ME2220: INDIVIDUAL PROJECT

PHASE-I

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PULL ALONG DOG

1. Description of the toy:

The pull-along dog toy is a captivating blend of engineering ingenuity and playful charm. It features four legs driven by crank-rocker mechanisms, synchronized through rotating wheels, which allows the dog to simulate walking motion as it is pulled. The toy's tail wags rhythmically, driven by a clever slotted-link mechanism coupled with the rear leg's motion. Additionally, the ears flap independently, activated by a string-pulling mechanism, adding an extra layer of dynamic interaction. What stands out about this toy is the elegant integration of multiple mechanisms along with the precision with which the linkages are synchronized, demonstrating the beauty of mechanical motion and the delightful representation of engineering principles in an engaging way.

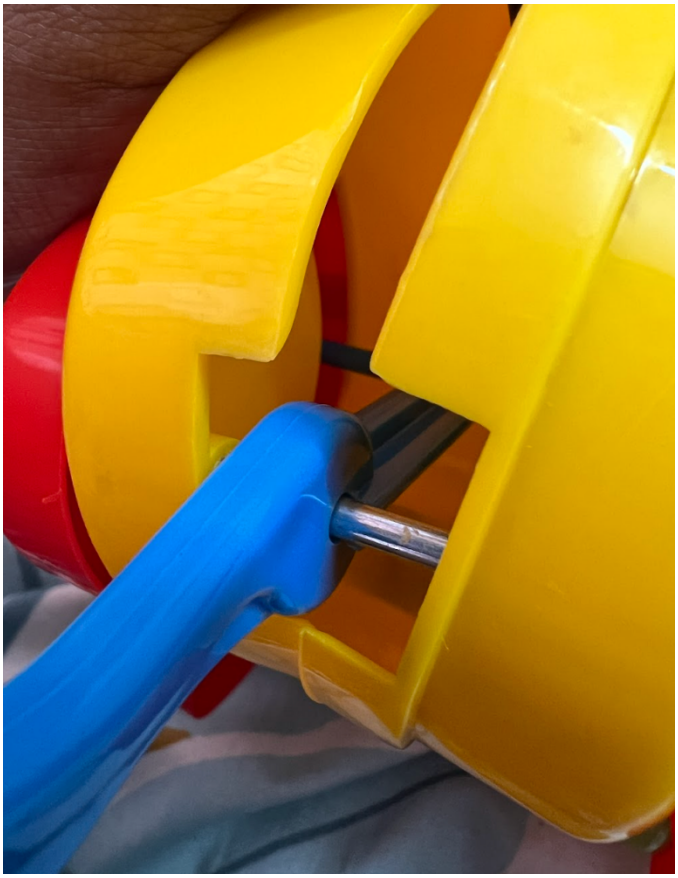
2. Photo of the toy procured:

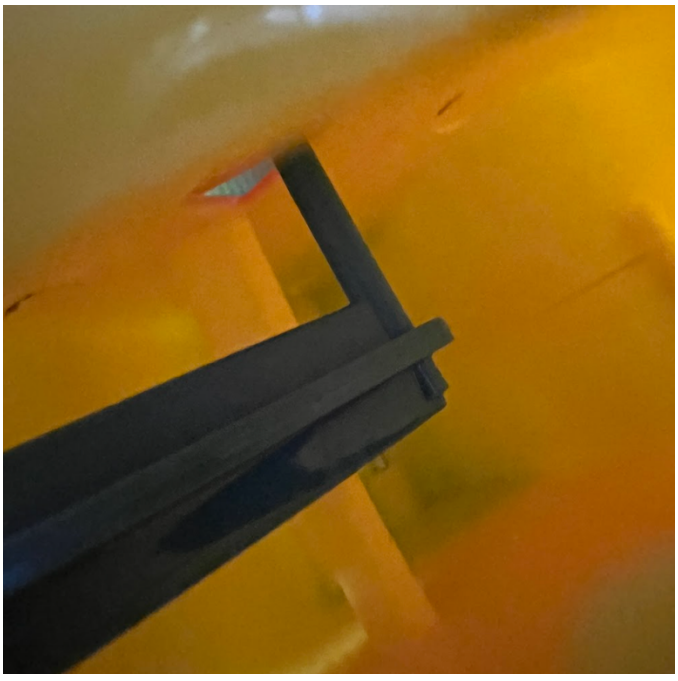
3. Photo of the disassembled toy:

(unfortunately, I wasn't able to completely disassemble the toy as there were metal rods passing through the axles, which were strongly attached.)

Internal view of the toy:
(Metal rods are the axles of the wheels; plastic rods act as compound revolute pairs for the legs)

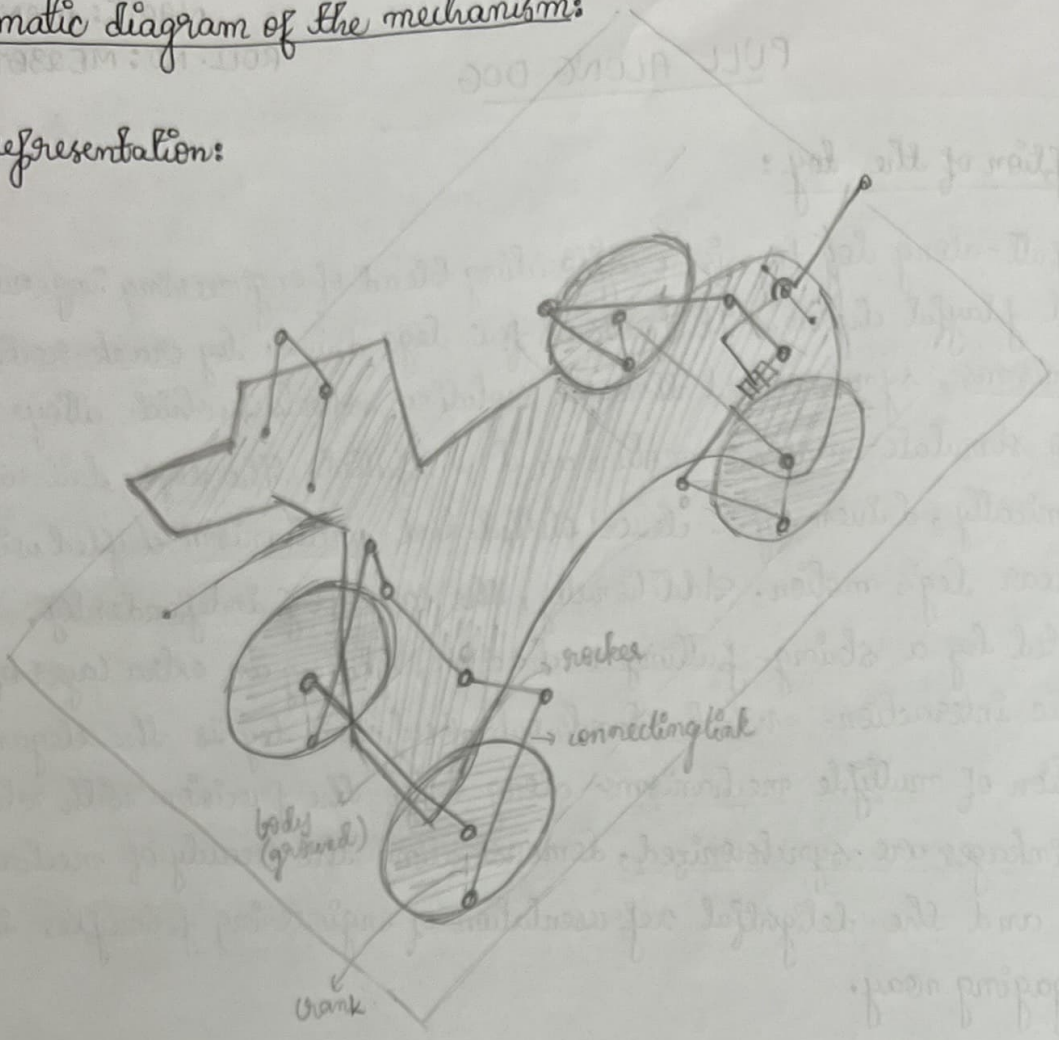
Slotted link mechanism in the tail:
(The slot is present in one of the rear legs; there is also a slot in the yellow body to ensure that the tail link can move in the slot of the leg)



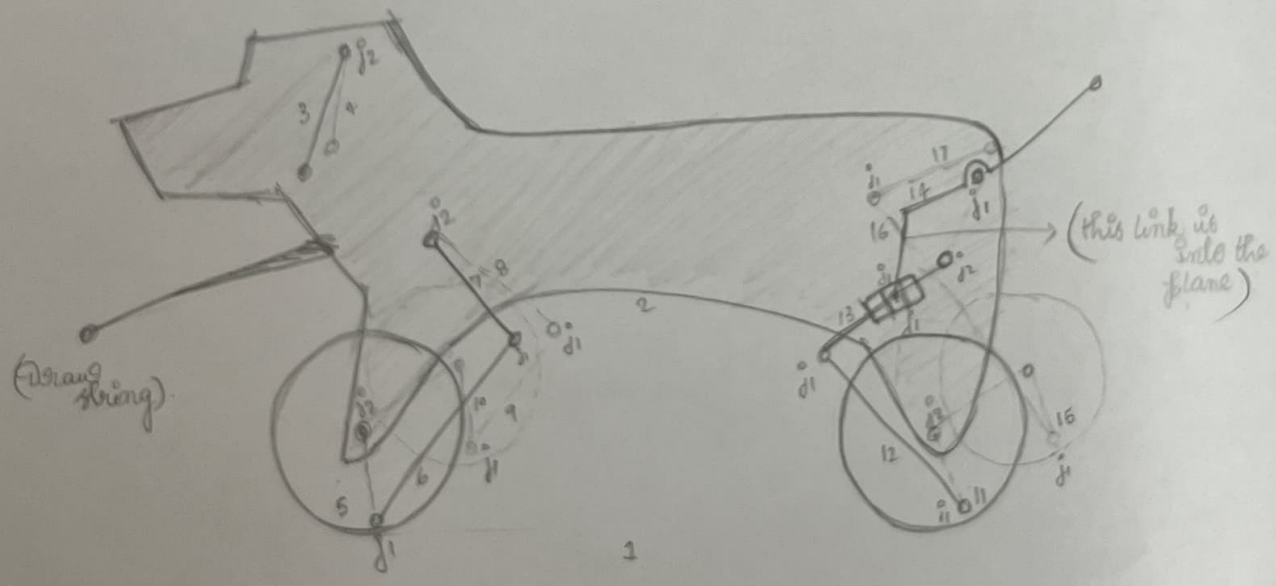


4. Kinematic diagram of the mechanism:

3D representation:



2D representation:



$n = 17, \; j_1 = 11, \; j_2 = 5$

Mobility Analysis:

Grübler's equation (for planar mechanisms):

$$F = 3(n - n_R - 1) - 2(j - j_R) - h - F_K$$

For n (no. of links): 17 links

1. Ground: 1 link
2. Body of the dog: 1 link
3. Leg mechanisms (4 crank-rocker mechanisms) — 12 links

   In each leg, input(crank) is the wheel - 1
   connector is the leg - 1
   output is the rocker (upper leg) - 1 } 3
   ground is body - included
4. Tail mechanism (slotted-link): 1 link
5. Ear mechanism — 2 links

For n_R (redundant links): zero

For j (no. of kinematic pairs): 21.

$$j = j_1 + 2j_2 + 3j_3 + \cdots + nj_n$$

Here,

j_1 (simple kinematic pairs) = 11

- In legs, 2 in each crank-rocker mechanism ⇒ 8 revolute pairs
- 1 slider ⇒ 1 prismatic pair
- Link connected to slider ⇒ 1 revolute pair
- Link aiding in tail oscillation ⇒ 1 revolute pair

j_2 (compound kinematic pairs) = 5

- In front & rear legs, a pinned connection connected the axles and upper legs (2+2) = 4
- In ears, (1 ear + 1 body + 1 ear) = 1

$\therefore j = 11 + 2(5) = 21$

For j_R (redundant kinematic pairs): zero.

For h (higher pairs): zero.

For F_R (redundant degrees of freedom): $F_R = 4$

1. Coupled front & rear wheels (2 DOFs removed):
   - The front wheels are connected via a rod (considered as a compound revolute pair), reducing 1 DOF
   - Similarly, for the rear wheels.
2. Coupled motion of legs & tail (1 DOF removed):
   - The tail's motion is coupled to rear legs, reducing 1 DOF
3. Toys' forward motion coupled to wheels (1 DOF removed):
   - The toys' forward motion depends on the rotation of the wheels, reducing 1 DOF.

Substituting into the Grubler's equation,

$$\begin{aligned} F &= 3(17-0-1) - 2(21-0) - 0 - 4 \\ &= 3(16) - 2(21) - 4 \\ &= 48 - 42 - 4 \\ &= 2 \end{aligned}$$

$\therefore$ Degrees of freedom of the mechanism = 2.

Physical interpretation:

1 DOF: movement of legs & wagging of tail when pulled by a string.
1 DOF: independent movement of ears (i.e. not dependent on pulling the toy).

5. Additional mechanism that I would like to add:

✓ Side-to-side head tilting mechanism:

I would like to convert the rotatory motion of the front wheel into the side-to-side motion of the head using a cam-follower system (or) gear system.

Idea, using a cam-follower system:

- Add a pivot joint (revolute pair) at the neck of the toy; attached to the body on the other end
- The head is mounted on the pivot, so any torque applied to the pivot causes the head to tilt.
- Attach an eccentric cam to the axle of the front wheel
- Its follower is connected to a connecting link (rod) which is further connected to a lever arm, connected to the pivot
- The follower's vertical movement is converted into side-to-side tilting by the connecting link and lever arm.

(Rough kinematic diagram).