

Structural synthesis of innovative gripping mechanisms for wood harvesting

- 1. The presentation topic*
- 2. The issue formulation*
- 3. The structural synthesis of a gripping mechanism*
- 4. The results*
- 5. Conclusion*

Research topic

Innovation
and
design
methodologies

ECOMEF project

Eco-design of a
mechanized
equipment for
hardwood harvesting

THESIS

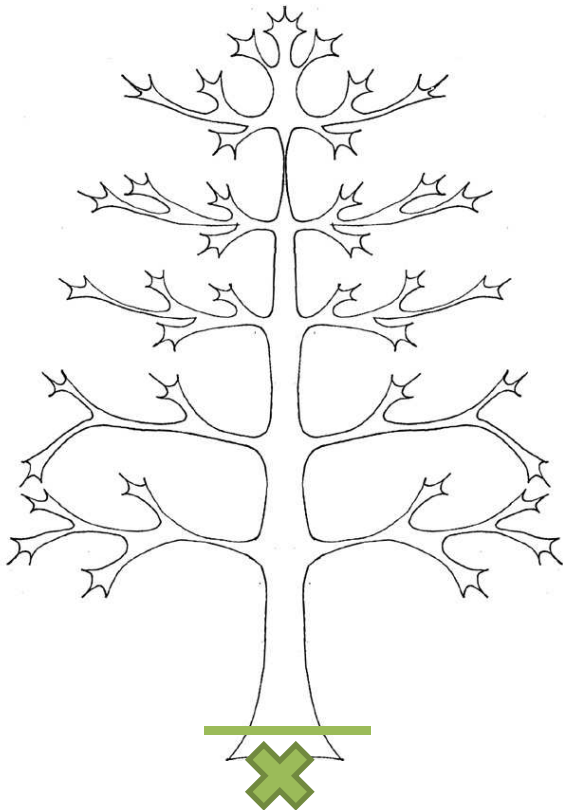
Research work supervised by:
- Grigore GOGU (thesis advisor)
- Jean-Christophe FAUROUX

Project:
- 4 years
- 3.8 millions Euros

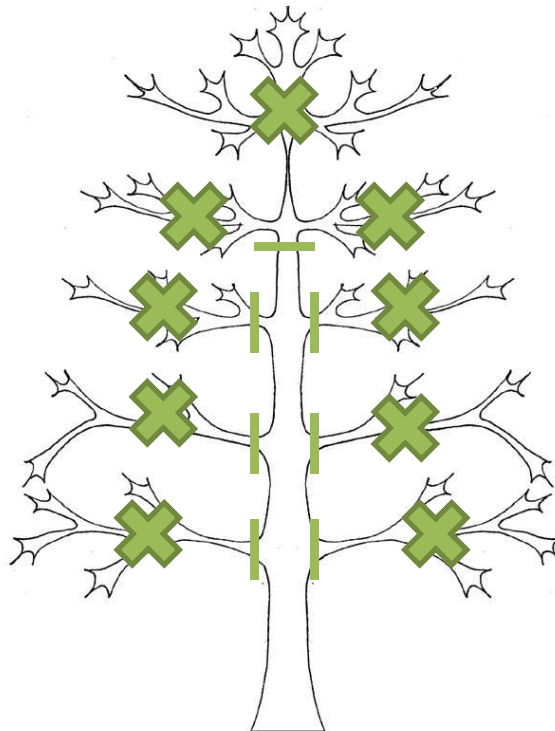
Wood harvesting

The basic operations

1-Felling



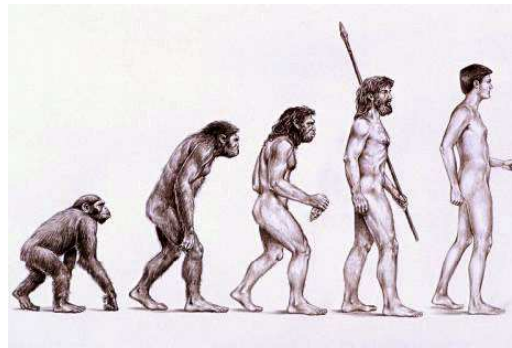
2-Delimiting



3-Cutting to length



The mechanization of wood harvesting



Saw



Ax



Motorized chain saw

Harvester

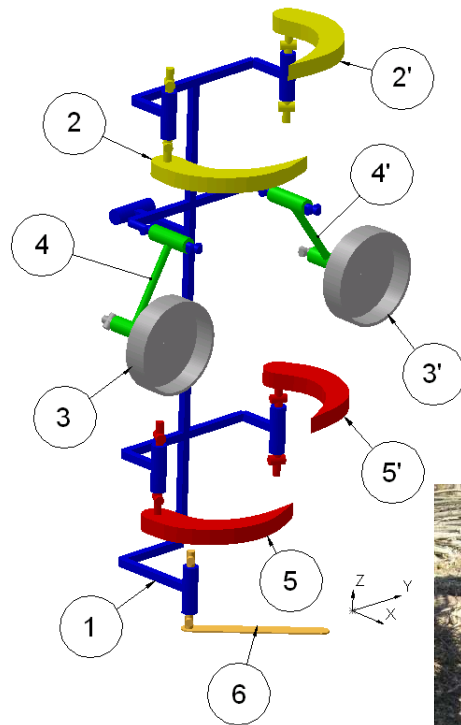


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Two kinds of standard gripping mechanisms for the rollers

Lateral gripping mechanism:



LOGMAX 7000



1 : body

2-2' : upper mobile knives

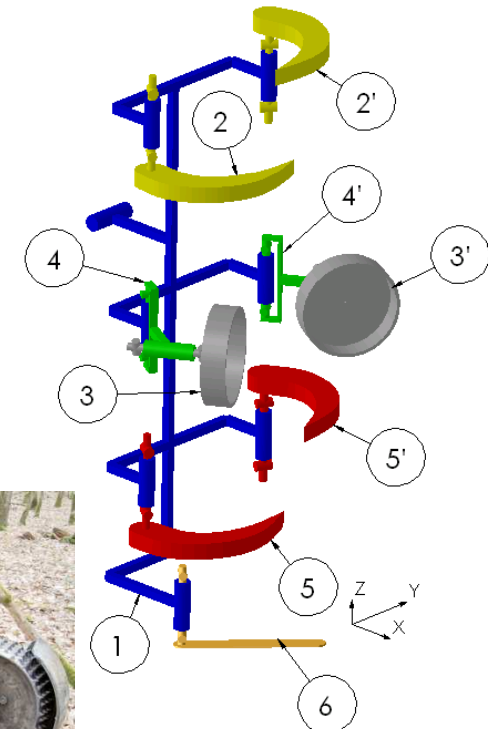
3-3' : rollers

4-4' : support arms

5-5' : lower mobile knives

6 : retractable chain saw

Concentric gripping mechanism:

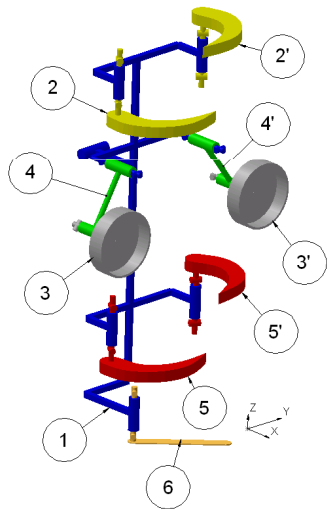


PONSSE H60 bw



Advantages and drawbacks of each solution

Lateral gripping mechanism:



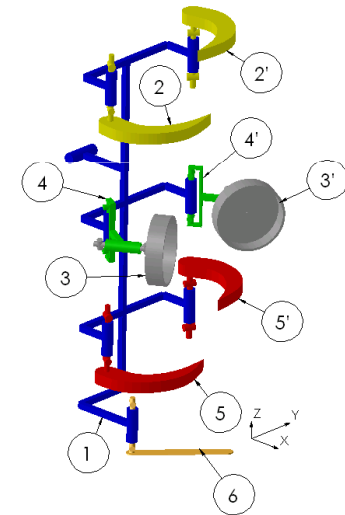
Allows to grip a small tree (diameter).



Keeps a heavy trunk against the body.



Concentric gripping mechanism:



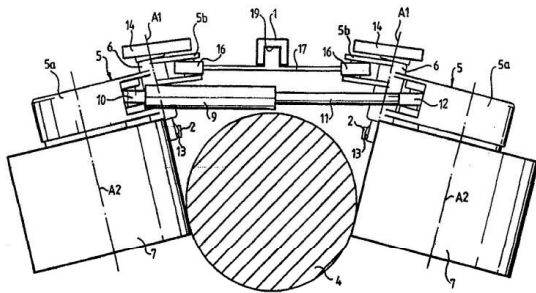
Physical contradiction (TRIZ theory):

The gripping mechanism must be “lateral” in order to grip small trees AND “concentric” in order to keep heavy trunks against the body.



Separation principle :
Separation based on different conditions

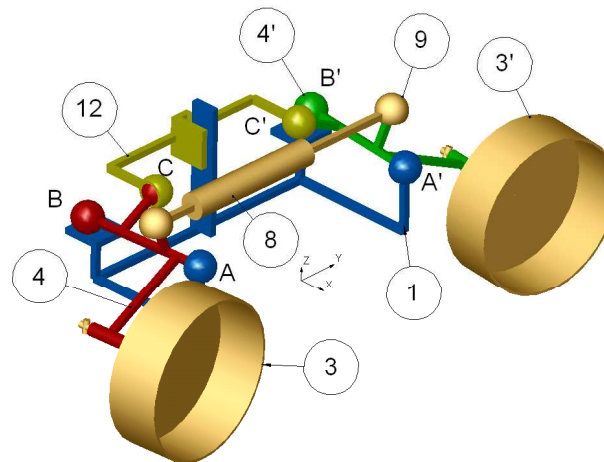
A different gripping mechanism : SP MASKINER's patent



Patent n°WO9854949A1



SP MASKINER SP561 LF



Kinematic diagram

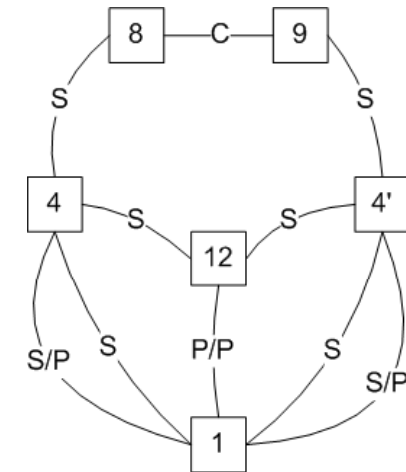
1 : body / frame

3-3' : rollers

4-4' : support arms

8-9 : linear actuator

12 : slider



Structural graph

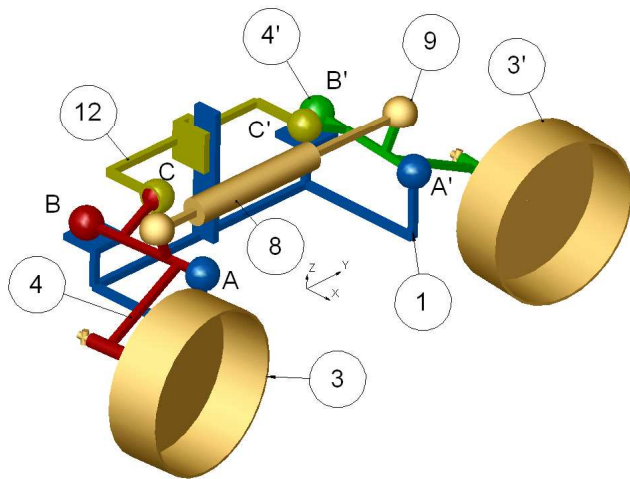
C : cylindrical

S : spherical

P/P : planar contact

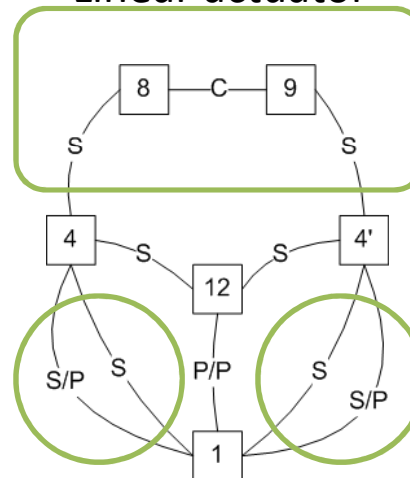
S/P : sphere / plane contact

Generating other mechanisms



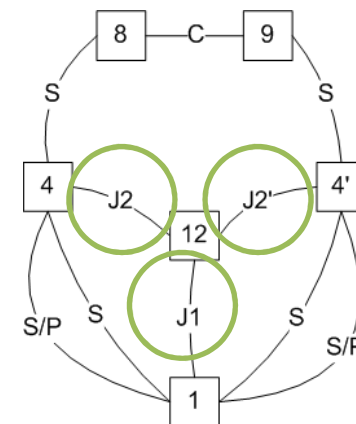
Kinematic diagram

Linear actuator



Two basic rotations

Structural graph



The coupling mechanism

Structural graph

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Structural parameters

Formulae

$$M = \sum_{i=1}^p f_i - r$$

$$r = \sum_{i=1}^k S_{Gi} - S + r_l$$

$$N = 6 \cdot q - r$$

$$T = M - S$$

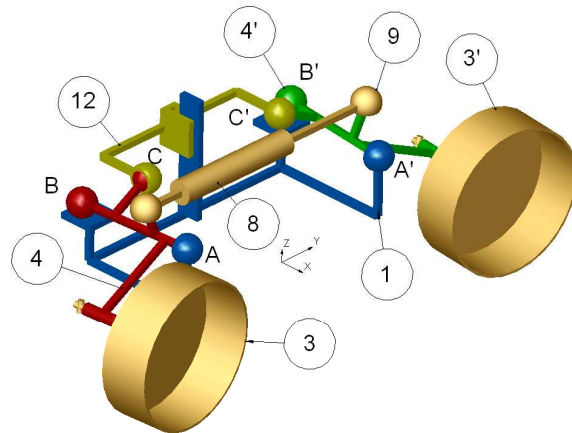
$$q = p - m + 1$$

A mechanism with many loops

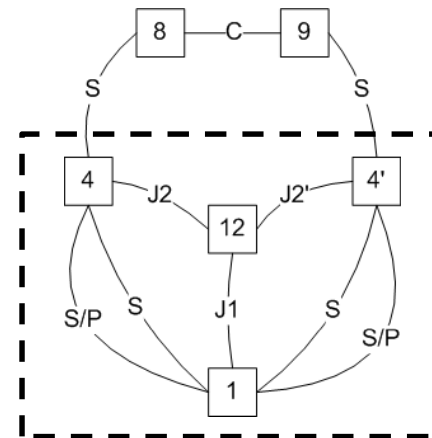
Grübler – Kutzbach formula gives wrong results
GOGU formulae

- M mobility.
(number of independent kinematic parameters needed to define the configuration of the mechanism)
- f_i degree of freedom in the joint i .
- r number of joint parameters that lose their independence in the loop closure.
(for closed loop mechanisms)
- p number of joints in the mechanism.
- S_{Gi} connectivity between the last link of the open kinematic chain G_i and the body, before closure.
- S connectivity between the body and the link joining all the mechanism limbs.
- r_l sum of the r values generated by the internal loops in the different limbs of the mechanism.
- k number of limbs in the mechanism.
- N number of overconstraints.
- q number of independent loops in a multi-loop mechanism (Euler's formula).
- m number of links in the mechanism.
- T structural redundancy.

Simplifications – step 1: removing the actuator



Kinematic diagram



Structural graph

Unactuated mechanism
("u" index)

frame = part n°4
end-effector = part n°4'

$$\left. \begin{array}{l} S = S_u \\ r_l = r_{lu} \\ S_{G(\text{actuator})} = 6 \end{array} \right\} r = r_u + 6$$

$$\left. \begin{array}{l} m = m_u + 2 \\ p = p_u + 3 \end{array} \right\} q = q_u + 1$$

$$M = \sum_{\text{unactuated}} f_i + \sum_{\text{actuator}} f_i - r$$

$$\sum_{\text{actuator}} f_i = 3 + 2 + 3 = 8$$

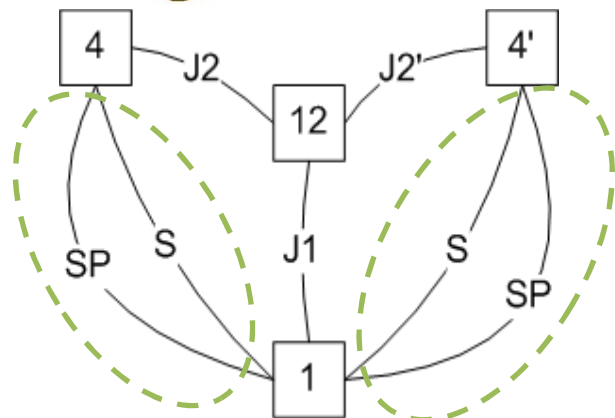
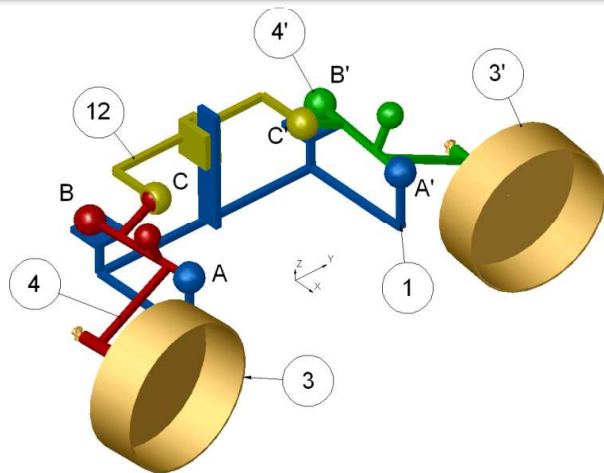
$$M = M_u + 2$$

$$N = 6 \cdot q - r$$

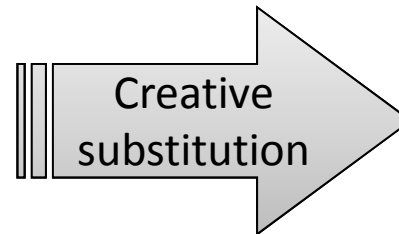
$$N = N_u$$

Simplifications – step 2: creative partial substitution

Original SP MASKINER mechanism

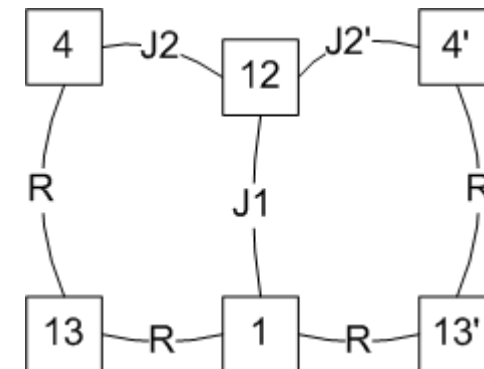
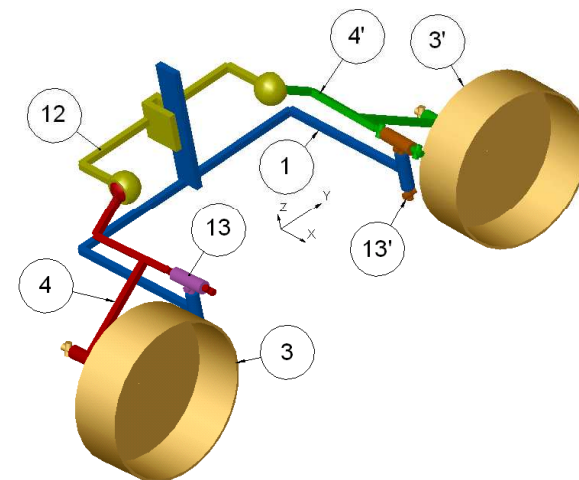


Kinematic diagrams

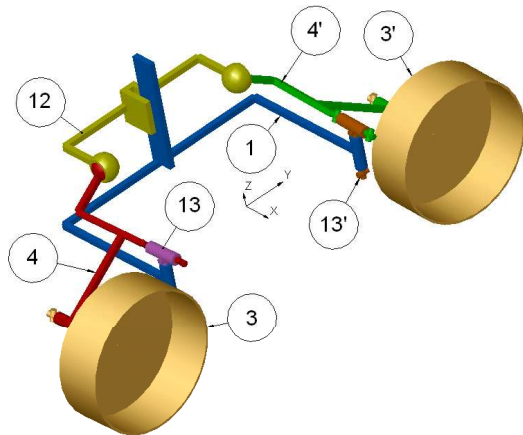


Structural graphs

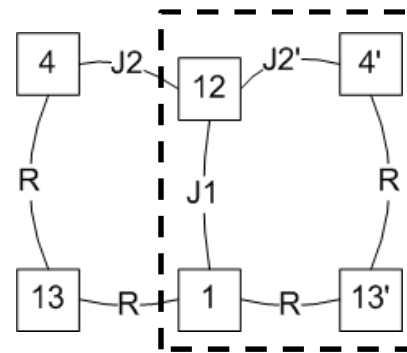
New mechanism



Simplifications – step 3: simplification by symmetry



Kinematic diagram



Structural graph

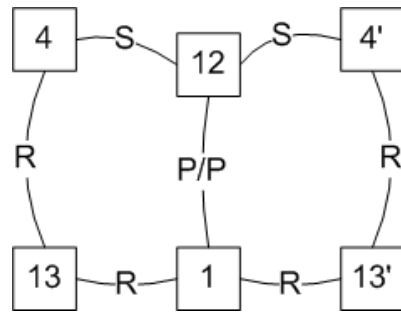


half mechanism
("h" index)

$$\left. \begin{array}{l} m_u = 2 \cdot m_h - 2 \\ p_u = 2 \cdot p_h - 1 \end{array} \right\} q_u = 2 \cdot q_h \left. \begin{array}{l} N_u = N_h = 0 \\ r_u = 2 \cdot r_h \end{array} \right\} M_u = 2 \cdot \sum_{half} f_i - \sum_{common} f_i - r_u$$

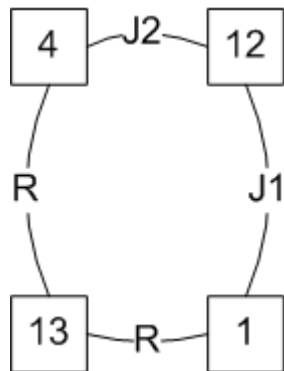
$M_u = 2 \cdot M_h - f_{(J1)}$

Final equations



Simplified unactuated mechanism

$$\left. \begin{aligned} M_u &= 1 \\ M_u &= 2 \cdot M_h - f_{(J1)} \end{aligned} \right\} f_{(J1)} = 2 \cdot M_h - 1$$



Half mechanism

$$\left. \begin{aligned} q &= 1 \\ N_h &= 0 \end{aligned} \right\} r_h = 6$$

$$\longrightarrow M_h = f_{(J1)} + f_{(J2)} + 1 + 1 - 6$$

$$f_{(J1)} + f_{(J2)} = M_h + 4$$

Resolution and listing the 9 solutions

$$\begin{cases} 0 \leq M \leq 6 \\ 0 \leq f_i \leq 6 \end{cases}$$

$$\begin{cases} f_{(J1)} = 2 \cdot M_h - 1 \\ f_{(J1)} + f_{(J2)} = M_h + 4 \end{cases}$$

name	degree of freedom
R: revolute	1
P: prismatic	1
C: cylindrical	2
S: spherical	3
P/P: planar contact	3
S/C: sphere / cylinder contact	4
C/P: cylinder / plane contact	4
S/P: sphere / plane contact	5

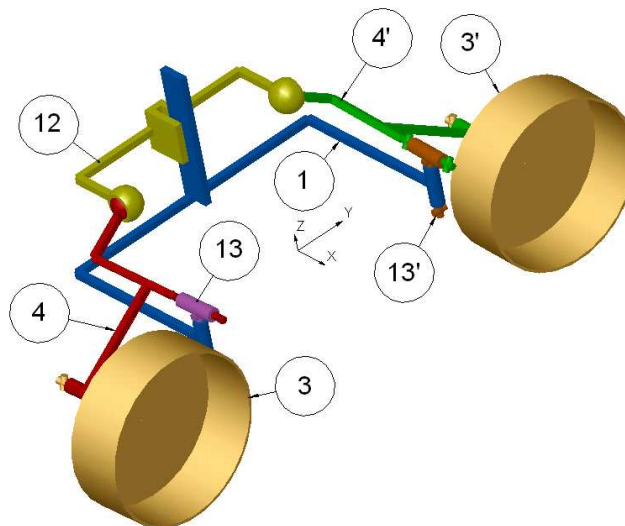
M_h	$f_{(J1)}$	Possibilities for J1	$f_{(J2)}$	Possibilities for J2	Nb of combinations (J1,J2)
1	1	2 (P or R)	4	2 (C/P or S/C)	4
2	3	2 (S or P/P)	3	2 (S or P/P)	4
3	5	1 (S/P)	2	1 (C)	1
TOTAL:					9

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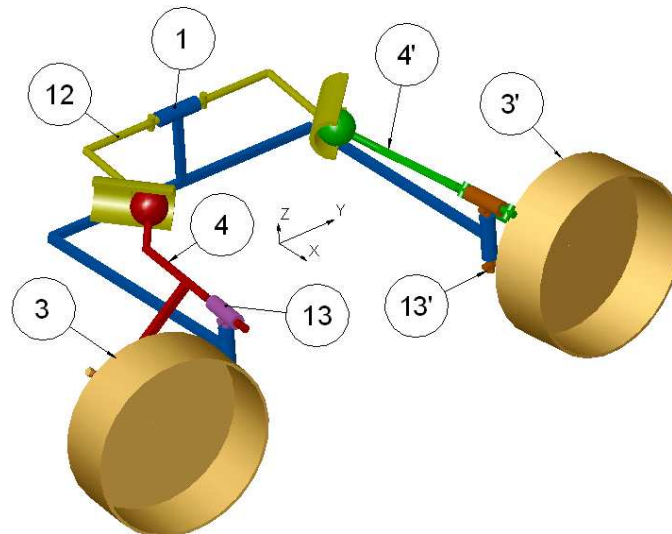
Initial mechanism : J1 = planar (P/P) and J2 = spherical (S)

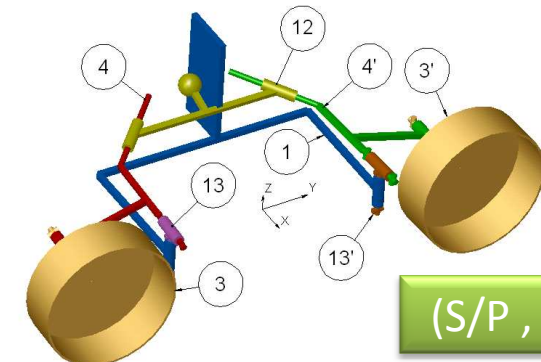
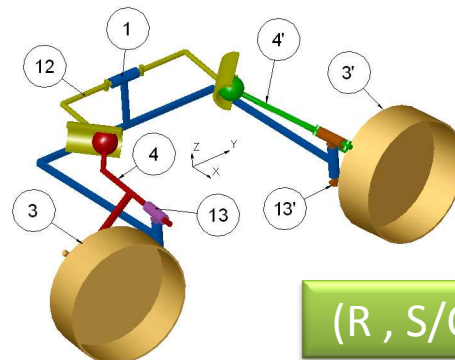
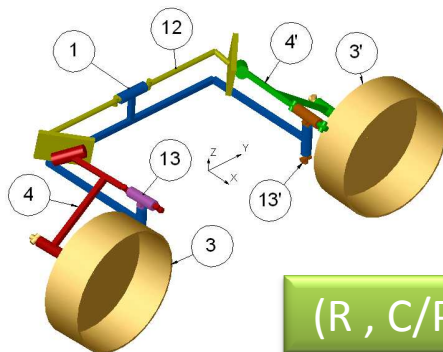
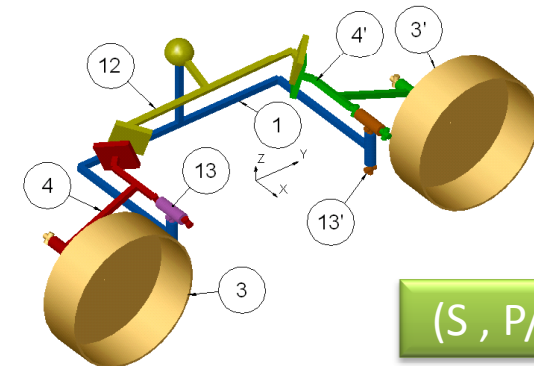
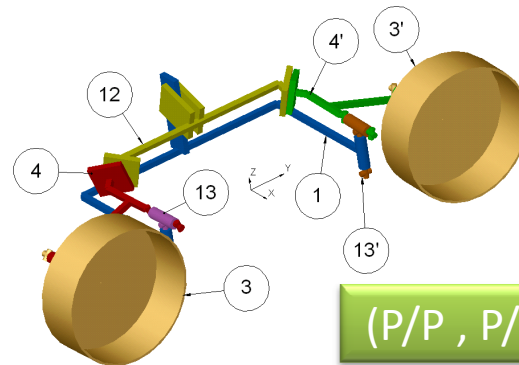
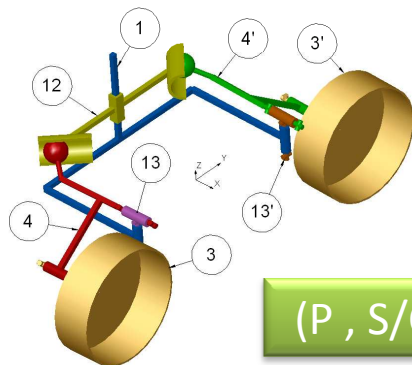
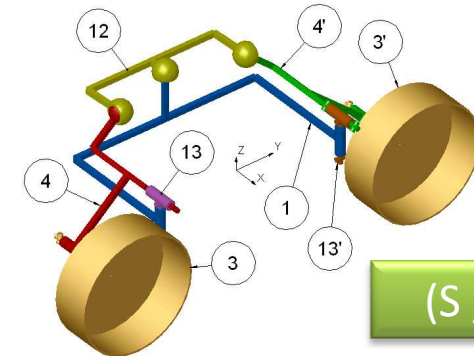
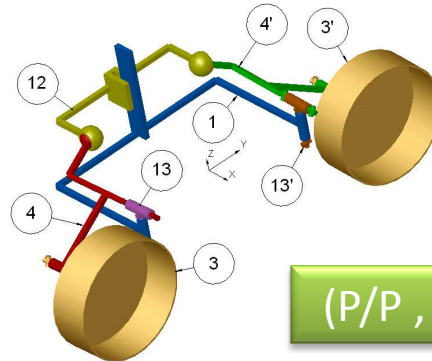
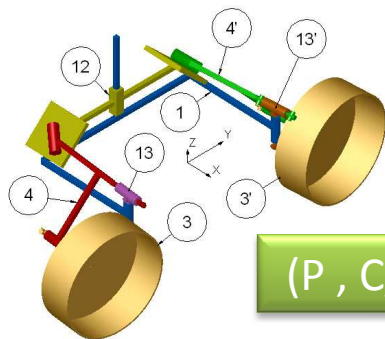
M_h	$f_{(J1)}$	Possibilities for J1	$f_{(J2)}$	Possibilities for J2	Nb of combinations (J1,J2)
1	1	2 (P or R)	4	2 (C/P or S/C)	4
2	3	2 (S or P/P)	3	2 (S or P/P)	4
3	5	1 (S/P)	2	1 (C)	1
TOTAL:					9



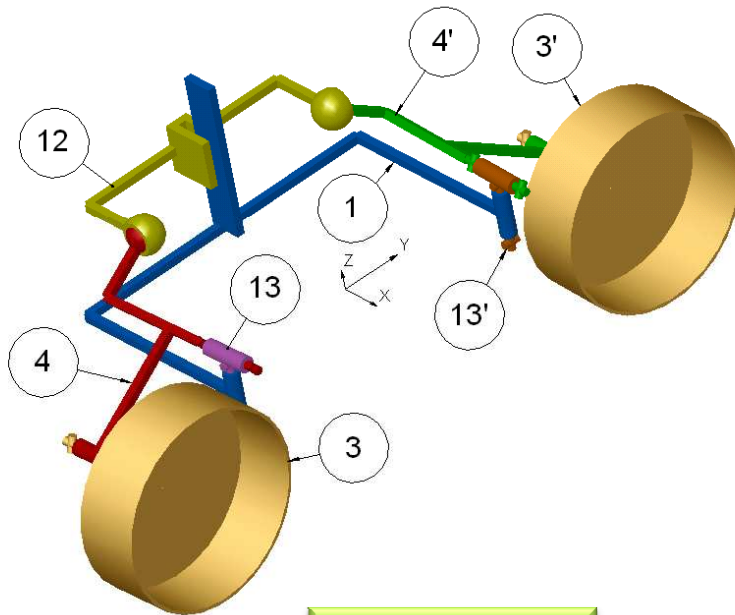
Example : J1 = revolute (R) and J2 = sphere/cylinder (S/C)

M_h	$f_{(J1)}$	Possibilities for J1	$f_{(J2)}$	Possibilities for J2	Nb of combinations (J1,J2)
1	1	2 (P or R)	4	2 (C/P or S/C)	4
2	3	2 (S or P/P)	3	2 (S or P/P)	4
3	5	1 (S/P)	2	1 (C)	1
TOTAL:					9

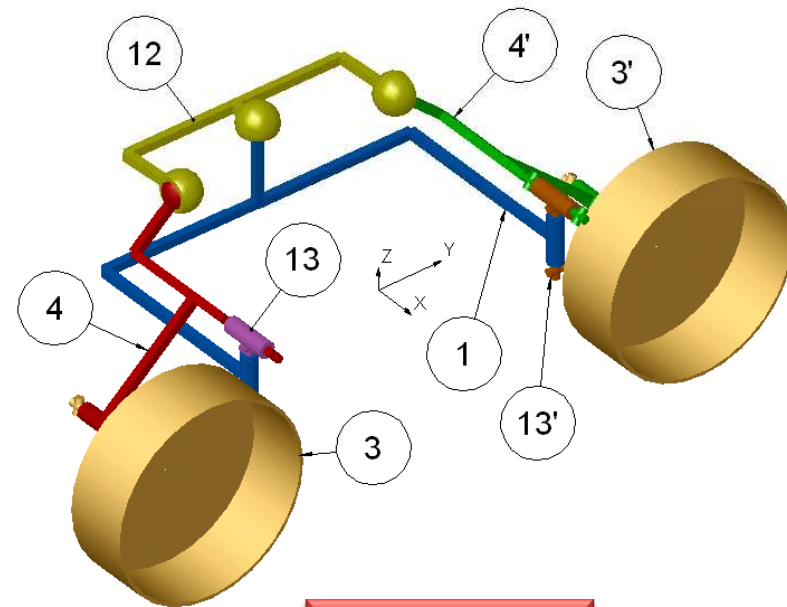




Results : Is the movement symmetric?



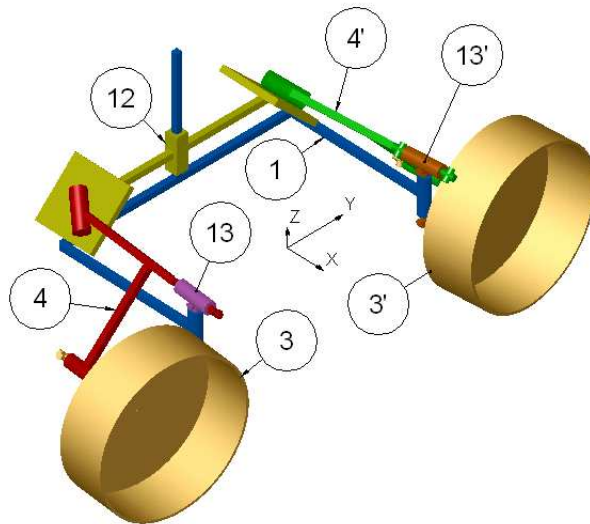
YES



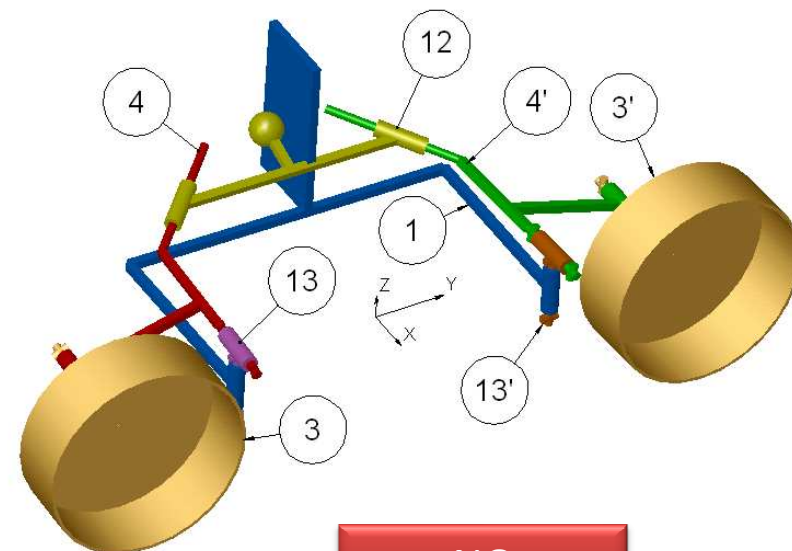
NO

Results : Do the half mechanisms work separately or not?

M_h	$f_{(J1)}$	Possibilities for J1	$f_{(J2)}$	Possibilities for J2	Nb of combinations (J1,J2)
1	1	2 (P or R)	4	2 (C/P or S/C)	4
2	3	2 (S or P/P)	3	2 (S or P/P)	4
3	5	1 (S/P)	2	1 (C)	1
TOTAL:					9



YES



NO

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A new methodology for structural innovation

1. 2 kinds of standard gripping mechanisms
2. 1 Physical contradiction (TRIZ) : separation principle
3. Patent research : SP MASKINER
4. Structural synthesis of the gripping mechanisms
 - a. Simplification : linear actuator
 - b. Simplification : the parallel joints
 - c. Simplification : symmetry
 - d. Equations
 - e. 9 solutions
5. Kinematic diagrams

This method generates the **exhaustive** set of alternative solutions with the same DOF and behavior of a reference mechanism.

A new methodology for structural innovation

Advantages:

- ✓ Exhaustive
- ✓ Graph enumeration can be automated

Future work:

- ✓ Convert a structural graph into a kinematic diagram
- ✓ Choosing the right orientation of axis for R-C-P-S/C joints, of plane for P/P-S/P
- ✓ Dimensioning (distances between axes and part dimensions)

Any question ?

