx*(cos(yaw_pan_base)*(sin(pitch_tilt_pan)*(sin
(roll_ximea_tilt)*sin(yaw_ximea_tilt) + cos(roll_ximea_tilt)*cos(yaw_ximea_tilt)*sin
(pitch_ximea_tilt)) - cos(pitch_tilt_pan)*cos(pitch_ximea_tilt)*cos(yaw_ximea_tilt)) +
sin(yaw_pan_base)*(cos(roll_ximea_tilt)*sin(yaw_ximea_tilt) - cos(yaw_ximea_tilt)*sin
(pitch_ximea_tilt)*sin(roll_ximea_tilt))) + y_base_imperx*(sin(yaw_pan_base)*(sin
(pitch_tilt_pan)*(sin(roll_ximea_tilt)*sin(yaw_ximea_tilt) + cos(roll_ximea_tilt)*cos
(yaw_ximea_tilt)*sin(pitch_ximea_tilt)) - cos(pitch_tilt_pan)*cos(pitch_ximea_tilt)*cos
(yaw_ximea_tilt)) - cos(yaw_pan_base)*(cos(roll_ximea_tilt)*sin(yaw_ximea_tilt) - cos
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(yaw_ximea_tilt)*sin(pitch_ximea_tilt)*sin(roll_ximea_tilt))) - y_tilt_pan*(cos
(roll_ximea_tilt)*sin(yaw_ximea_tilt) - cos(yaw_ximea_tilt)*sin(pitch_ximea_tilt)*sin
(roll_ximea_tilt)) + z_tilt_pan*(sin(roll_ximea_tilt)*sin(yaw_ximea_tilt) + cos
(roll_ximea_tilt)*cos(yaw_ximea_tilt)*sin(pitch_ximea_tilt)) + z_base_imperx*(cos
(pitch_tilt_pan)*(sin(roll_ximea_tilt)*sin(yaw_ximea_tilt) + cos(roll_ximea_tilt)*cos
(yaw_ximea_tilt)*sin(pitch_ximea_tilt)) + cos(pitch_ximea_tilt)*cos(yaw_ximea_tilt)*sin
(pitch_tilt_pan)) + x_tilt_pan*cos(pitch_ximea_tilt)*cos(yaw_ximea_tilt)]
[ sin(pitch_base_imperx)*(cos(pitch_tilt_pan)*(cos(yaw_ximea_tilt)*sin(roll_ximea_tilt) -
cos(roll_ximea_tilt)*sin(pitch_ximea_tilt)*sin(yaw_ximea_tilt)) - cos(pitch_ximea_tilt)
*sin(pitch_tilt_pan)*sin(yaw_ximea_tilt)) + cos(pitch_base_imperx)*cos(yaw_base_imperx)*
(cos(yaw_pan_base)*(sin(pitch_tilt_pan)*(cos(yaw_ximea_tilt)*sin(roll_ximea_tilt) - cos
(roll_ximea_tilt)*sin(pitch_ximea_tilt)*sin(yaw_ximea_tilt)) + cos(pitch_tilt_pan)*cos
(pitch_ximea_tilt)*sin(yaw_ximea_tilt)) + sin(yaw_pan_base)*(cos(roll_ximea_tilt)*cos
(yaw_ximea_tilt) + sin(pitch_ximea_tilt)*sin(roll_ximea_tilt)*sin(yaw_ximea_tilt))) - cos
(pitch_base_imperx)*sin(yaw_base_imperx)*(sin(yaw_pan_base)*(sin(pitch_tilt_pan)*(cos
(yaw_ximea_tilt)*sin(roll_ximea_tilt) - cos(roll_ximea_tilt)*sin(pitch_ximea_tilt)*sin
(yaw_ximea_tilt)) + cos(pitch_tilt_pan)*cos(pitch_ximea_tilt)*sin(yaw_ximea_tilt)) - cos
(yaw_pan_base)*(cos(roll_ximea_tilt)*cos(yaw_ximea_tilt) + sin(pitch_ximea_tilt)*sin
(roll_ximea_tilt)*sin(yaw_ximea_tilt))), - (cos(roll_base_imperx)*cos(yaw_base_imperx) +
sin(pitch_base_imperx)*sin(roll_base_imperx)*sin(yaw_base_imperx))*(sin(yaw_pan_base)*
(sin(pitch_tilt_pan)*(cos(yaw_ximea_tilt)*sin(roll_ximea_tilt) - cos(roll_ximea_tilt)*sin
(pitch_ximea_tilt)*sin(yaw_ximea_tilt)) + cos(pitch_tilt_pan)*cos(pitch_ximea_tilt)*sin
(yaw_ximea_tilt)) - cos(yaw_pan_base)*(cos(roll_ximea_tilt)*cos(yaw_ximea_tilt) + sin
(pitch_ximea_tilt)*sin(roll_ximea_tilt)*sin(yaw_ximea_tilt))) - (cos(roll_base_imperx)
*sin(yaw_base_imperx) - cos(yaw_base_imperx)*sin(pitch_base_imperx)*sin
(roll_base_imperx))*(cos(yaw_pan_base)*(sin(pitch_tilt_pan)*(cos(yaw_ximea_tilt)*sin
(roll_ximea_tilt) - cos(roll_ximea_tilt)*sin(pitch_ximea_tilt)*sin(yaw_ximea_tilt)) + cos
(pitch_tilt_pan)*cos(pitch_ximea_tilt)*sin(yaw_ximea_tilt)) + sin(yaw_pan_base)*(cos
(roll_ximea_tilt)*cos(yaw_ximea_tilt) + sin(pitch_ximea_tilt)*sin(roll_ximea_tilt)*sin
(yaw_ximea_tilt))) - cos(pitch_base_imperx)*sin(roll_base_imperx)*(cos(pitch_tilt_pan)*
(cos(yaw_ximea_tilt)*sin(roll_ximea_tilt) - cos(roll_ximea_tilt)*sin(pitch_ximea_tilt)
*sin(yaw_ximea_tilt)) - cos(pitch_ximea_tilt)*sin(pitch_tilt_pan)*sin(yaw_ximea_tilt)),
(sin(roll_base_imperx)*sin(yaw_base_imperx) + cos(roll_base_imperx)*cos(yaw_base_imperx)
*sin(pitch_base_imperx))*(cos(yaw_pan_base)*(sin(pitch_tilt_pan)*(cos(yaw_ximea_tilt)*sin
(roll_ximea_tilt) - cos(roll_ximea_tilt)*sin(pitch_ximea_tilt)*sin(yaw_ximea_tilt)) + cos
(pitch_tilt_pan)*cos(pitch_ximea_tilt)*sin(yaw_ximea_tilt)) + sin(yaw_pan_base)*(cos
(roll_ximea_tilt)*cos(yaw_ximea_tilt) + sin(pitch_ximea_tilt)*sin(roll_ximea_tilt)*sin
(yaw_ximea_tilt))) + (cos(yaw_base_imperx)*sin(roll_base_imperx) - cos(roll_base_imperx)
*sin(pitch_base_imperx)*sin(yaw_base_imperx))*(sin(yaw_pan_base)*(sin(pitch_tilt_pan)*
(cos(yaw_ximea_tilt)*sin(roll_ximea_tilt) - cos(roll_ximea_tilt)*sin(pitch_ximea_tilt)
*sin(yaw_ximea_tilt)) + cos(pitch_tilt_pan)*cos(pitch_ximea_tilt)*sin(yaw_ximea_tilt)) -
cos(yaw_pan_base)*(cos(roll_ximea_tilt)*cos(yaw_ximea_tilt) + sin(pitch_ximea_tilt)*sin
(roll_ximea_tilt)*sin(yaw_ximea_tilt))) - cos(pitch_base_imperx)*cos(roll_base_imperx)*
(cos(pitch_tilt_pan)*(cos(yaw_ximea_tilt)*sin(roll_ximea_tilt) - cos(roll_ximea_tilt)*sin
(pitch_ximea_tilt)*sin(yaw_ximea_tilt)) - cos(pitch_ximea_tilt)*sin(pitch_tilt_pan)*sin
(yaw_ximea_tilt)), y_ximea_tilt + y_tilt_pan*(cos(roll_ximea_tilt)*cos(yaw_ximea_tilt) +
sin(pitch_ximea_tilt)*sin(roll_ximea_tilt)*sin(yaw_ximea_tilt)) - z_tilt_pan*(cos
(yaw_ximea_tilt)*sin(roll_ximea_tilt) - cos(roll_ximea_tilt)*sin(pitch_ximea_tilt)*sin
(yaw_ximea_tilt)) + x_base_imperx*(cos(yaw_pan_base)*(sin(pitch_tilt_pan)*(cos
(yaw_ximea_tilt)*sin(roll_ximea_tilt) - cos(roll_ximea_tilt)*sin(pitch_ximea_tilt)*sin
(yaw_ximea_tilt)) + cos(pitch_tilt_pan)*cos(pitch_ximea_tilt)*sin(yaw_ximea_tilt)) + sin

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(yaw_pan_base)*(cos(roll_ximea_tilt)*cos(yaw_ximea_tilt) + sin(pitch_ximea_tilt)*sin
(roll_ximea_tilt)*sin(yaw_ximea_tilt))) - y_base_imperx*(sin(yaw_pan_base)*(sin
(pitch_tilt_pan)*(cos(yaw_ximea_tilt)*sin(roll_ximea_tilt) - cos(roll_ximea_tilt)*sin
(pitch_ximea_tilt)*sin(yaw_ximea_tilt)) + cos(pitch_tilt_pan)*cos(pitch_ximea_tilt)*sin
(yaw_ximea_tilt)) - cos(yaw_pan_base)*(cos(roll_ximea_tilt)*cos(yaw_ximea_tilt) + sin
(pitch_ximea_tilt)*sin(roll_ximea_tilt)*sin(yaw_ximea_tilt))) - z_base_imperx*(cos
(pitch_tilt_pan)*(cos(yaw_ximea_tilt)*sin(roll_ximea_tilt) - cos(roll_ximea_tilt)*sin
(pitch_ximea_tilt)*sin(yaw_ximea_tilt)) - cos(pitch_ximea_tilt)*sin(pitch_tilt_pan)*sin
(yaw_ximea_tilt)) + x_tilt_pan*cos(pitch_ximea_tilt)*sin(yaw_ximea_tilt)]
[
sin(pitch_base_imperx)*(sin(pitch_tilt_pan)*sin(pitch_ximea_tilt) - cos(pitch_tilt_pan)
*cos(pitch_ximea_tilt)*cos(roll_ximea_tilt)) - cos(pitch_base_imperx)*cos
(yaw_base_imperx)*(cos(yaw_pan_base)*(cos(pitch_tilt_pan)*sin(pitch_ximea_tilt) + cos
(pitch_ximea_tilt)*cos(roll_ximea_tilt)*sin(pitch_tilt_pan)) - cos(pitch_ximea_tilt)*sin
(roll_ximea_tilt)*sin(yaw_pan_base)) + cos(pitch_base_imperx)*sin(yaw_base_imperx)*(sin
(yaw_pan_base)*(cos(pitch_tilt_pan)*sin(pitch_ximea_tilt) + cos(pitch_ximea_tilt)*cos
(roll_ximea_tilt)*sin(pitch_tilt_pan)) + cos(pitch_ximea_tilt)*cos(yaw_pan_base)*sin
(roll_ximea_tilt)),
(sin(yaw_pan_base)*(cos(pitch_tilt_pan)*sin(pitch_ximea_tilt) + cos(pitch_ximea_tilt)*cos
(roll_ximea_tilt)*sin(pitch_tilt_pan)) + cos(pitch_ximea_tilt)*cos(yaw_pan_base)*sin
(roll_ximea_tilt))*(cos(roll_base_imperx)*cos(yaw_base_imperx) + sin(pitch_base_imperx)
*sin(roll_base_imperx)*sin(yaw_base_imperx)) + (cos(yaw_pan_base)*(cos(pitch_tilt_pan)
*sin(pitch_ximea_tilt) + cos(pitch_ximea_tilt)*cos(roll_ximea_tilt)*sin(pitch_tilt_pan))
- cos(pitch_ximea_tilt)*sin(roll_ximea_tilt)*sin(yaw_pan_base))*(cos(roll_base_imperx)
*sin(yaw_base_imperx) - cos(yaw_base_imperx)*sin(pitch_base_imperx)*sin
(roll_base_imperx)) - cos(pitch_base_imperx)*sin(roll_base_imperx)*(sin(pitch_tilt_pan)
*sin(pitch_ximea_tilt) - cos(pitch_tilt_pan)*cos(pitch_ximea_tilt)*cos(roll_ximea_tilt)),
- (sin(yaw_pan_base)*(cos(pitch_tilt_pan)*sin(pitch_ximea_tilt) + cos(pitch_ximea_tilt)
*cos(roll_ximea_tilt)*sin(pitch_tilt_pan)) + cos(pitch_ximea_tilt)*cos(yaw_pan_base)*sin
(roll_ximea_tilt))*(cos(yaw_base_imperx)*sin(roll_base_imperx) - cos(roll_base_imperx)
*sin(pitch_base_imperx)*sin(yaw_base_imperx)) - (cos(yaw_pan_base)*(cos(pitch_tilt_pan)
*sin(pitch_ximea_tilt) + cos(pitch_ximea_tilt)*cos(roll_ximea_tilt)*sin(pitch_tilt_pan))
- cos(pitch_ximea_tilt)*sin(roll_ximea_tilt)*sin(yaw_pan_base))*(sin(roll_base_imperx)
*sin(yaw_base_imperx) + cos(roll_base_imperx)*cos(yaw_base_imperx)*sin
(pitch_base_imperx)) - cos(pitch_base_imperx)*cos(roll_base_imperx)*(sin(pitch_tilt_pan)
*sin(pitch_ximea_tilt) - cos(pitch_tilt_pan)*cos(pitch_ximea_tilt)*cos(roll_ximea_tilt)),
z_ximea_tilt - z_base_imperx*(sin(pitch_tilt_pan)*sin(pitch_ximea_tilt) - cos
(pitch_tilt_pan)*cos(pitch_ximea_tilt)*cos(roll_ximea_tilt)) - x_tilt_pan*sin
(pitch_ximea_tilt) - x_base_imperx*(cos(yaw_pan_base)*(cos(pitch_tilt_pan)*sin
(pitch_ximea_tilt) + cos(pitch_ximea_tilt)*cos(roll_ximea_tilt)*sin(pitch_tilt_pan)) -
cos(pitch_ximea_tilt)*sin(roll_ximea_tilt)*sin(yaw_pan_base)) + y_base_imperx*(sin
(yaw_pan_base)*(cos(pitch_tilt_pan)*sin(pitch_ximea_tilt) + cos(pitch_ximea_tilt)*cos
(roll_ximea_tilt)*sin(pitch_tilt_pan)) + cos(pitch_ximea_tilt)*cos(yaw_pan_base)*sin
(roll_ximea_tilt)) + z_tilt_pan*cos(pitch_ximea_tilt)*cos(roll_ximea_tilt) +
y_tilt_pan*cos(pitch_ximea_tilt)*sin(roll_ximea_tilt)]
[
0,
0,
0,
1]

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ans =

-0.1964	-0.9794	0.0474	3.1597
0.5937	-0.1572	-0.7891	0.4304
0.7803	-0.1268	0.6124	0.3876
0	0	0	1.0000

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