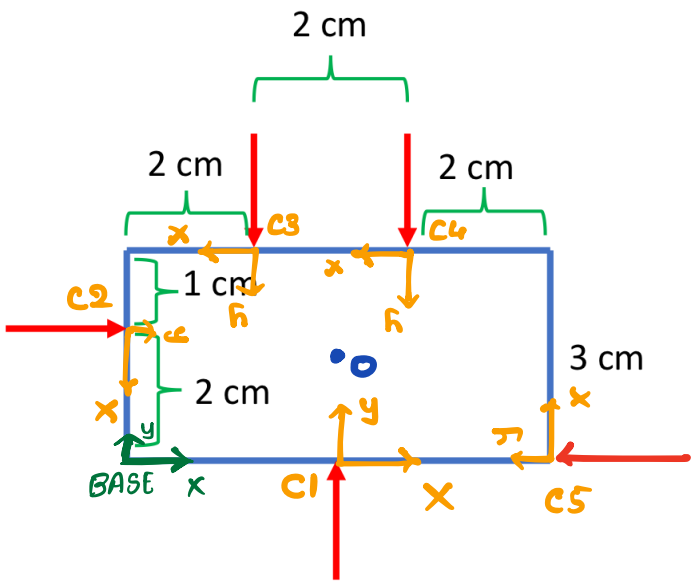


→ Let's consider a base frame at the lower left corner & calculate all the contact points w.r.t. Base.

C1 = (3, 1.5) with $\theta_1 = 0$

C2 = (0, 2) with $\theta_2 = -90°$

C3 = (2, 3) with $\theta_3 = 180°$

C4 = (4, 3) with $\theta_4 = 90°$

→ Let the initial position of the contact point 5 be (6, 0) - lower right angle and we will move it by 0.1 cm on each iteration.

⟹ Grasp Quality Criteria

1) Minimum singular Value of G

$$Q_{MSV} = \sigma_{min}(G)$$

```
function Q_MSV_min = minimum_singular_value(G)
    singular_values = svd(G * transpose(G));
    non_zero_singular_values = round(singular_values, 4);

    msv_min = [];

    for i = 1: size(non_zero_singular_values)
        if(non_zero_singular_values(i) ~= 0)
            msv_min = [msv_min; non_zero_singular_values(i)];
        end
    end
    Q_MSV_min = min(msv_min);
end
```

2) Volume of ellipsoid in the wrench space.

$$Q\_VEW = \sqrt{\det(G \cdot G^T)}$$

```
function Q_VEW = volume_of_the_ellipsoid(G)
    Q_VEW = sqrt(det(transpose(G) * G));
end
```

3) Grasp Isotropy Index

$$Q_{GII} = \frac{\sigma_{min}(G)}{\sigma_{max}(G)}$$

```
function Q_MSV_max = maximum_singular_value(G)
    singular_values = svd(G * transpose(G));
    Q_MSV_max = max(singular_values);
end

function Q_GII = grasp_isotropy_index(G)
    Q_GII = minimum_singular_value(G)/maximum_singular_value(G);
end
```

* Grasp Quality Matrix.

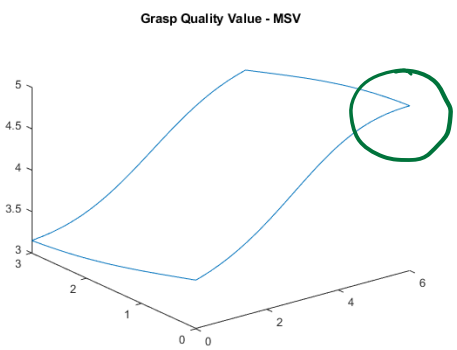
```
function [pos1, pos2, pos3] = run_quality_metrics(contact, Q)
    %Metric 1
    [M1, I1] = max(Q(:,1));
    pos1 = contact(I1,:);

    %Metric 2
    [M2, I2] = max(Q(:,2));
    pos2 = contact(I2,:);

    %Metric 3
    [M3, I3] = max(Q(:,3));
    pos3 = contact(I3,:);
end
```

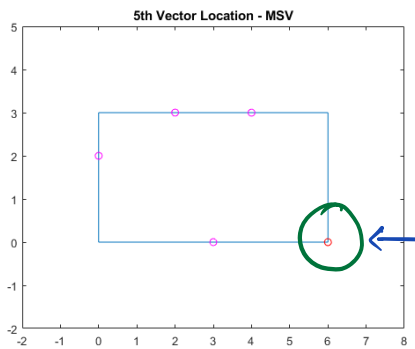
→ This function returns the best position to apply 5th force vector as per the selected criteria.

```
Best Contact Point for 5 as per Q_MSV =
     6     0

Best Contact Point for 5 as per Q_VEW =
     6     0

Best Contact Point for 5 as per Q_GII =
    3.8000         0
```

* Q_MSV :-

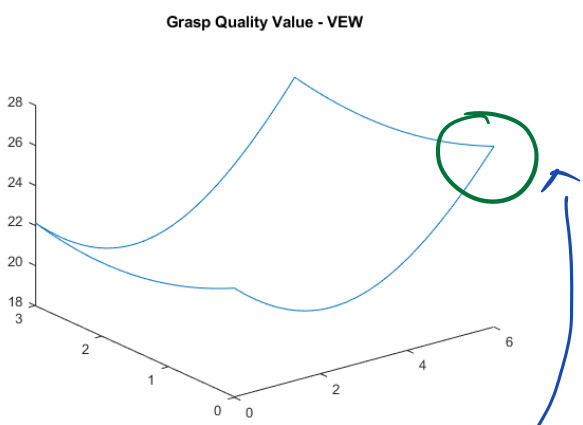
Q_MSV calculates how far the grasp is from its singular configuration.

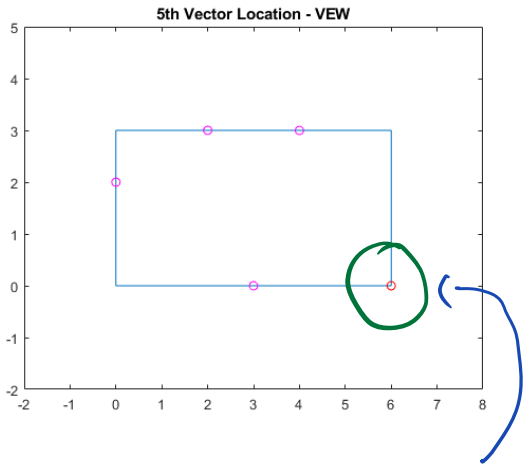




← Best location to stay away from singularity.

★ Q_VEW :-

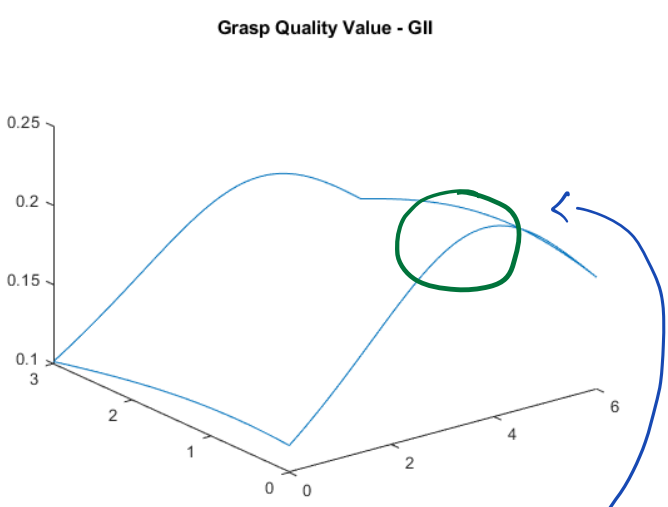


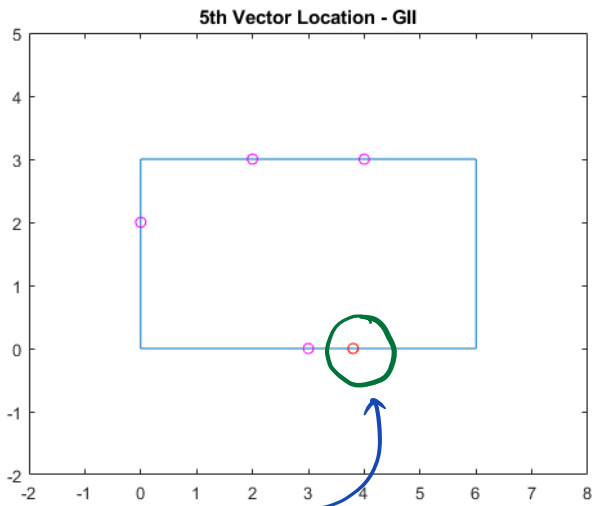


All the forces in the wrench space are Maximum.

The global contribution of all the forces are maximum here, that denotes the best grasp.

★ Q_ GII :-





Applying 5th force vector here would give the best grasp irrespective of the object's orientation.

This location denotes the uniformity of all the force vectors to the object's internal forces. Hence irrespective of the object's orientation. applying 5th force vector on this point should give the best grasp.