

SINGULARITY

in Mobile Symmetric Frameworks

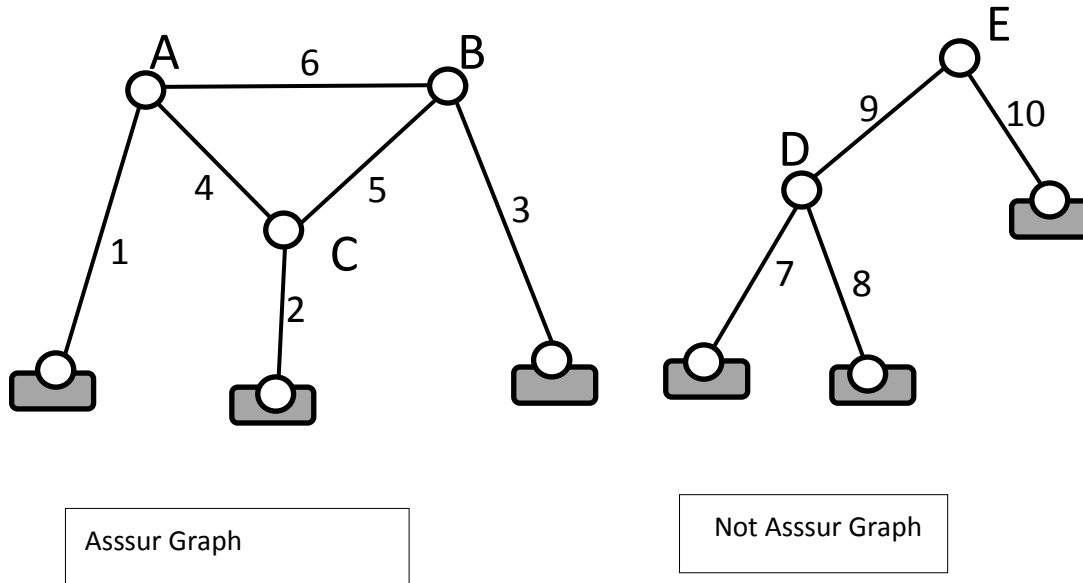
Offer Shai

- The main definition of Assur Graphs.
- The singularity of Assur Graphs .
- Deriving the symmetric frameworks with finite motions through Assur Graph singularity.
- The method relies on:
 - **Face forces**
 - **Equimomental lines.**

Results

The main definition of Assur Graphs:

G is a bar&joint Assur Graph IFF G is a **pinned isostatic graph** and it does not contain any **proper pinned isostatic graph**.

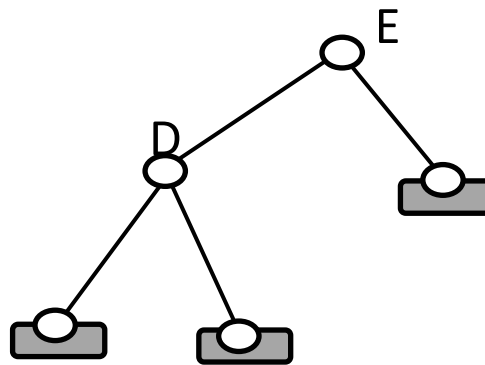


The **singularity** of Assur Graphs

Servatius B., Shai O. and Whiteley W., "Geometric Properties of Assur Graphs", European Journal of Combinatorics, Vol. 31, No. 4, May, pp. 1105-1120, 2010.

Assur Graph Singularity Theorem (Servatius et al., 2010):

G is an Assur Graph IFF it has a configuration in which there is a **unique self-stress** on **all** the edges and **all** the inner vertices have **1dof** and infinitesimal motion .



This topology does not have such configuration.

In Assur Graphs, it is easy to prove:

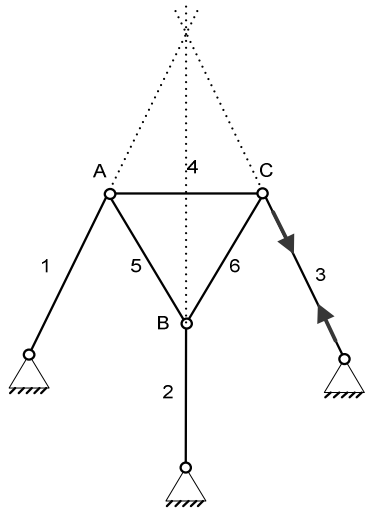
If there is a **unique self-stress** on **all** the edges
THEN **all** the inner vertices have **1dof** and
infinitesimal motion.

So, the problem is to **characterize** the
configurations where there is a unique self-
stress on all the edges.

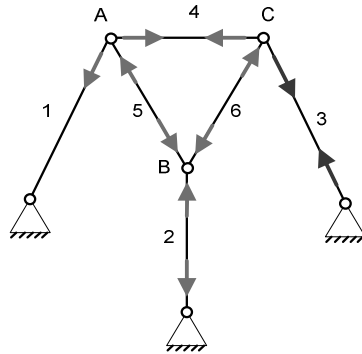
Deployable/foldable Tensegrity Assur robot

- The robots works **constantly at the singular** position.
- The control is very easy (controls only one element).

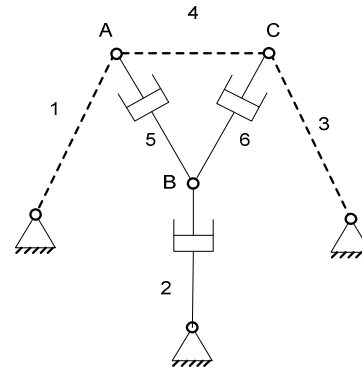
Tensegrity Assur Graph at the Singular Position



(a)

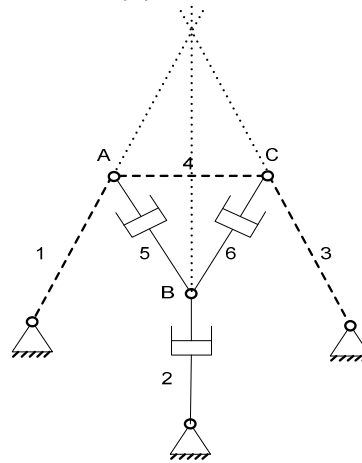


(b)

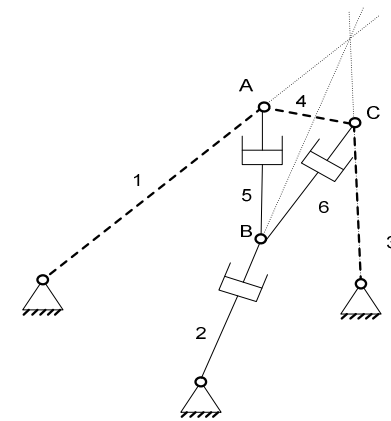


(c)

Changing the singular point in the triad



(a)



(b)

From singular Assur Graphs into Symmetric Frameworks with finite motions

This is done in three steps:

***1.Characterize the singularity* of the**

given Assur Graph — apply a combinatorial method that uses face force (projection of polyhedron).

2.Transform the infinitesimal motion into finite motion using sliders and other methods (not systematic, yet).

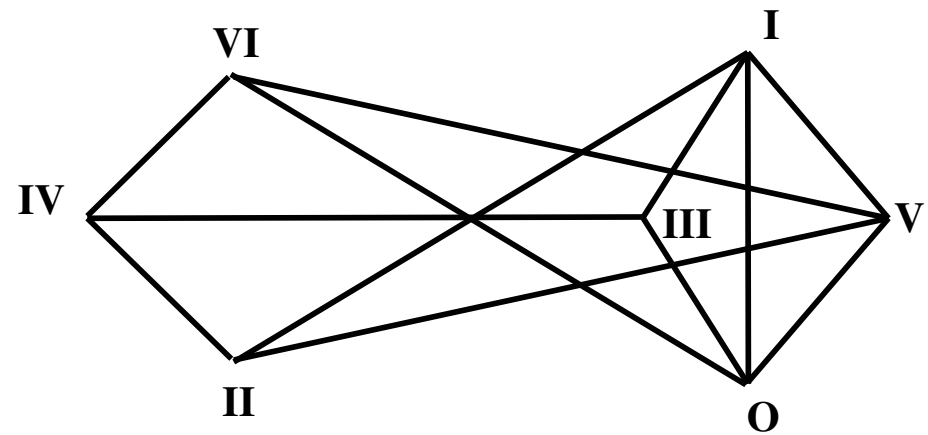
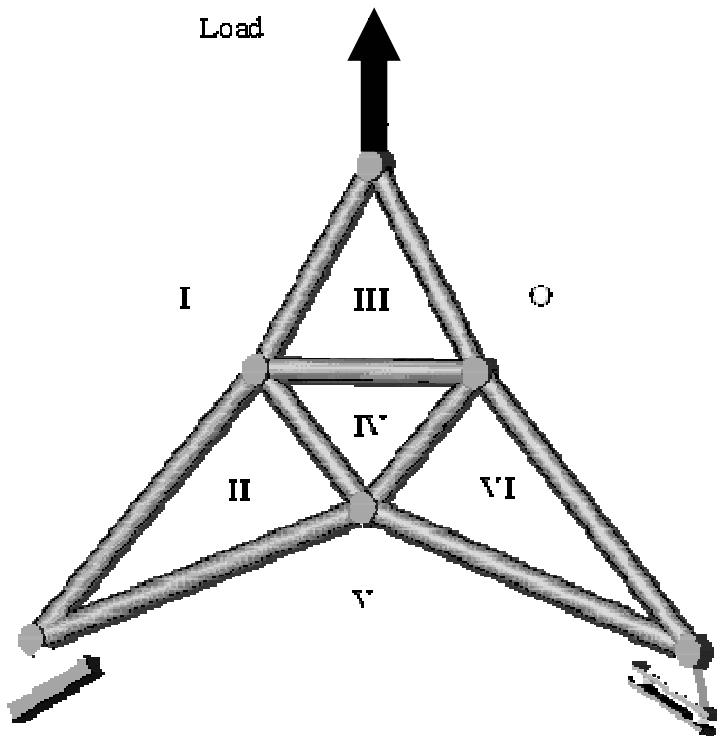
3.Replication — resulting with floating overbraced framework.

Face Force –

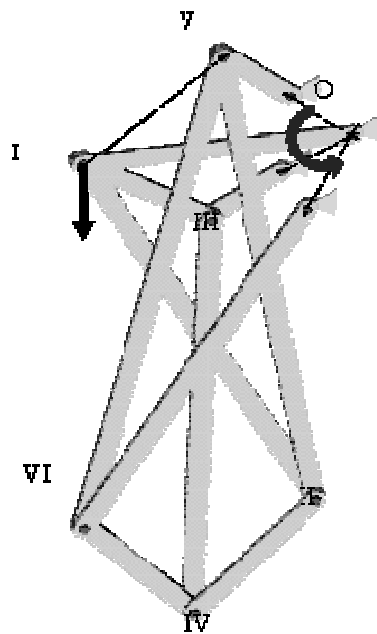
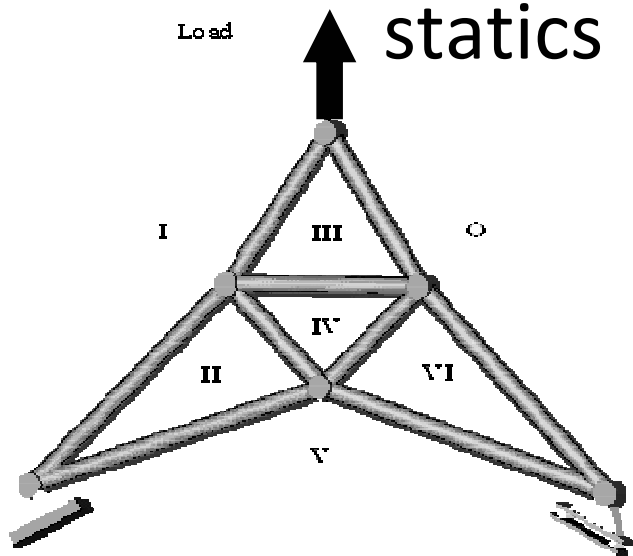
a force appearing in
Maxwell's diagram.

It is a force acting in a face, like a
mesh current in electricity.

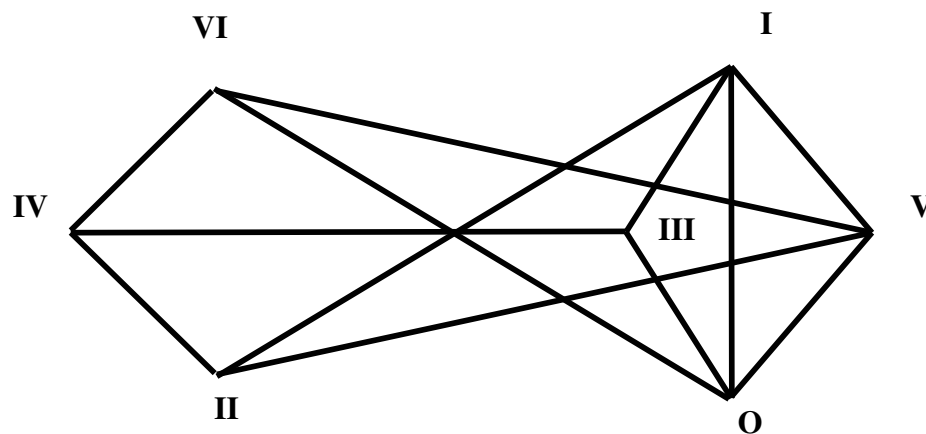
Maxwell Diagram



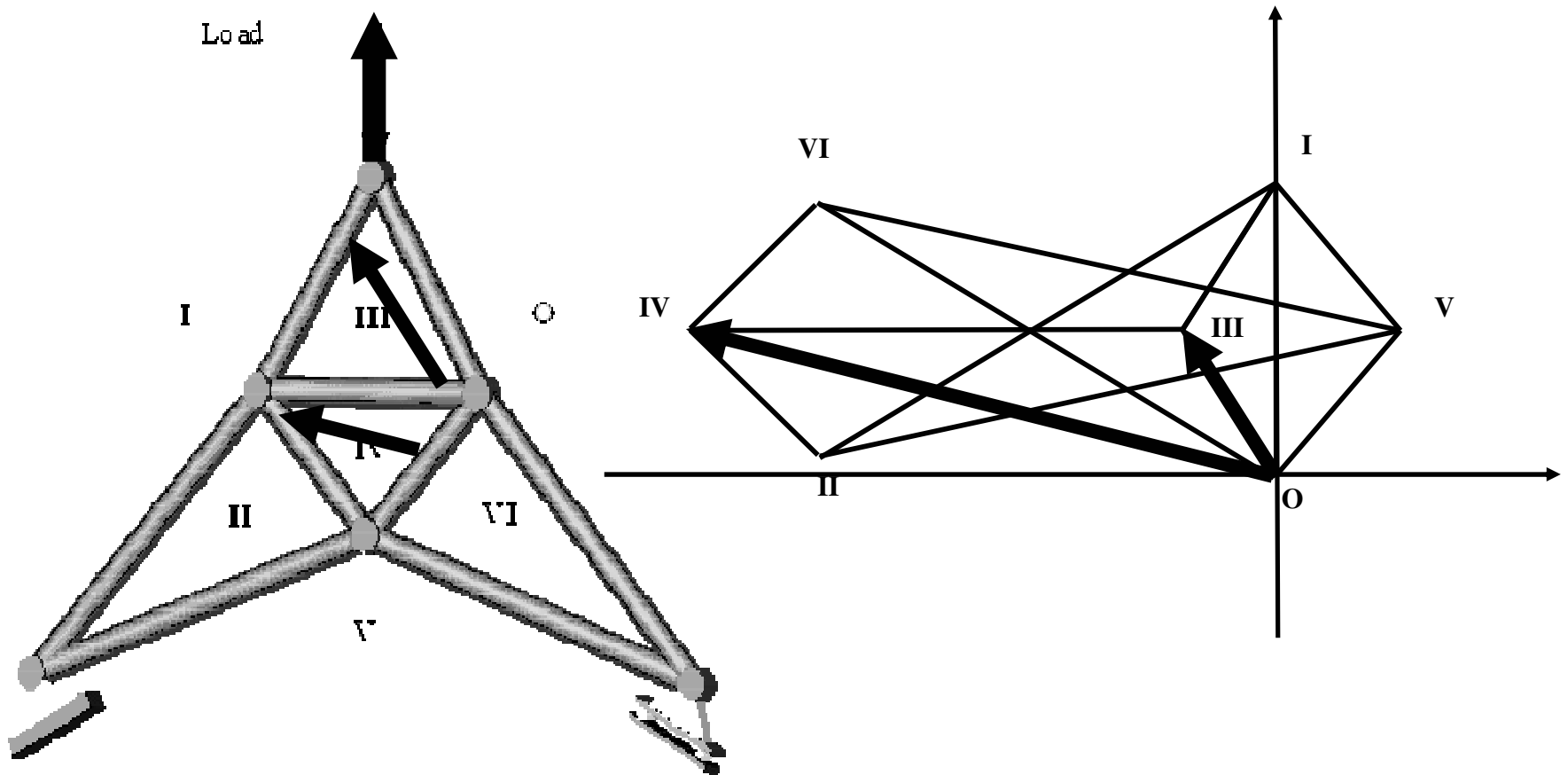
Face force is the corresponding entity in statics of absolute linear velocity of the dual mechanism.



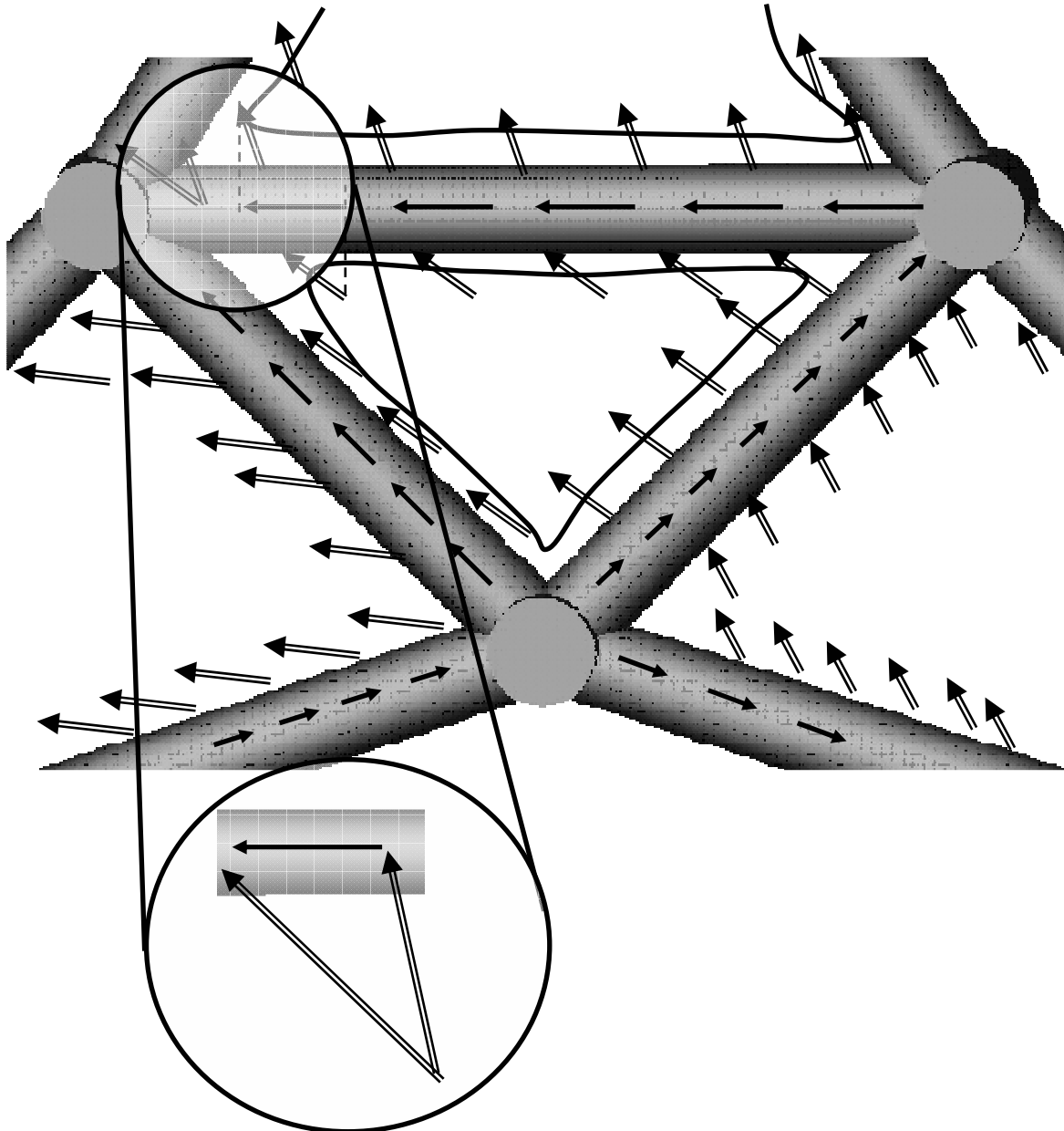
Dual
mechanism



The force in the bar is equal to the **subtraction**
between its two adjacent **Face Forces**



Face Forces define ALL the forces in the bars.



If **Face Forces** are forces thus
where
do they act?

Where is the line upon which
they exert zero moment?

Relation between two forces:

For any two forces F_i , F_j in the plane there exists a line upon which they exert the same moment.

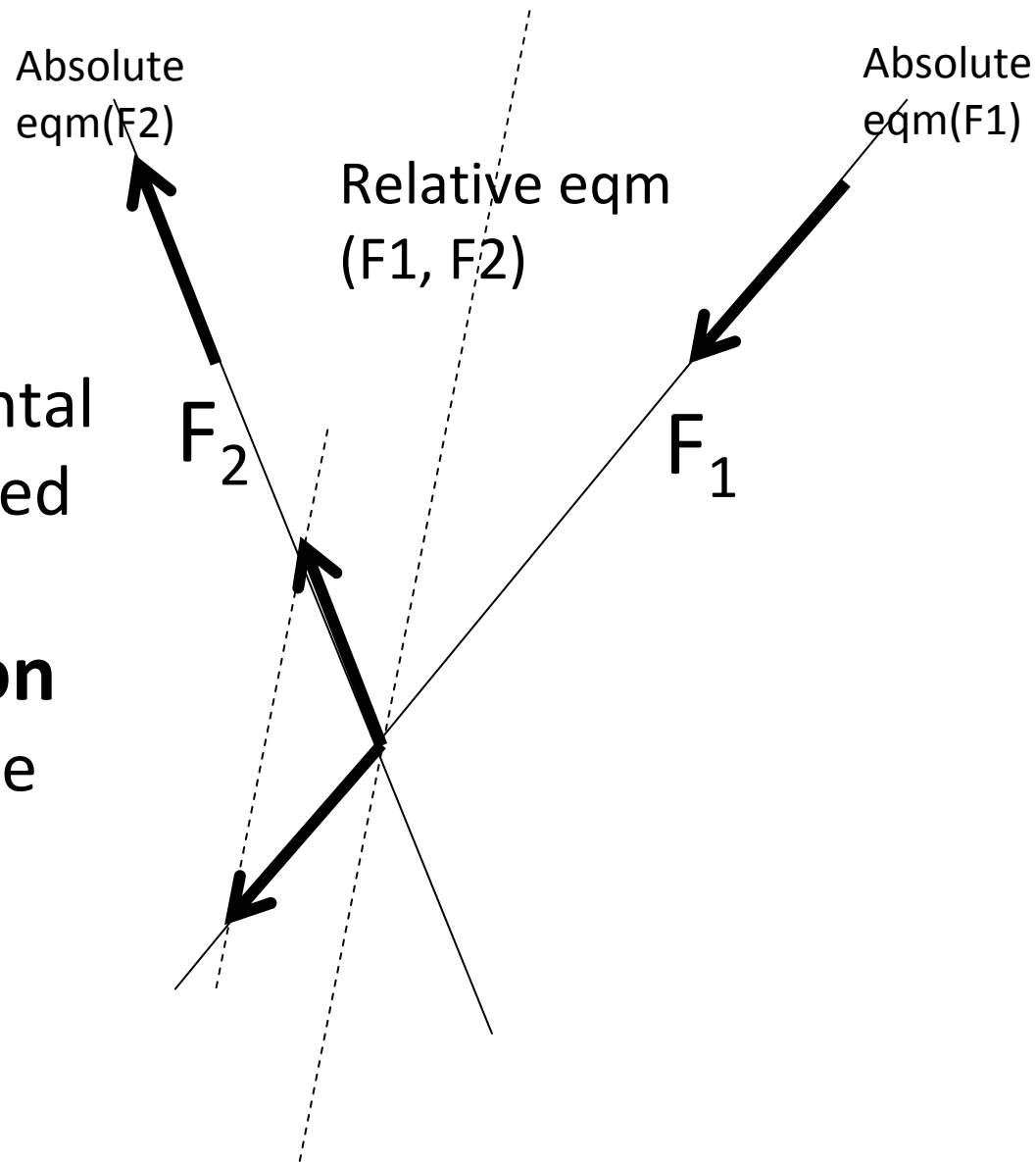
This line is termed: the relative **equimomental line** $eqm(F_i, F_j)$.

Finding the eqm(F_1, F_2)

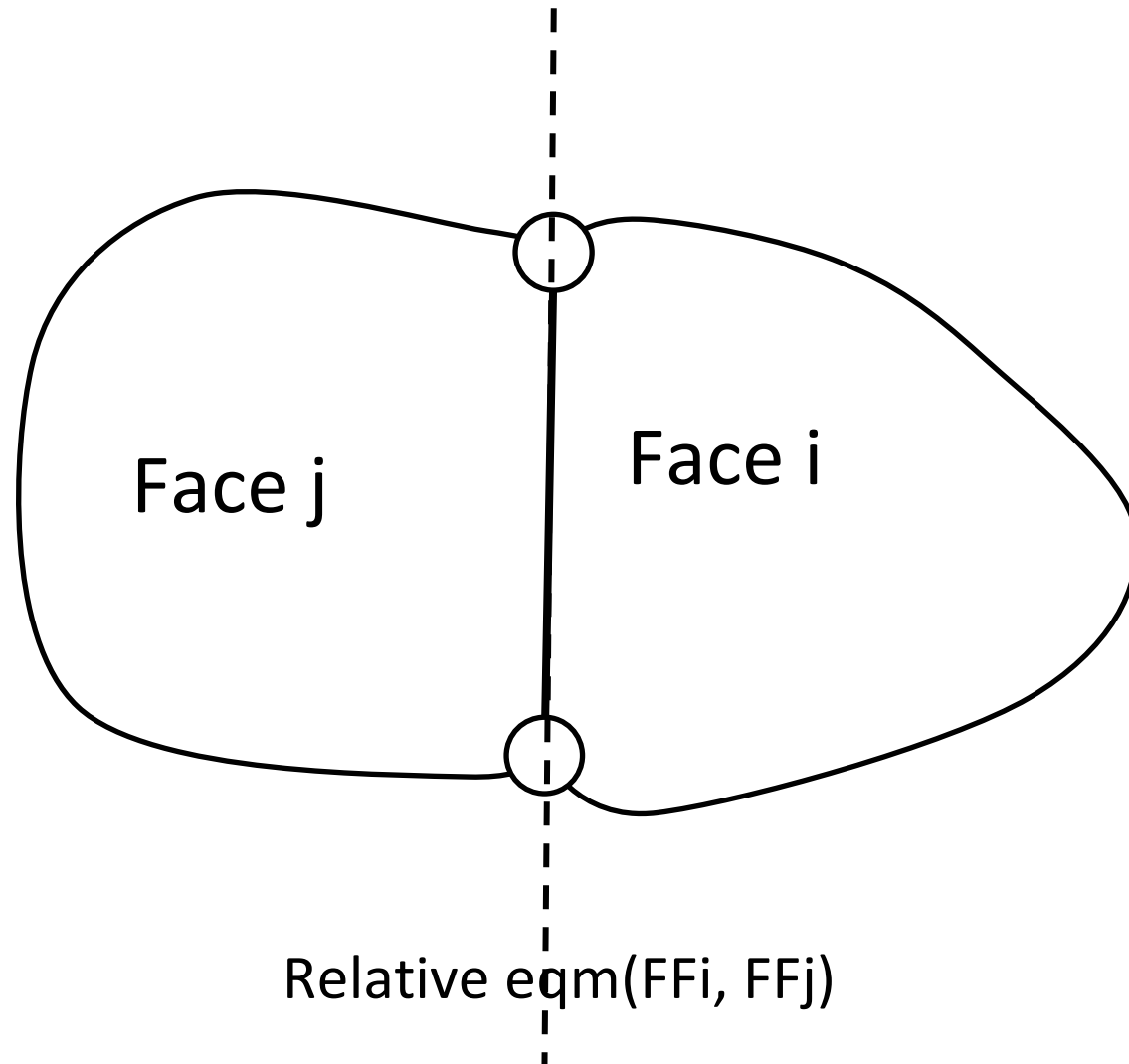


Finding the relative eqm(F1,F2)

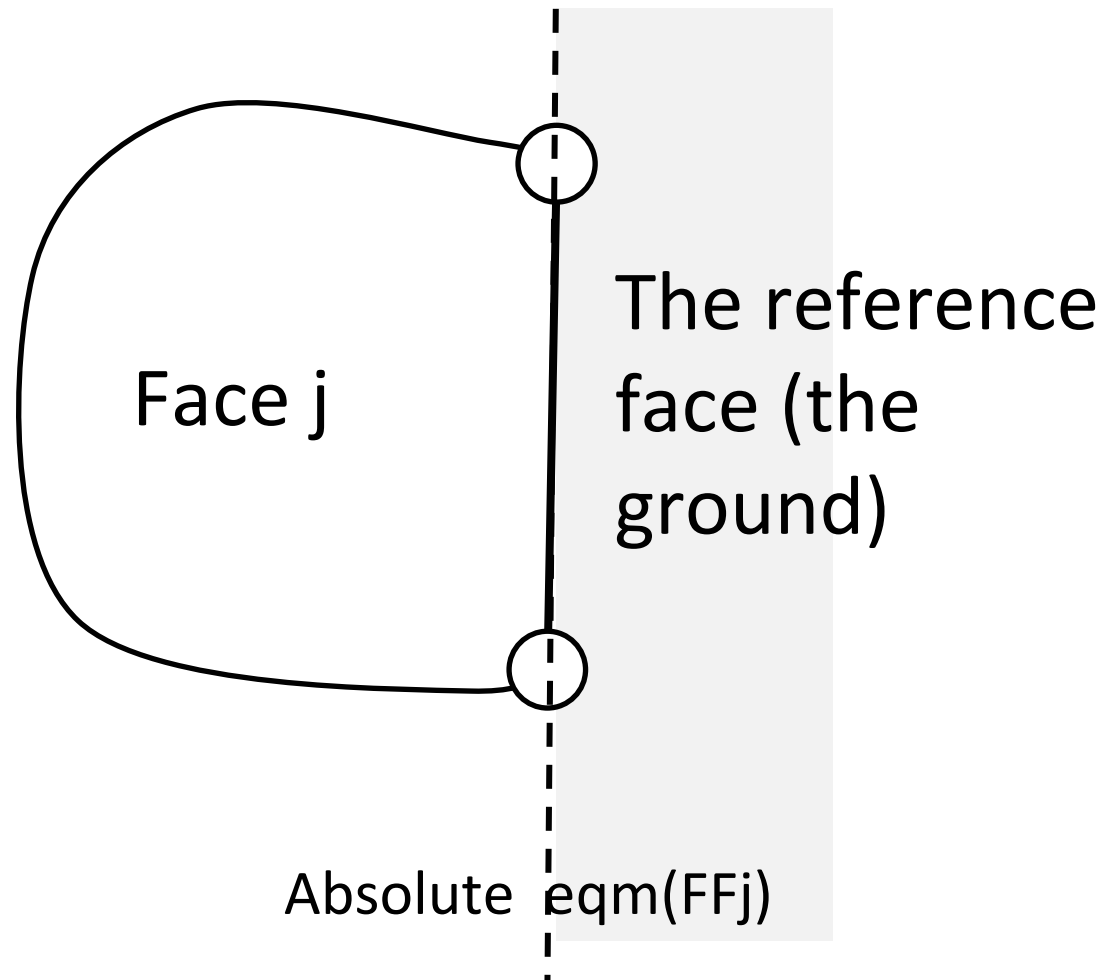
Equimomental
line is defined
by the
subtraction
between the
two forces.



Now, bars become the relative eqimomental lines of the two adjacent Face Forces.



If one of the adjacent faces is the zero face (reference face), thus the bar defines the absolute equimomental line of the other face.

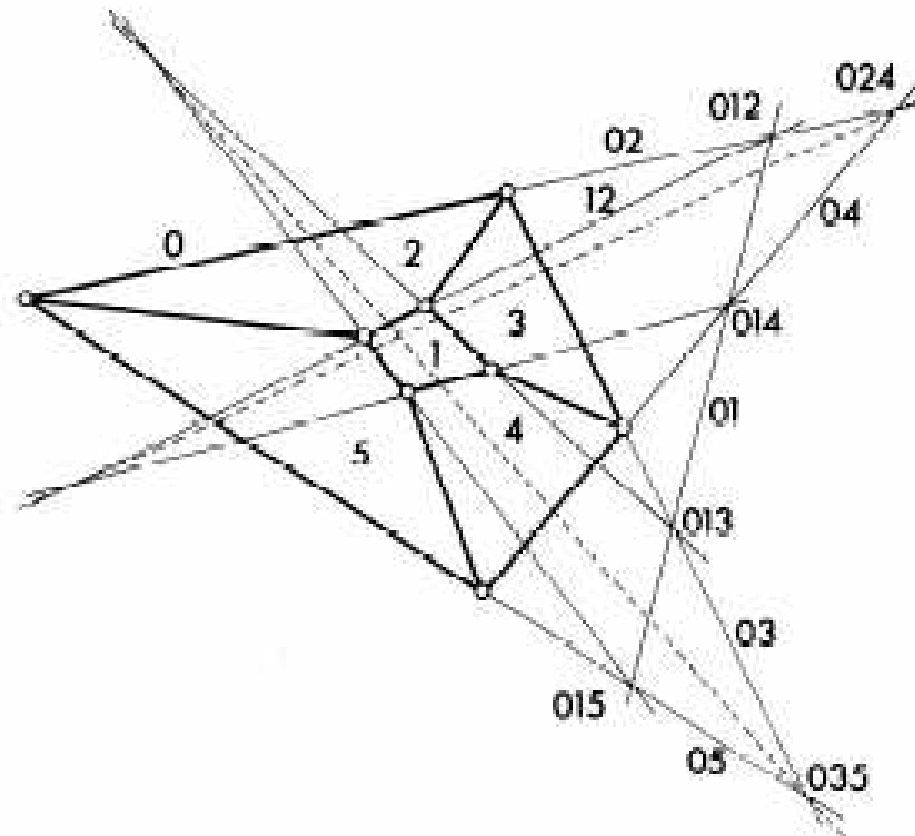


Theorem:

For any **three** forces, the corresponding three relative equimomental lines must intersect at the **same point**.

Now we can answer where the
Face Force acts.

Face forces and equimomental lines in projections of polyhedrons



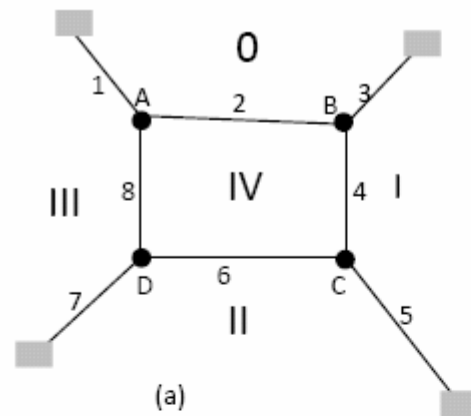
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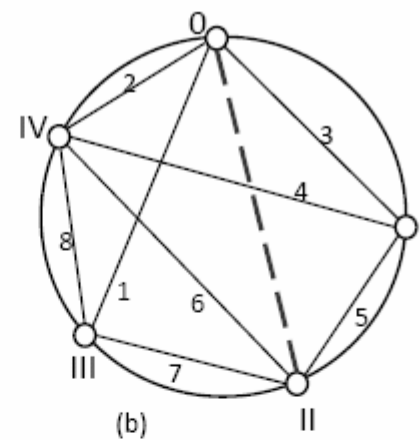
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 r r
 n n
 t t
 n n
 f f
 l l
 u u
 c c
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 a a
 d d
 o o
 v v

 i i

Characterization of the singularity of the Tetrad



The AG - tetrad



The Dual Kennedy circuit for the tetrad

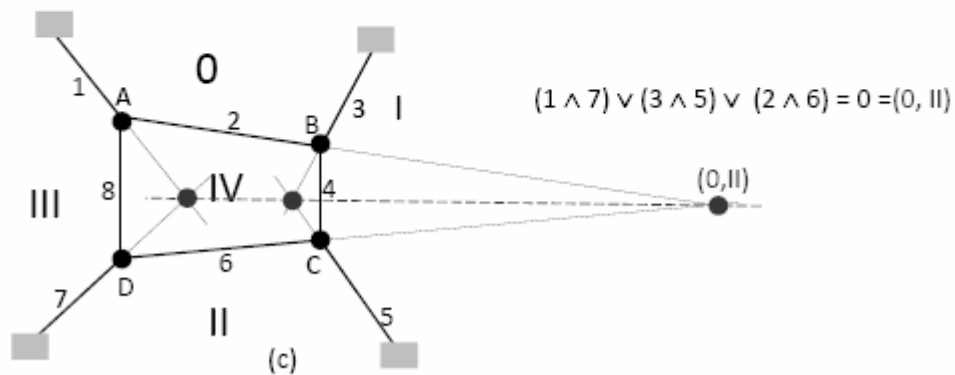
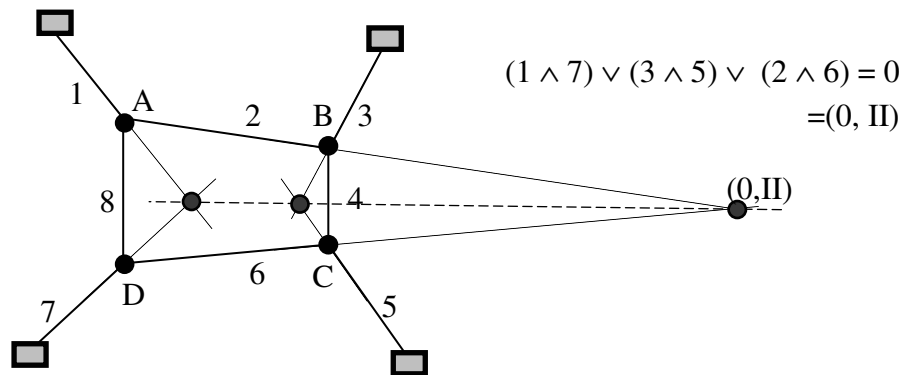
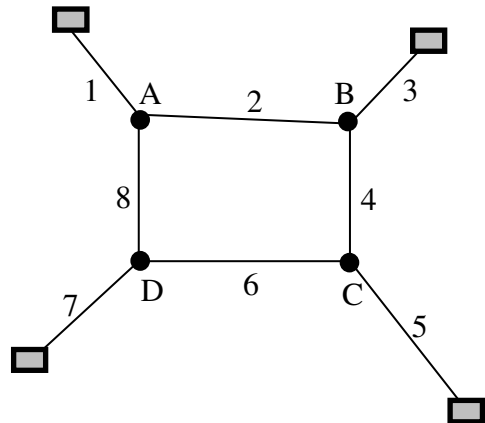


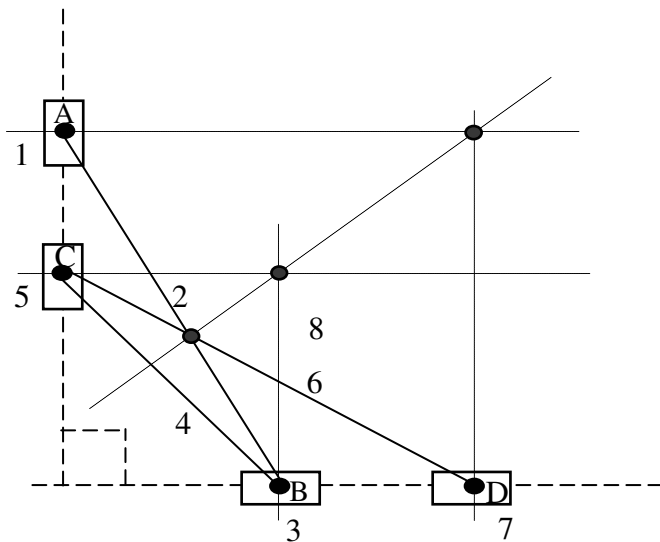
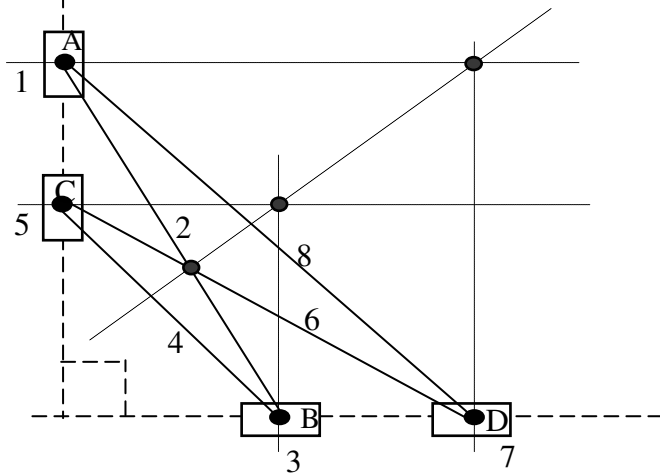
Figure 4. The characterization of the singular position of the tetrad – the three red points should be collinear.

The singular position of the Tetrad



Characterization done by
equimomental lines and face force

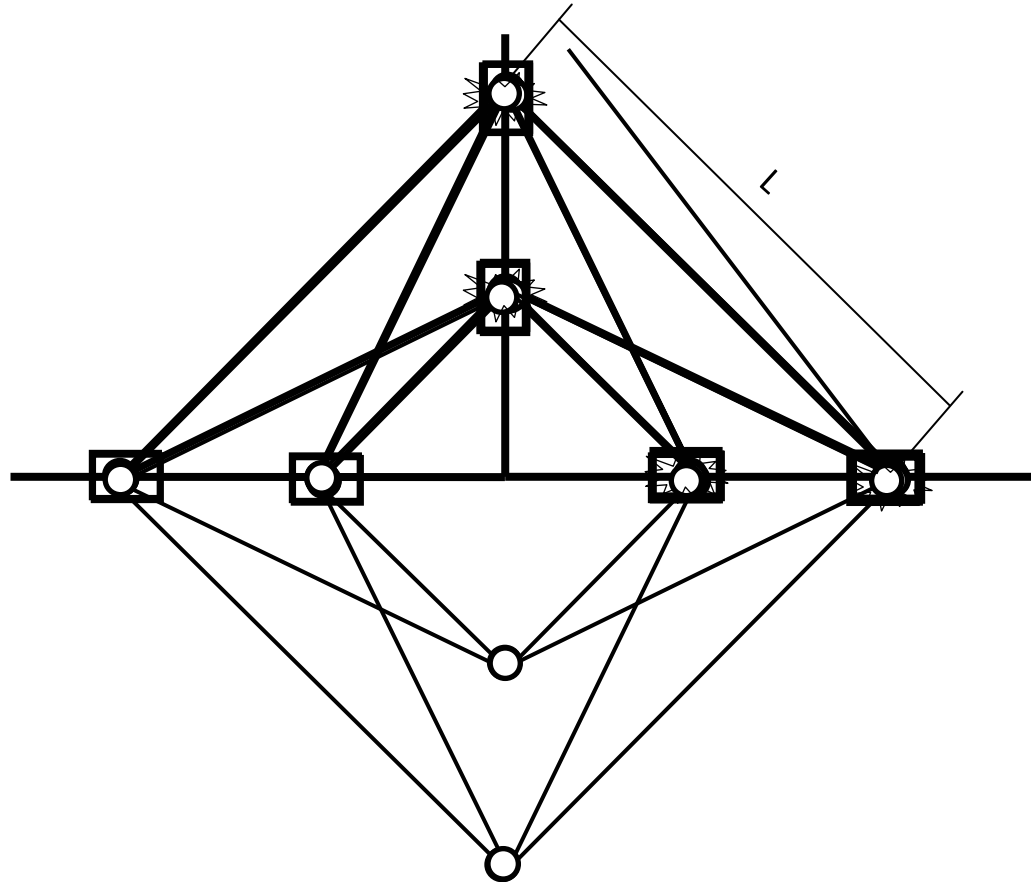
2. Transforming the infinitesimal motion of the Tetrad into finite motion



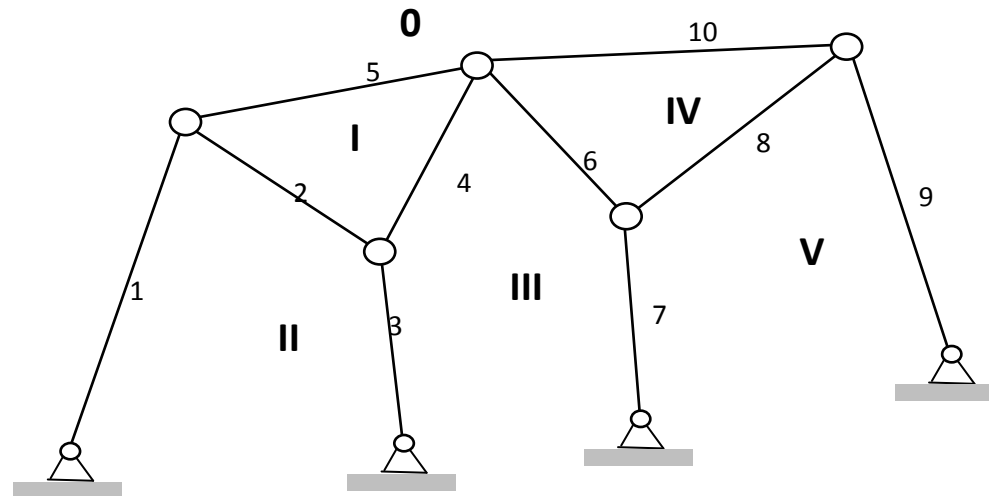
$$Y_A^2 + X_D^2 = (L_2^2 - X_B^2) + (L_6^2 - (L_4^2 - X_B^2))$$

$$= const$$

The replication step.



Last example – The double Triad Assur Graph



1. Singularity characterization of the Double Triad.

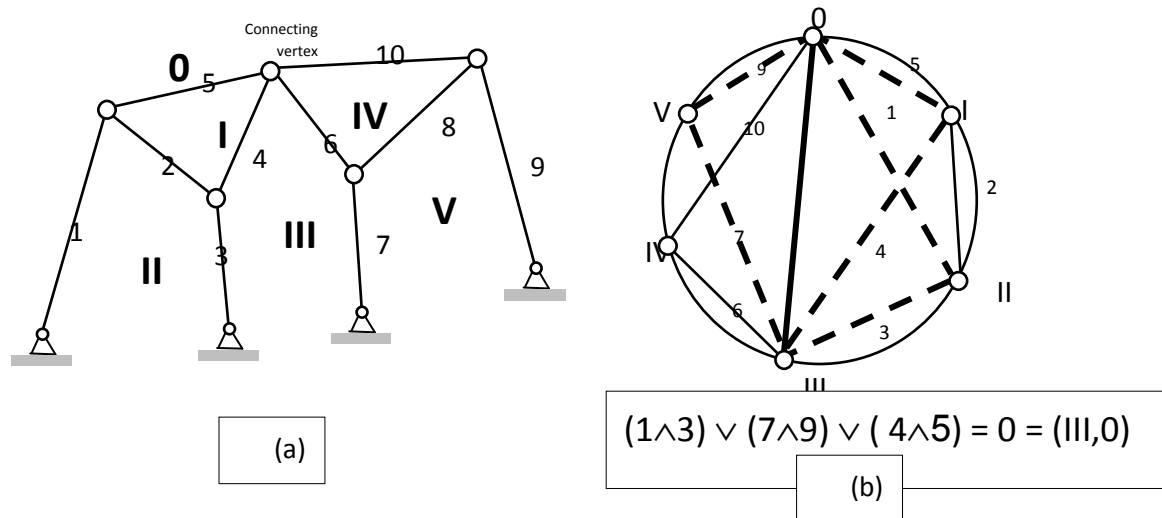


Figure 7. Characterization of the singular configuration of double triad through dual Kennedy circuit in statics.

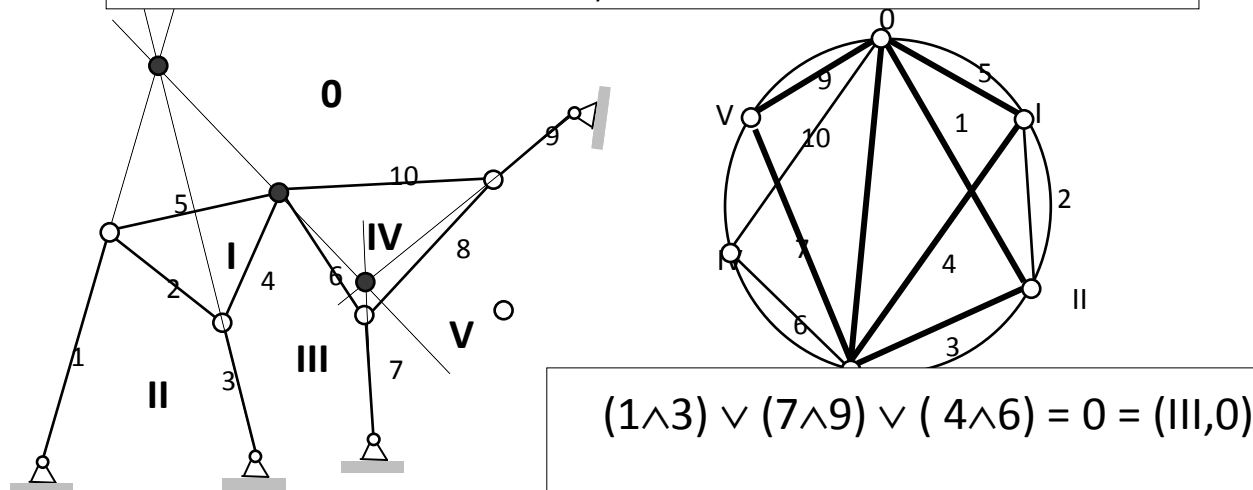
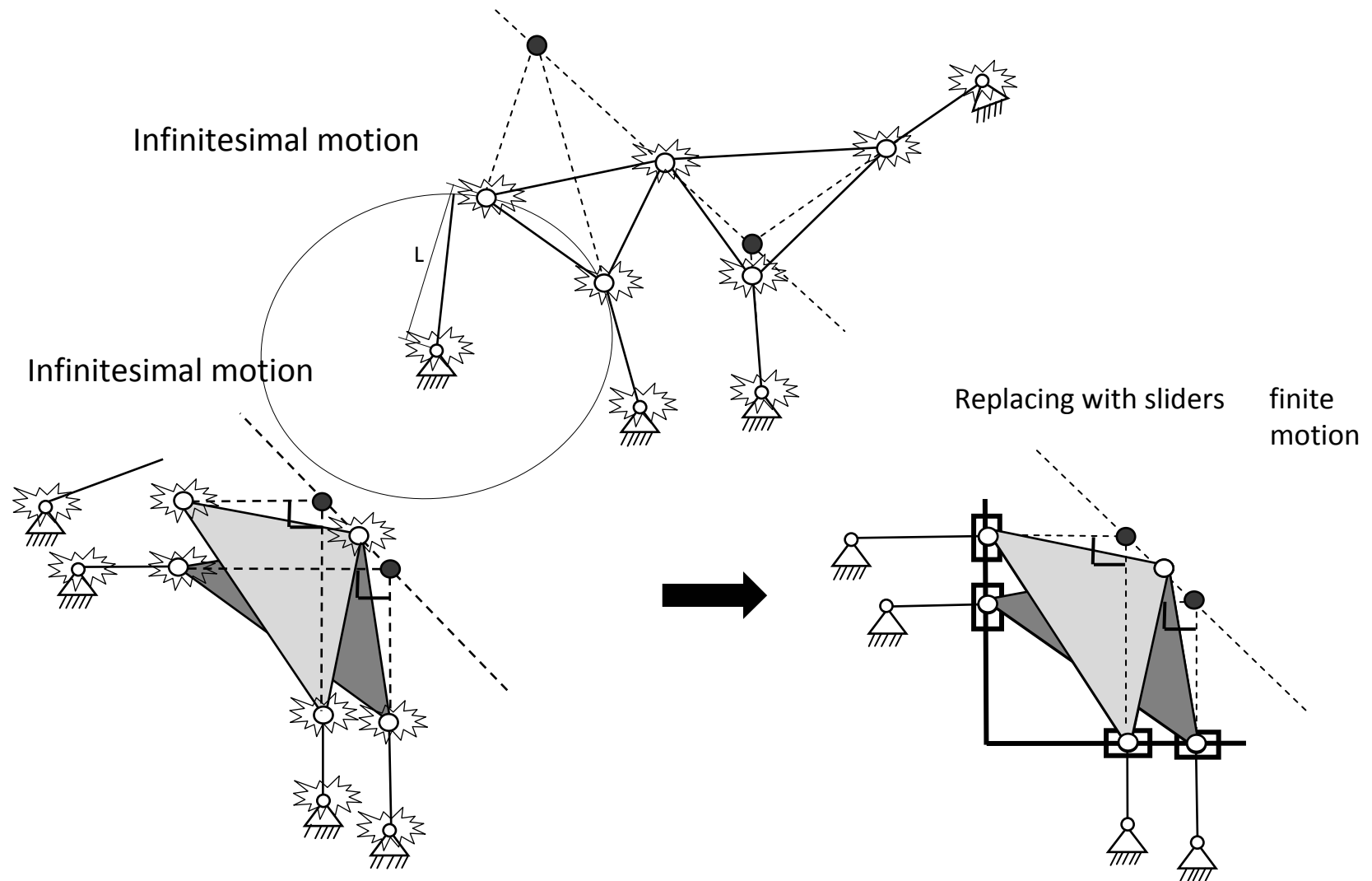
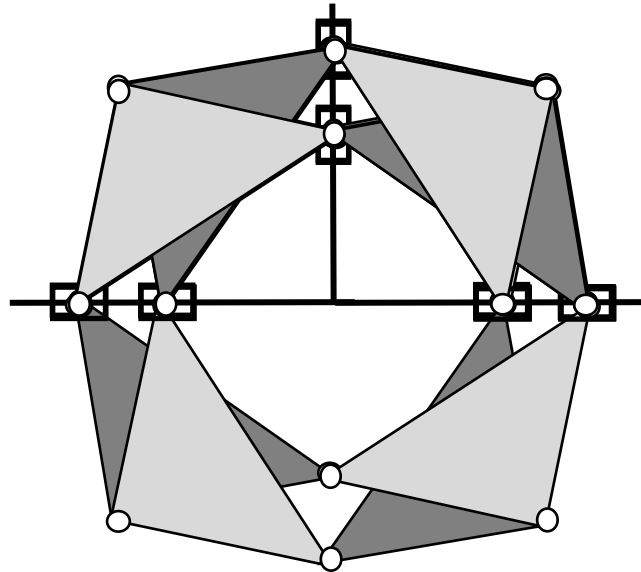


Figure 8. The double triad at the singular configuration having an infinitesimal motion.

2. Transforming the infinitesimal motion of the Double-triad into a finite motion



3. The replication step



Thank you!!!!