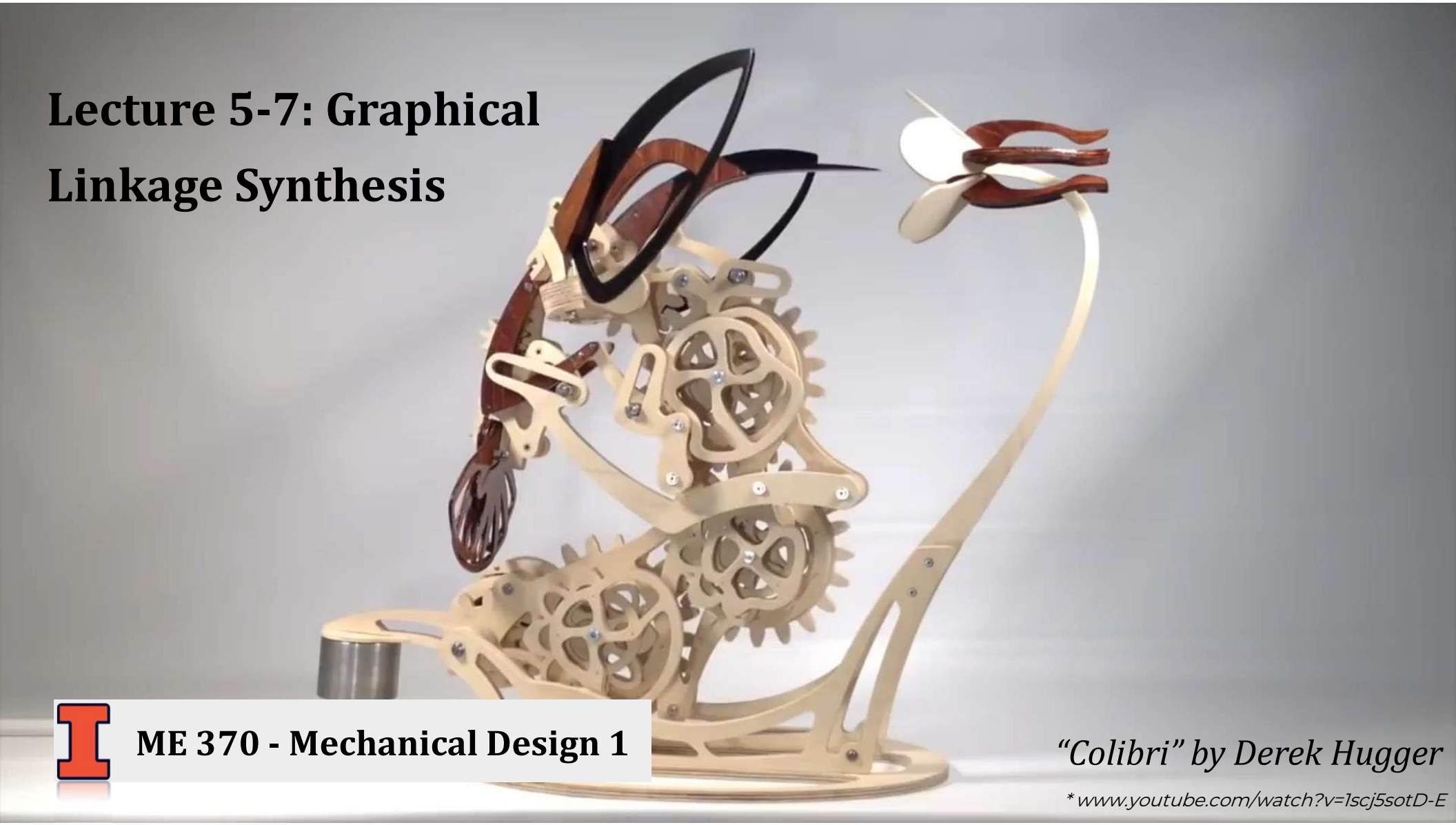
Lecture 5-7: Graphical Linkage Synthesis



ME 370 - Mechanical Design 1

"Colibri" by Derek Hugger

** www.youtube.com/watch?v=1scj5sotD-E*

Theo Jansen's Strandbeests

Beautiful example of Path Synthesis
https://www.youtube.com/watch?v=zYGVYLzN06g

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Topic 2: Graphical Linkage Synthesis

- Synthesis techniques
  - Generation types and strategies
- Motion synthesis: Two-position synthesis
  - Rocker output
  - Coupler output
  - Rotopoles
- Dyad drivers
- Quick return mechanisms
- Motion synthesis: Three-position synthesis
  - Specified moving points
  - Alternate moving points
- Path synthesis
  - Coupler curves

Kinematic or Mechanism Synthesis

- How do we design a mechanism to achieve desired functionality?

- **Kinematic (or Mechanism) synthesis**, determines the size and configuration of mechanisms that shape the flow of power through a mechanical system, or machine, to achieve a desired performance.

Kinematic synthesis - procedure

- Define desired motion
  - e.g. dispense candy, walking gait
- Choose mechanism type
  - e.g., crank-rocker, slider-crank
- Specify geometry
  - e.g., link lengths, type & # of joints
- Avoid undesirable behaviors
  - e.g., toggle positions, change points

Functional requirements → HcD

4 bar → inversions, isomers
6 bar

Synthesis

Grashof class

Choosing and refining mechanisms

- How to design a mechanism?

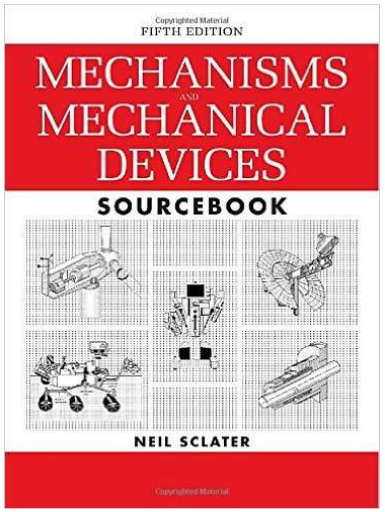
Research existing solutions

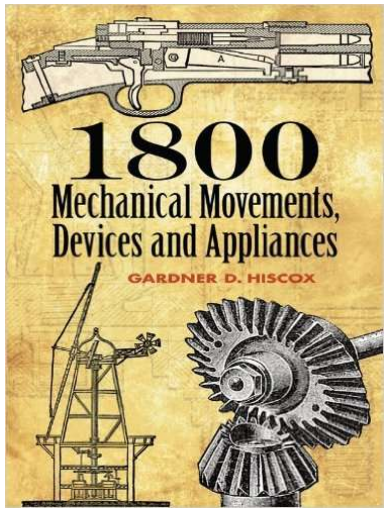
A day of deep historical searching is worth 6 months in the lab

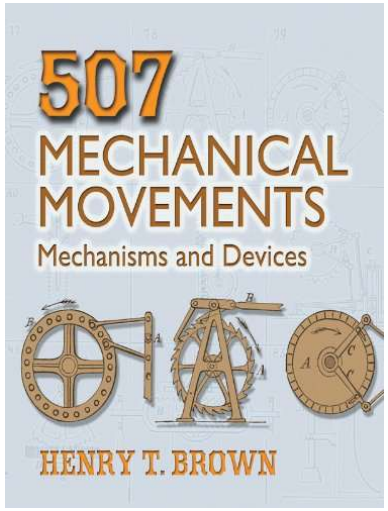
Compilations of solutions to different kinds of motion

1. Online and books are often divided by mechanism type (crank-rocker, slider-crank, 4- or 6-bar mechanism, using gears, using chains, etc,). What do you want?

by type ↓ find motions





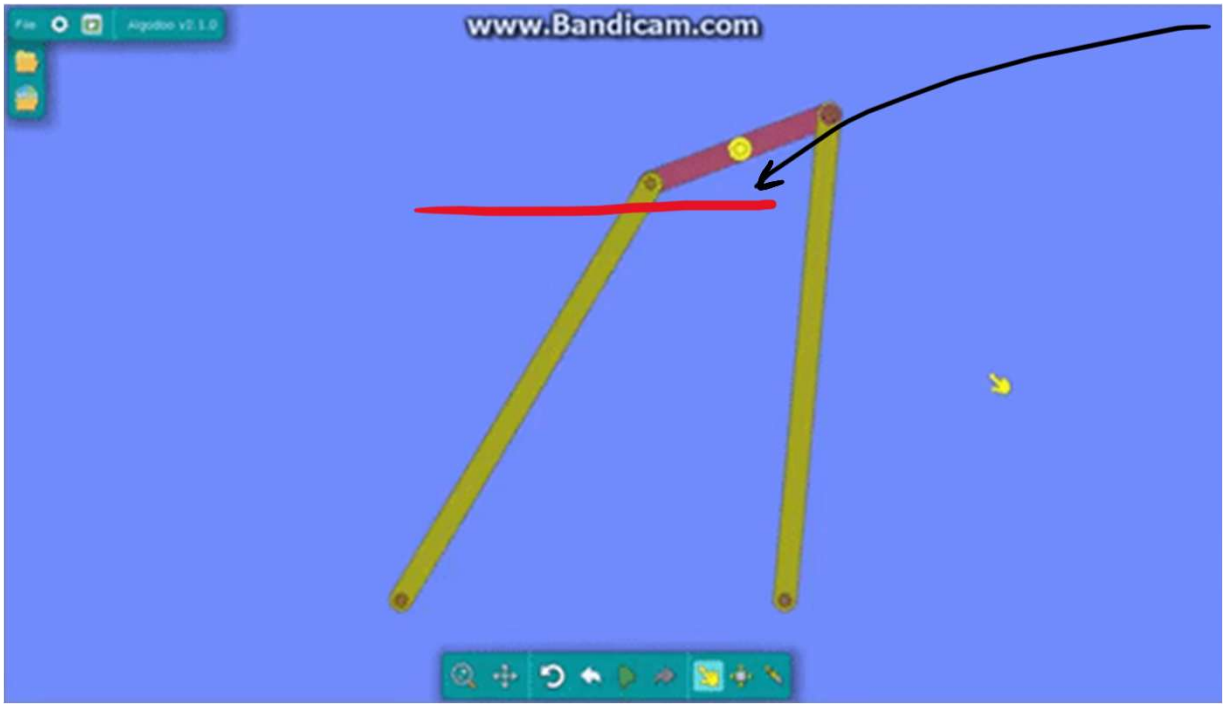


↘ by motions ↓ find types

2. Or, there are collections of ways to achieve common motions, like straight-line mechanisms…

Example: Straight line Motion

Chebyshev linkage



- 4 bar can produces lines
- can be adapted to use just a portion of the trajectory.

https://www.youtube.com/watch?v=o3oczQU8QlY

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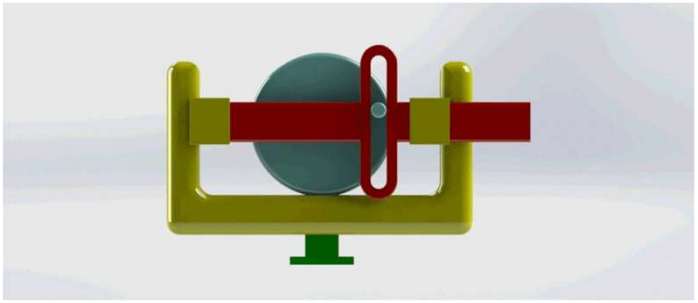
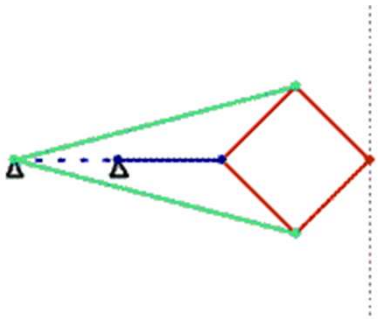
Other Straight-Line Mechanisms

Scotch Yoke

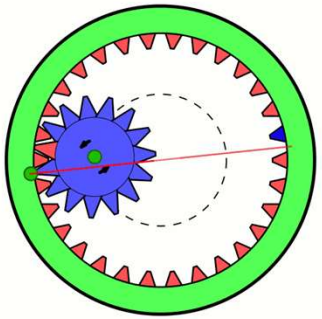


Peaucellier linkage

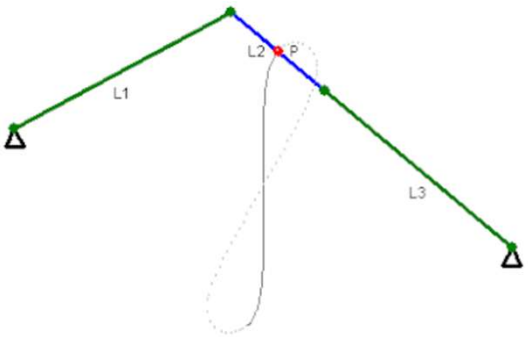


4 bar mechanis

Hypocycloidal Gears



Watts linkage



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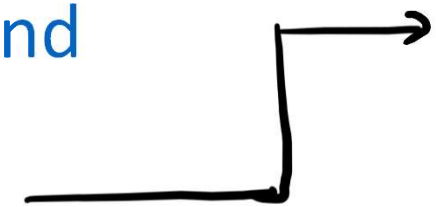
Choosing and refining mechanisms

- How to design a mechanism?

1. Research existing solutions
2. Analyze / Understand
3. Adapt / Improve



- Size, power, efficiency, constraints
- Linkages ok?
- Sliders ok? Friction?
- Does it need to be exactly a straight line, or is approximate ok?
- Is it ok to have part of the motion be not a straight line?

Adapting and improving linkage design

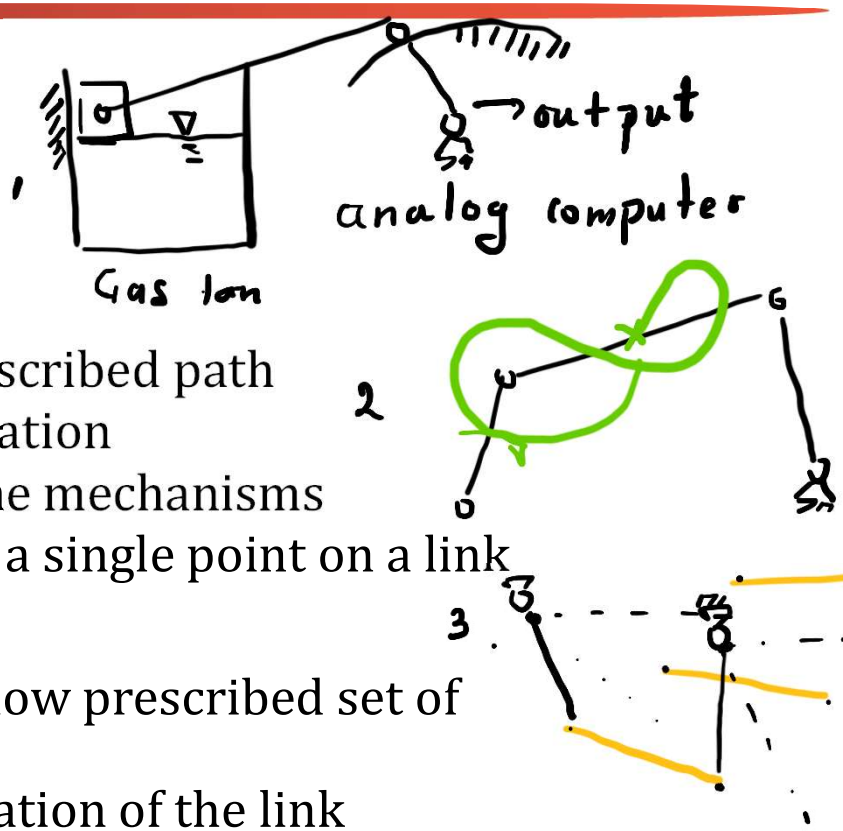
Computational Design of Mechanical Characters

S. Coros[1] B. Thomaszewski[1]
G. Noris[1] S. Sueda[2] M. Forberg[2]
R. Sumner[1] W. Matusik[3] B. Bickel[1]

[1]Disney Research Zurich [2]Disney Research Boston [3]MIT CSAIL

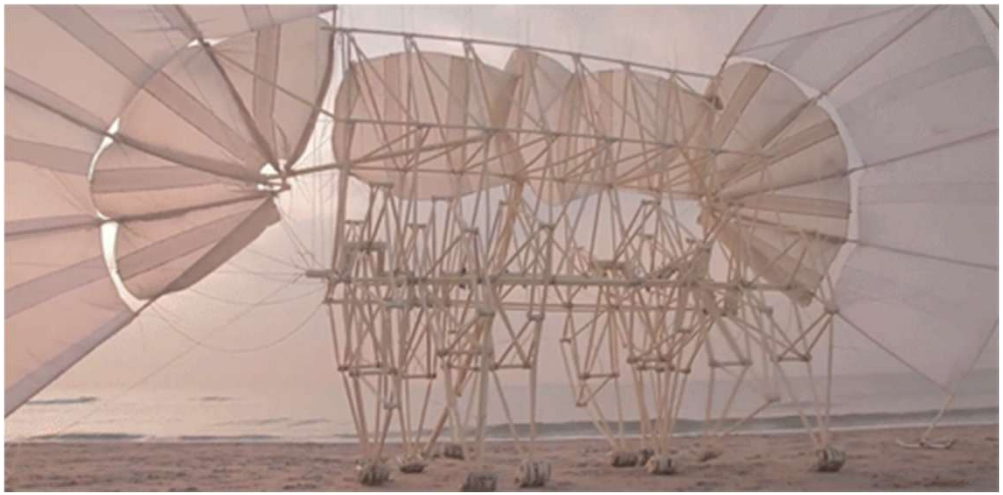
Generation types

- **Function generation**
  - Correlates input to output
  - $f(\theta_{crank})$
- **Path generation**
  - Control of a point to follow prescribed path
  - Not concerned with link orientation
  - e.g., coupler curves, straight-line mechanisms
  - Only prescribes the position of a single point on a link
- **Motion generation**
  - Control of a line (or link) to follow prescribed set of positions
  - Prescribes position **and** orientation of the link



Theo Jansen's Strandbeests

Animaris Vulgaris



Beautiful example of Path Synthesis
https://www.youtube.com/watch?v=zYGVYLzN06g
https://www.facebook.com/CenterforBioDiv/videos/10155746398505460/

Photo and gif credits: https://www.wired.com/2015/09/heres-chance-play-wind-powered-strandbeest/

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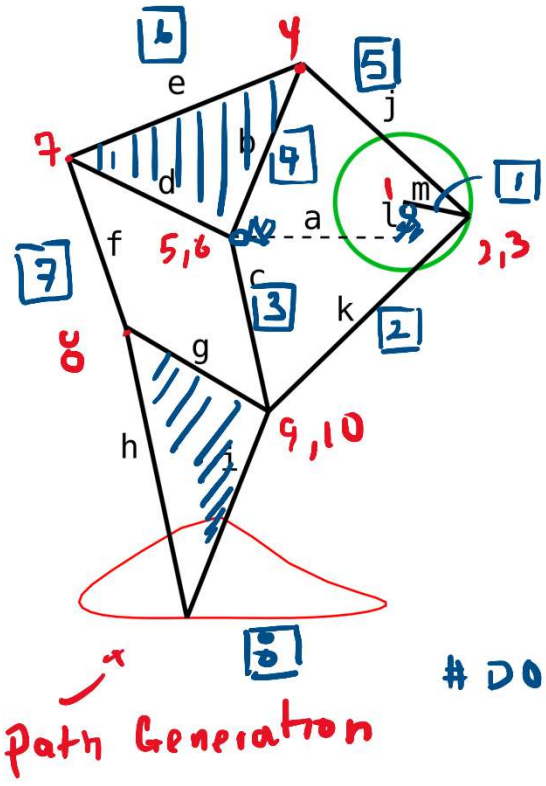
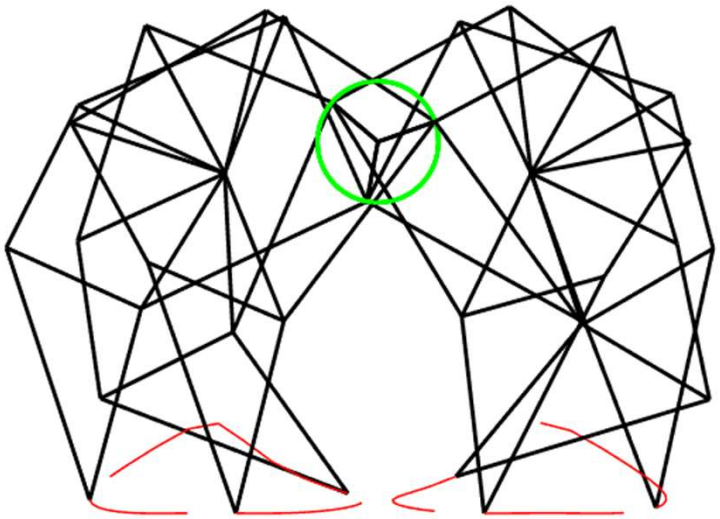
Example: Path Generation

- Jansen Leg mechanism



a=38.0
b=41.5
c=39.3
d=40.1
e=55.8
f=39.4
g=36.7
h=65.7
i=49.0
j=50.0
k=61.9
l= 7.8
m=15.0



DOF = 1 = 3(8-1) - 2 J1

J1 = 10

Example: the recliner

Is the movement of the foot rest on the recliner an example of path generation or motion generation?

motion Generation

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Linkage Synthesis – *creating* a mechanisms for an *output*

1. ***Graphical Motion Generation*** – have a *link* follow prescribed *positions.*
   - Create 2-position and 3-position
   - Add dyad drivers and utilizing quick return mechanisms
   - How to fix designs with toggle point problems
2. ***Path Generation*** – have a *point* follow a prescribed *path.*
   - Existing solutions, books, and look up tables
   - Using computer software to fine-tune or optimize a 4-bar output path

Graphical Linkage Synthesis Tools

- We will design mechanisms to achieve desired motion using graphical tools and the principles of geometry
- We need the following tools. Pull them out and have them ready

Ruler

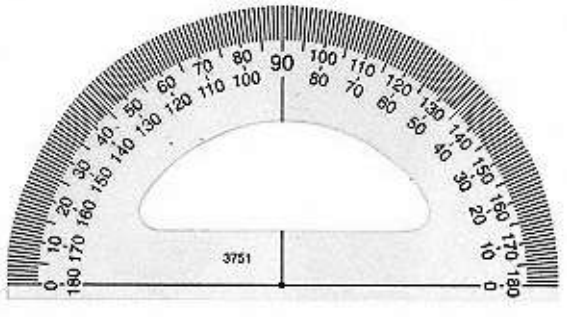
- Draw straight lines
- Measure size

Compass

- Draw constant R curves
- Bisect lines between points

Protractor

- Measure angles



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Graphical Linkage Synthesis

Goals:

Design a mechanism to achieve desired motion

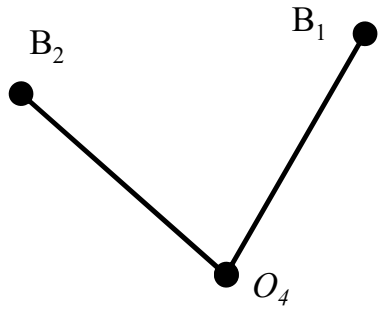
- Two position synthesis
  - Rocker output
  - Coupler output
  - Rotopole
- Three position synthesis

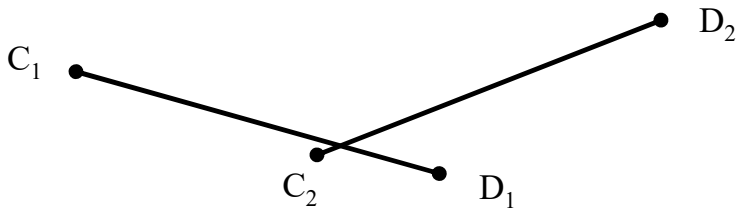
Be able to control the limits and positions of motion

- Dyad driver
- Alternative moving points

Be able to vary the timing of motion

- Quick return mechanisms





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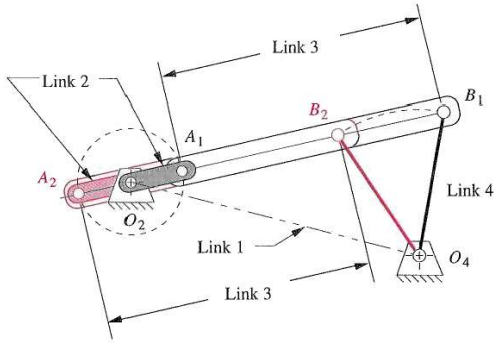
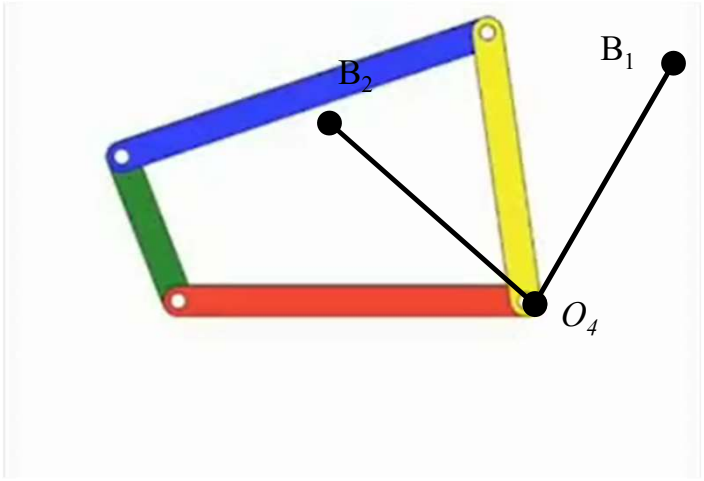
Two-position synthesis

Rocker output

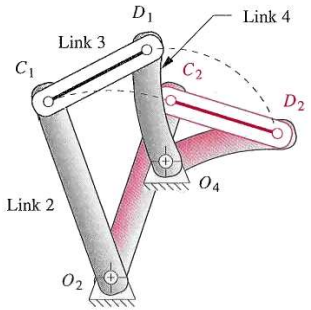
- Most suitable for when you want a Grashof crank-rocker
- Function generator
  - Output is the two angular positions of the rocker

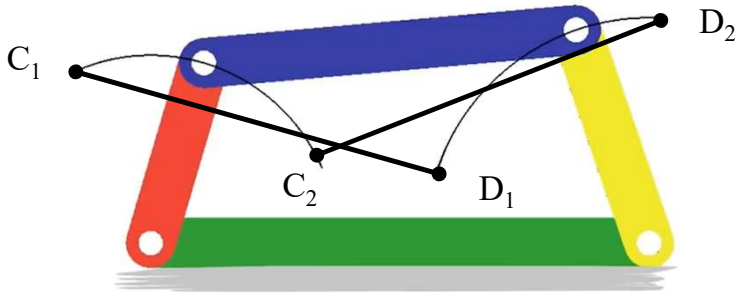




Coupler output

- Motion generator
  - Two positions of a line in the plane are the output
  - Often triple rocker





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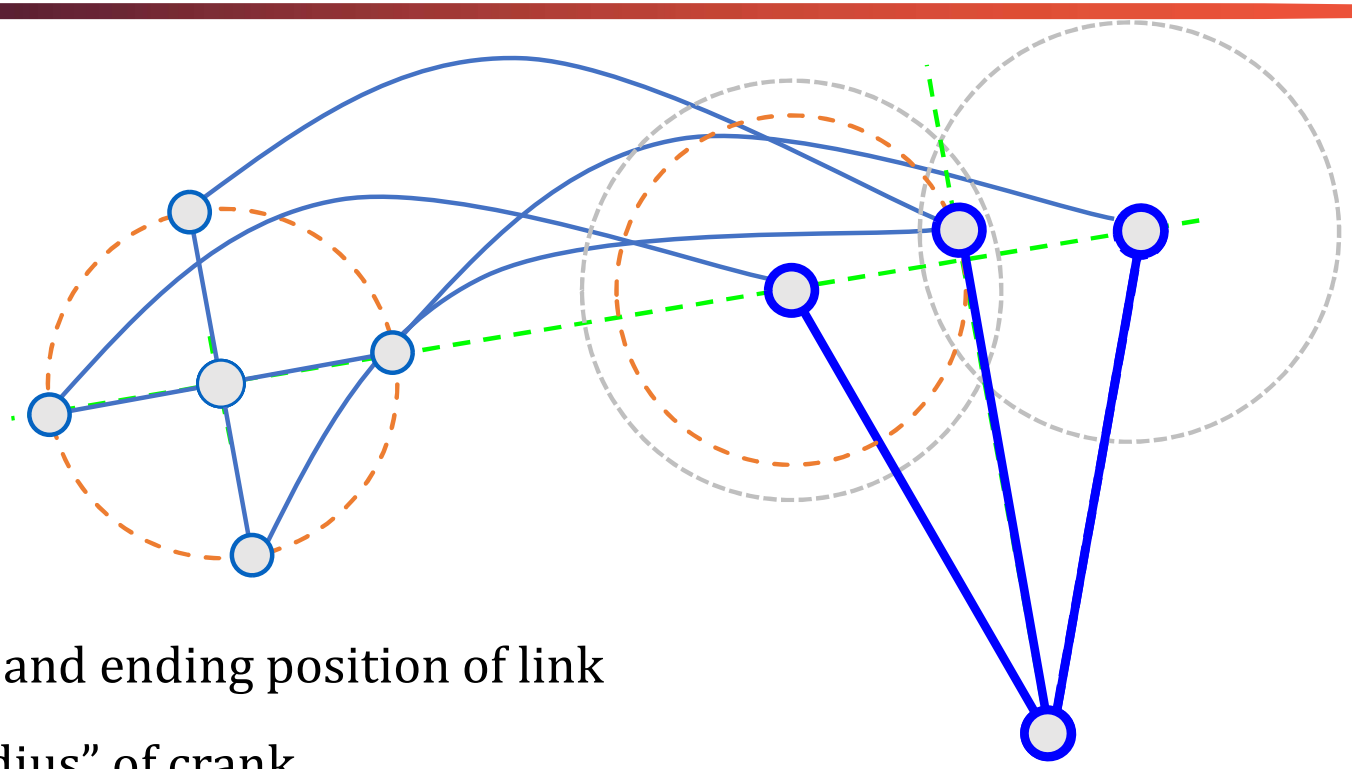
Graphically designing a Crank rocker



1. Bisect starting and ending position of link
2. Determine “radius” of crank
3. Select location of crank

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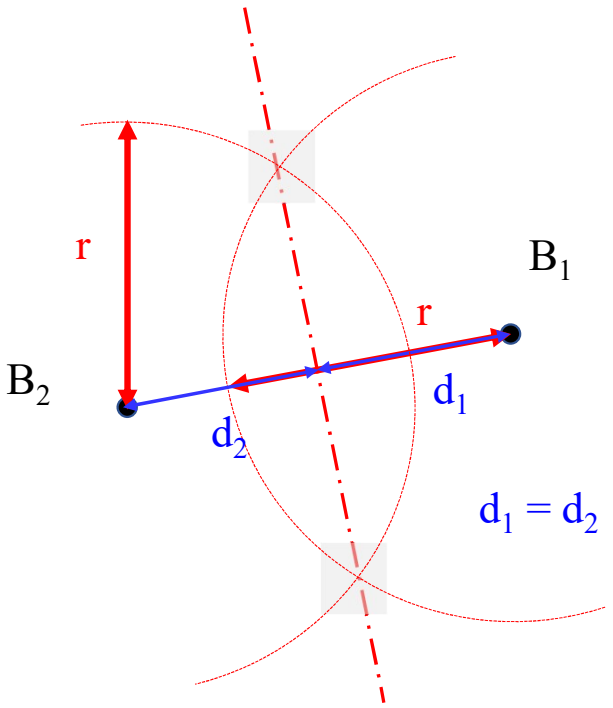
How to bisect a line with a compass

To evenly divide (bisect) the line

- Choose distance between compass points to be > ½ of line length
- Put point end of compass at one end of the line to be divided (pt. B_1)
- Lightly draw a semi-circle that intersects the line
- Put point end of compass at the other end of the line to be divided (pt. B_2)
- Lightly draw another semi-circle that intersects the line
- Lightly draw a construction line that connects the intersection of the two semi-circles. The intersection of this construction line with the given line is the bisecting point.



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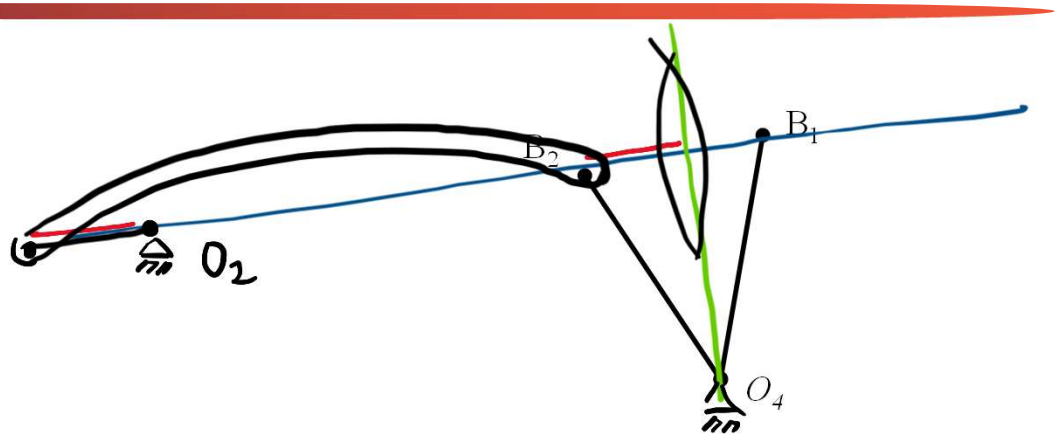
Rocker output

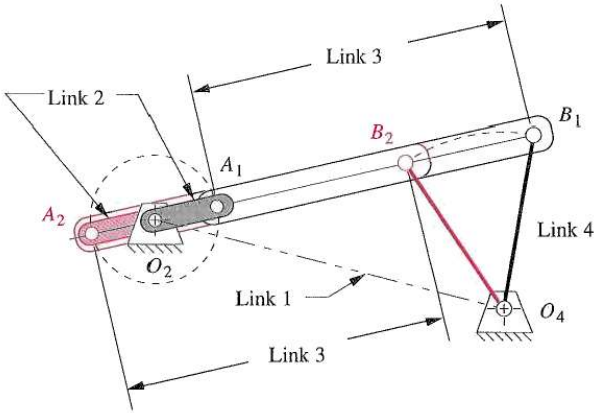
Given: Two rocker positions B_1O_4 and B_2O_4 (link 4), design a 4-bar linkage that will obtain both positions.

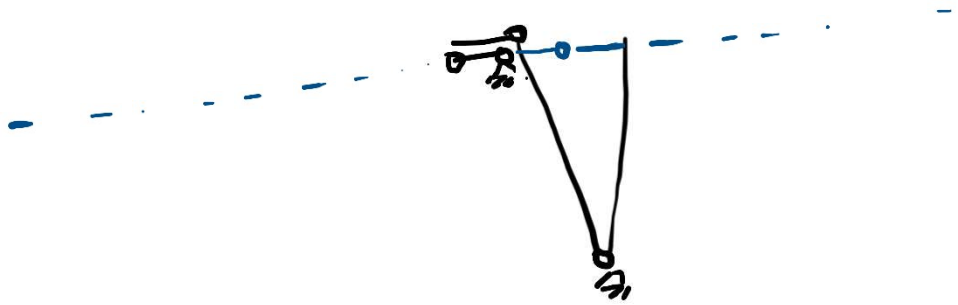
Synthesis Steps:

1. Extend B_1B_2.
2. Pick O_2 along line
3. Bisect B_1B_2.
4. Distance is radius around O_2
5. Label A_1 & A_2
6. Check for Grashof condition (**S + L < P + Q**)
7. If non-Grashof, redo steps 2-5.

Note: O2O4 forms link 1 (ground)







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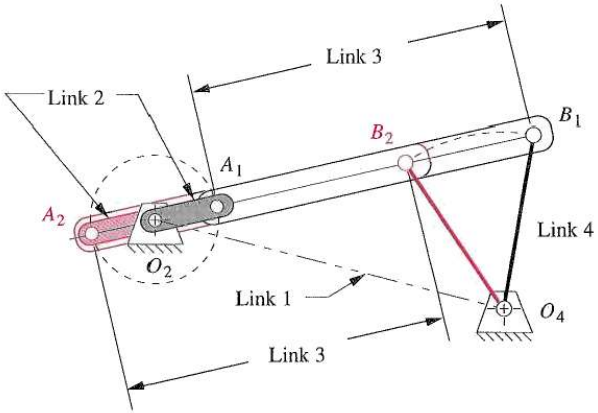

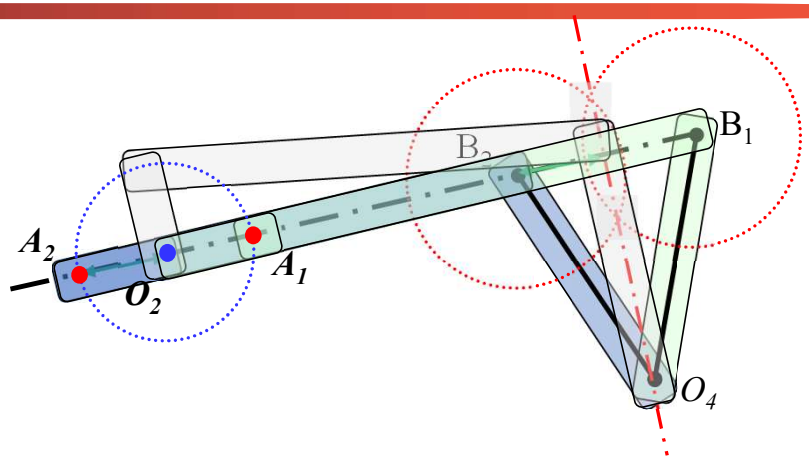

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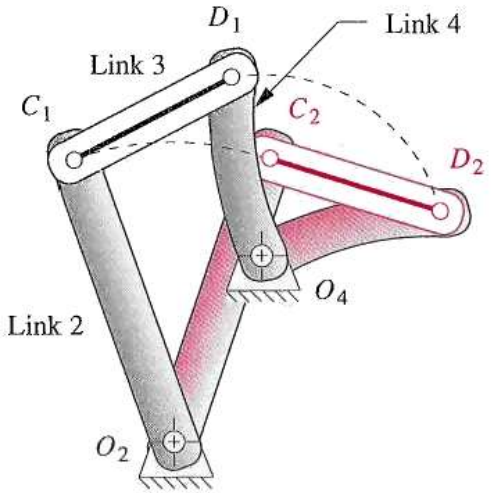
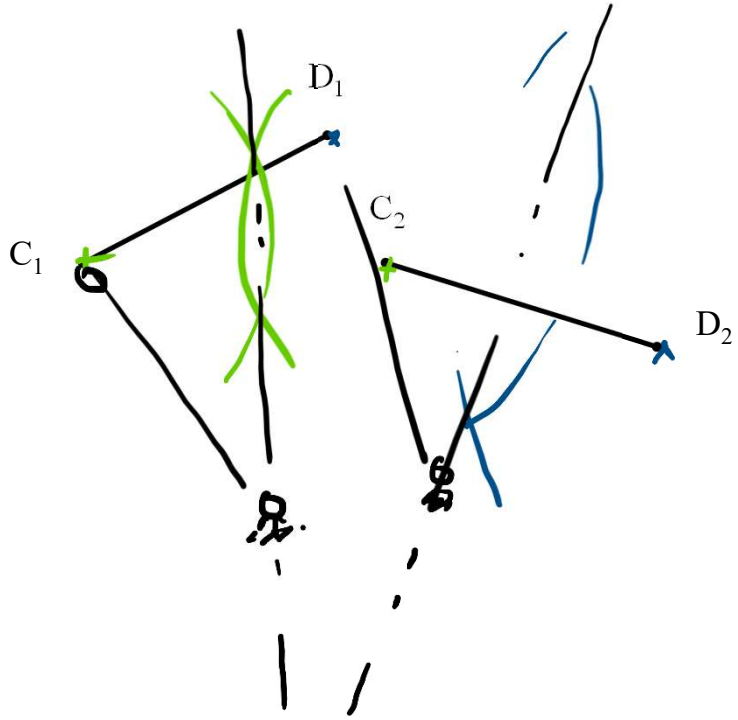
Coupler output

Given: Two coupler positions C_1D_1 and C_2D_2 (link 3), design a 4-bar linkage that will obtain both positions.

Synthesis Steps:

1. Bisect C_1C_2. Pick O_2 along line → forms link 2 (O_2C)
2. Bisect D_1D_2. Pick O_4 along line → forms link 4 (O_4D)
3. Check for Grashof condition





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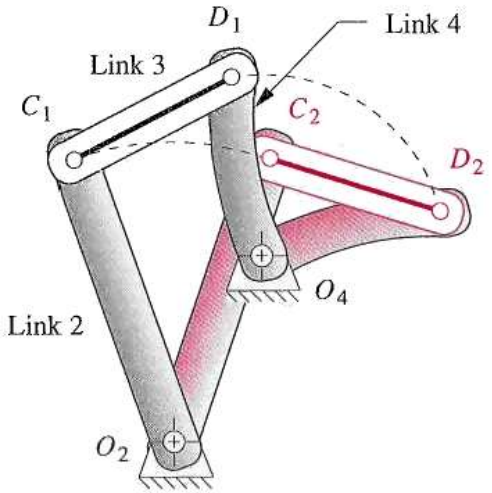

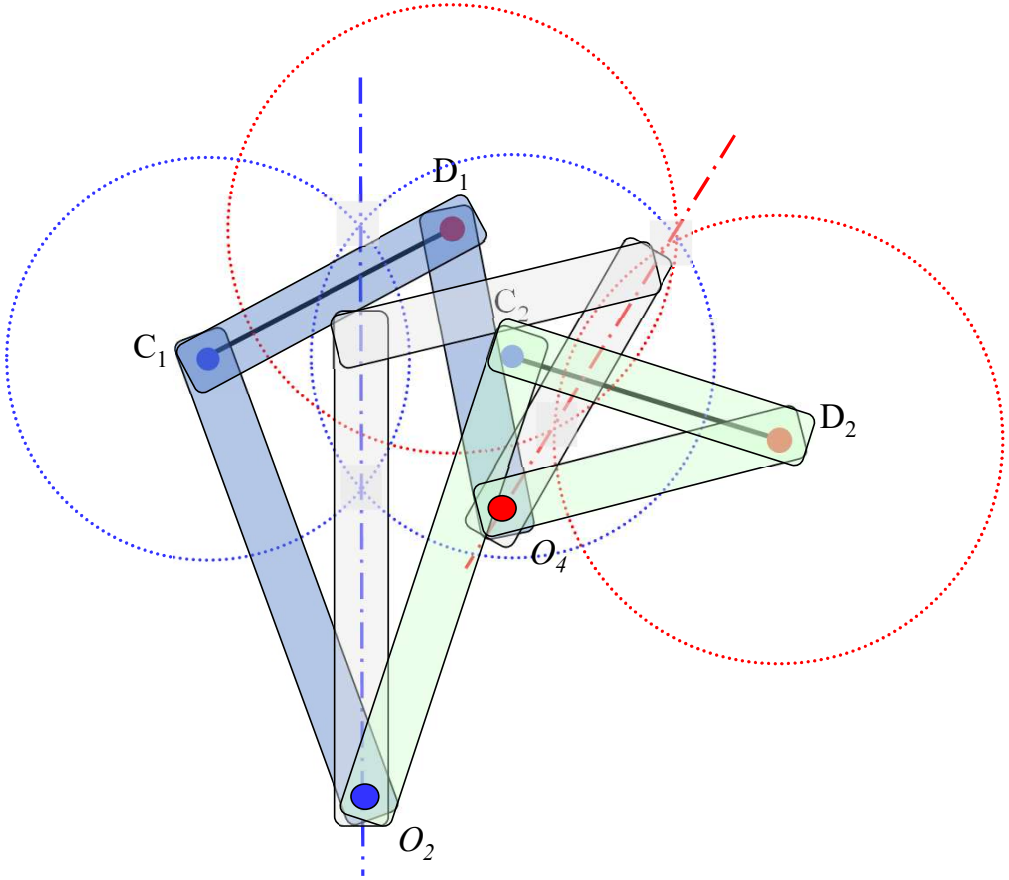

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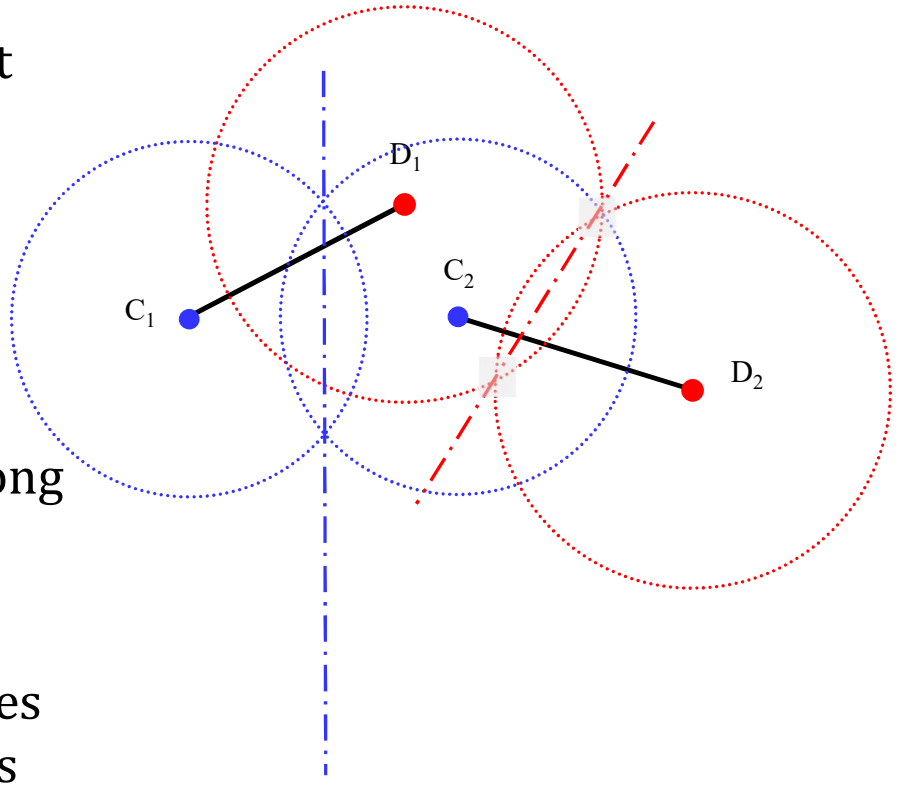
Lots of design freedom with 2-position synthesis

- The pin-joint of the first link can be located ANYWHERE along the bisecting line.
- The pin-joint of the second link can be located ANYWHERE along the bisecting line.
- There are an unlimited number of 4-bar linkages that can accomplish this movement



→ check Grashof for change points, toogle points
→ check transm. angle.