Design of the jumping robot “Grillo”

Umberto Scarfogliero
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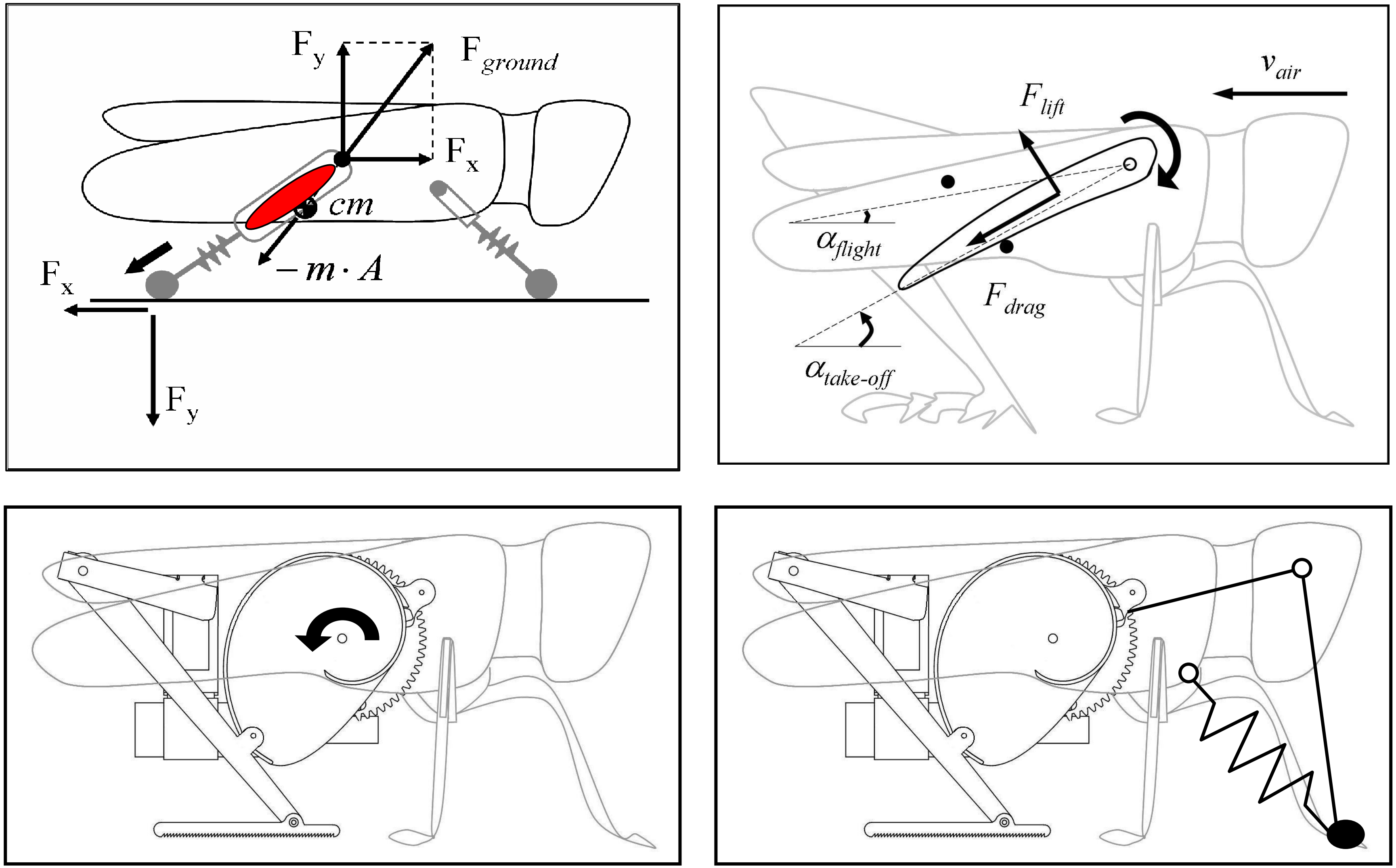
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F ground
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F lift
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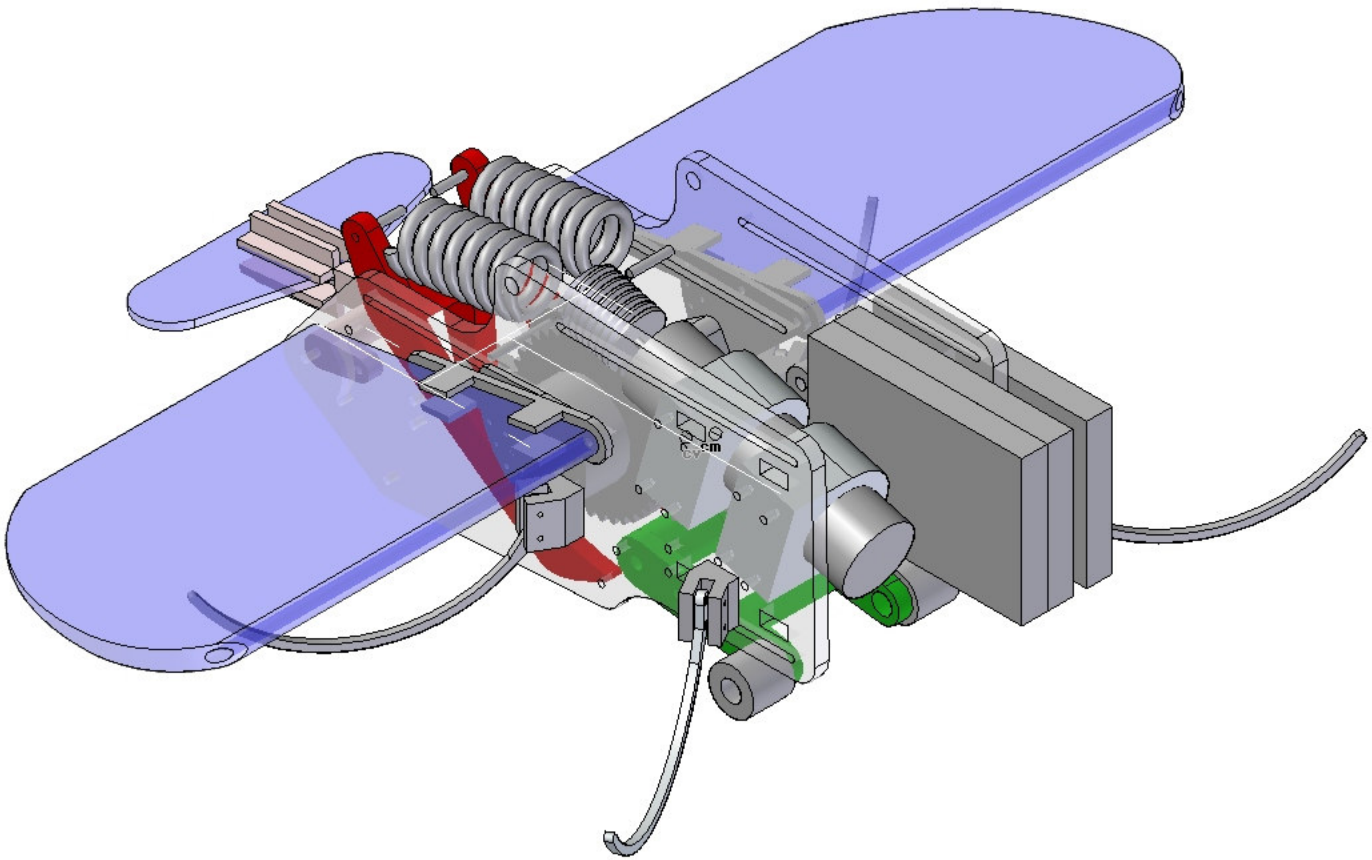
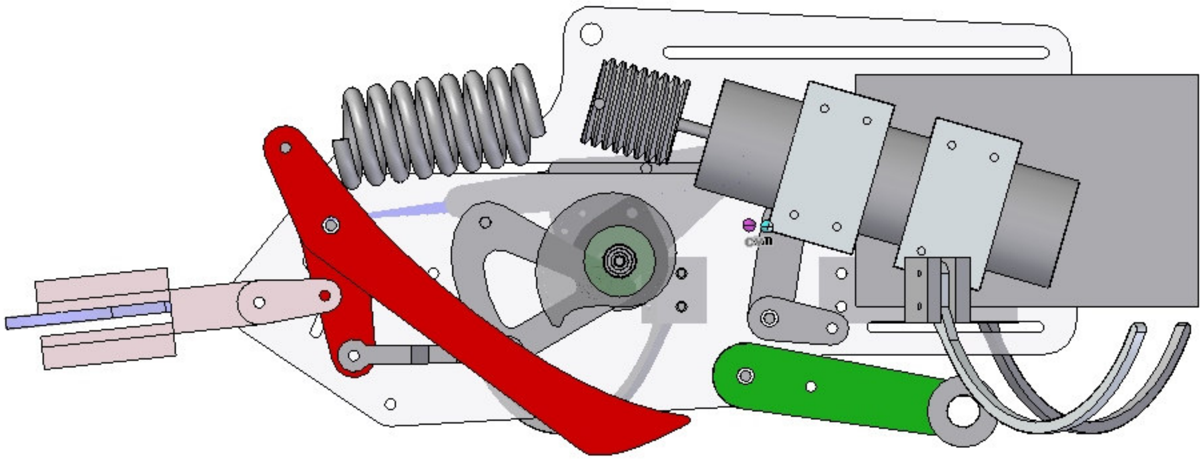
F drag
α take-off





Design considerations: robot parameters

Robot parameter	Value
Mass	70 [g]
Speed*	2 [m/s]
Rear leg length	34 [mm]
Forelegs length	29 [mm]
Power density	16 [W/kg]
Energy density	28 [Wh/kg]
Continuous run*	1 hour
Distance traveled*	7 [km]
Body length	90 [mm]
Relative Speed*	22 [body length/s]
Relative jump length*	18 [body length]
Motor max. power	1,1 [W]
Jump peak power*	16 [W]

Value
60-80 [g]
1,5 [m/s]
32 [mm]
28 [mm]
20-15 [W/kg]
75-55 [Wh/kg]
4 hours
20 [km]
50 [mm]
30 [body length/s]
12 [body length]
1,5 [W]
15 [W]

* Expected performances

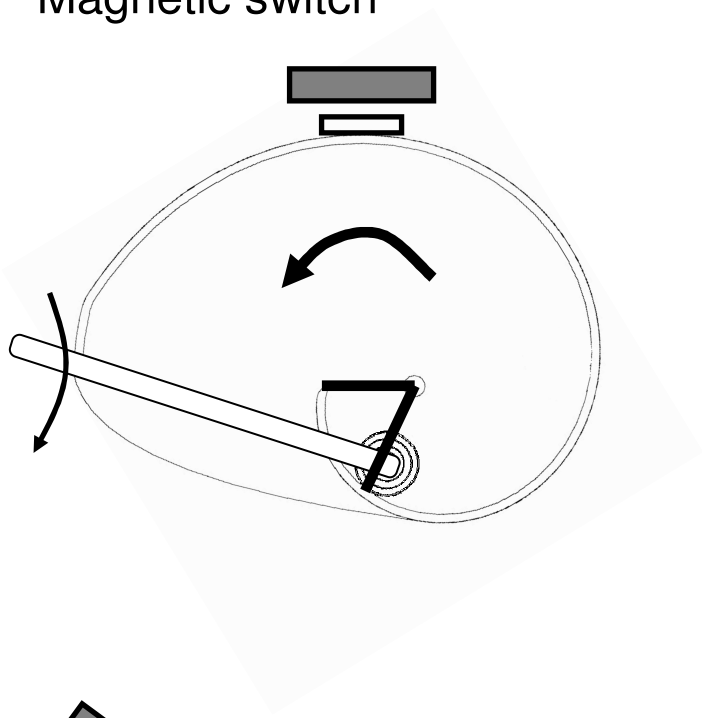
Forelegs:
We limit the impact energy that can be stored to the vertical impact energy, choosing the fore-legs stiffness in order to distribute the stored energy among the cam and the forelegs.

Es: Considering 30% vertical energy lost during flight phase, 0.6 vertical impact energy to in the cam and 0.4 in forelegs passive elongation: cam is rotated at landing by about 60 deg (18% of jumping energy)

How to trigger the jump, and thus, the actuation?

1. The motor complete the spring extension before landing: a switch that make the motor stop before the complete cam turn, so to make the impact trigger the jump: what at the first jump?
2. The motor gear ratio is chosen so that the complete cam rotation is finished at landing, or soon after, considering the longest possible jump: fine system tuning and high dependence on initial condition
3. …

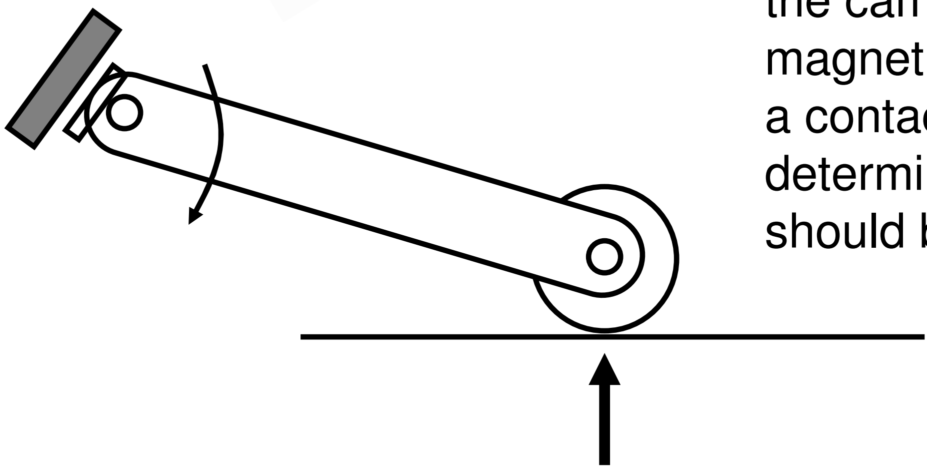
Magnetic switch



Possible solution:

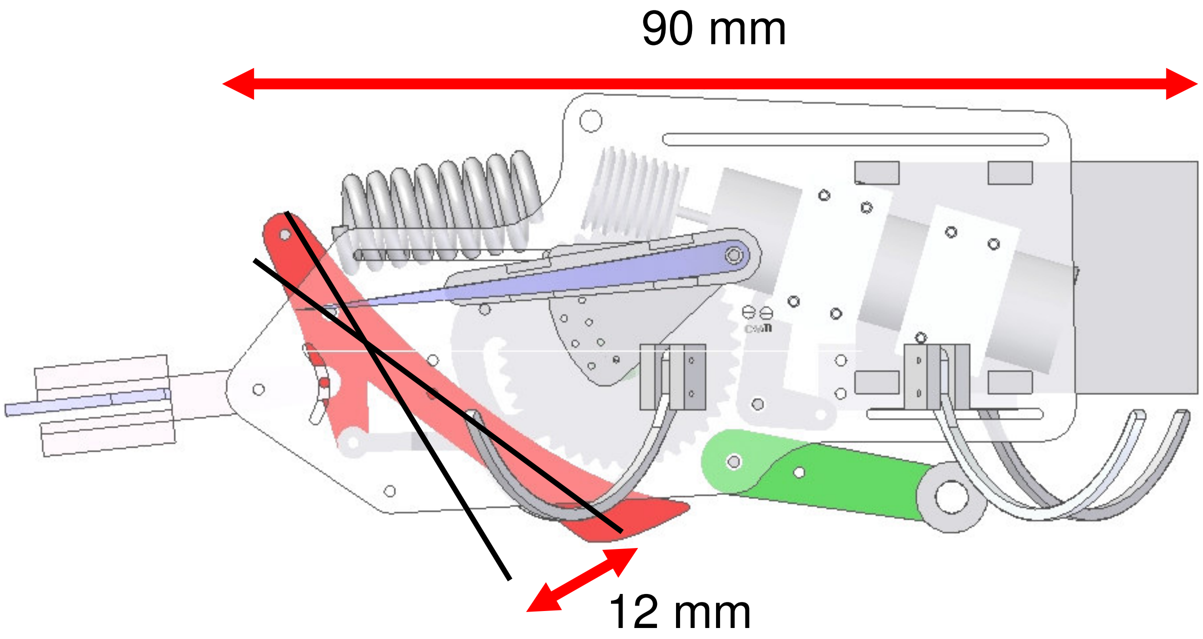
Forelegs not in contact: stop the motor rotation leaving the rotation angle that should be covered by the forelegs contribution

Forelegs in contact: the motor keep turning, at least, the forelegs contribution decrease the current drained by the motor

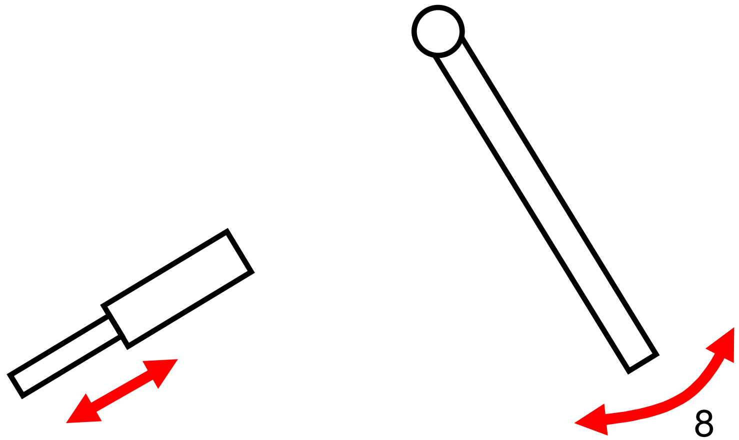


the cam position can be determined by a magnetic switch, while the ground contact with a contact switch or a magnetic switch, determining the leg rotation (the robot weight should be enough to activate it!)

Long *vs.* short rear leg elongation

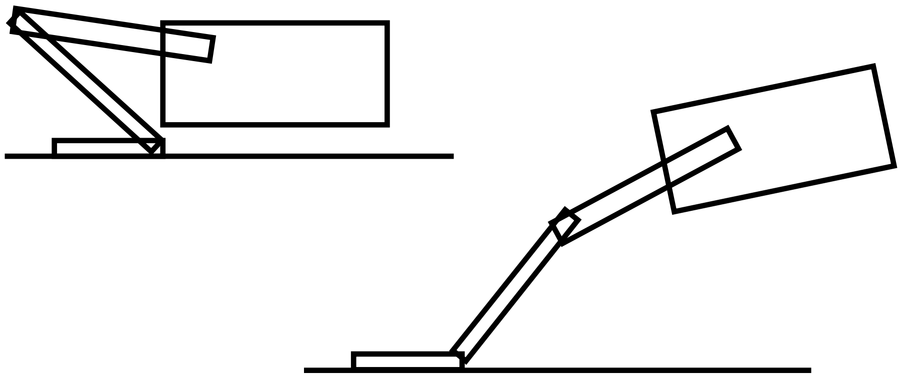


Leg rotation was reduced to 20° in order to keep foot motion close to an elongation rather than a rotation, in order to have a simple spring mass model and a simple leg design.



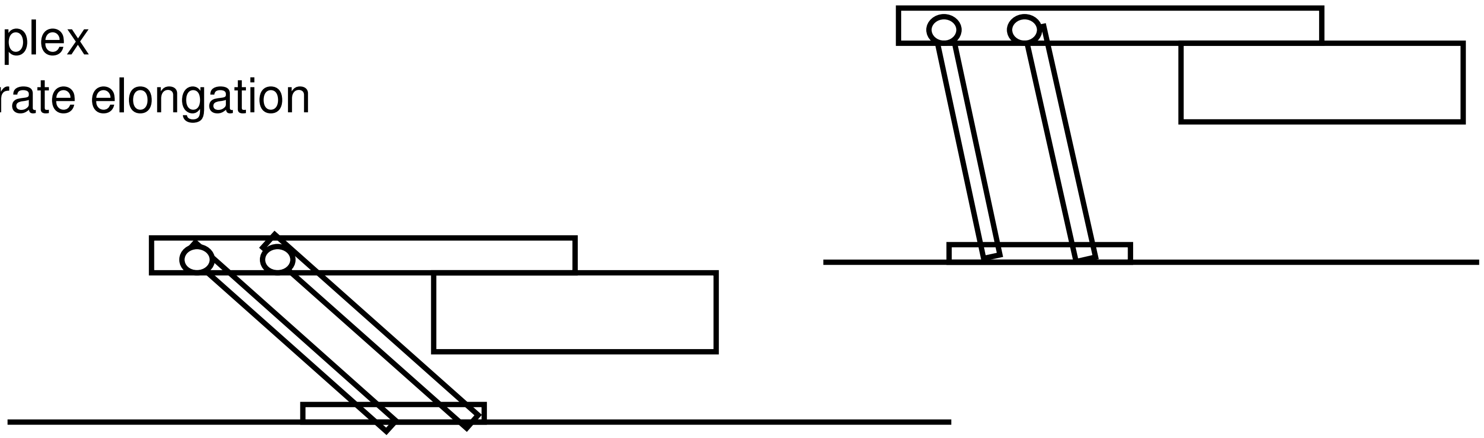
Pros: simple leg structure
Cons: high forces, even with flat force profile! (55 body weight: 36 N)

Other possible solutions:

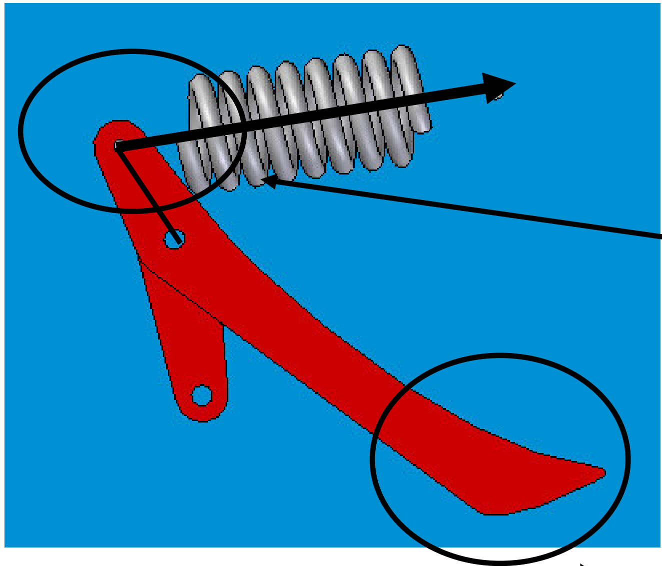


Highly complex
Big elongation

Quite complex
Still moderate elongation



Feet: rear legs

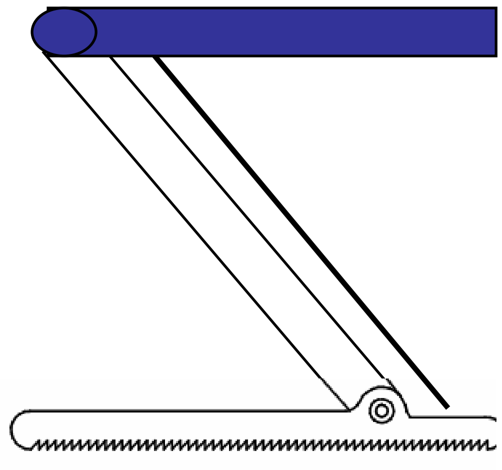


Spring lever arm, as EMA, can be varied according to the spring used.
Change the arm-force angle?

Simplified design: rounded foot

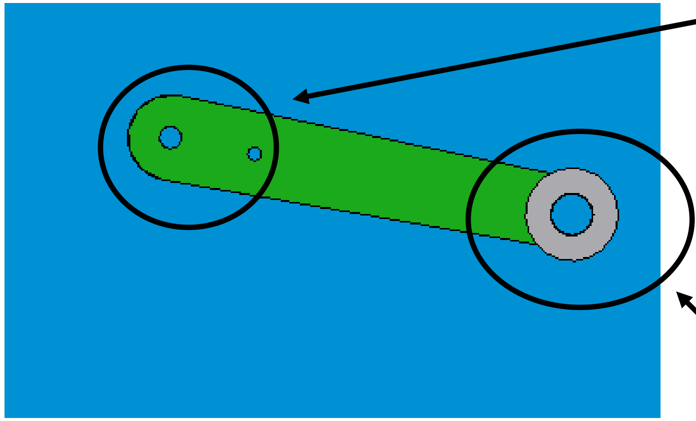
Varying the foot profile we can change the force profile, as the force arm changes accordingly

Previous design:



Friction with the ground: mono-directional?

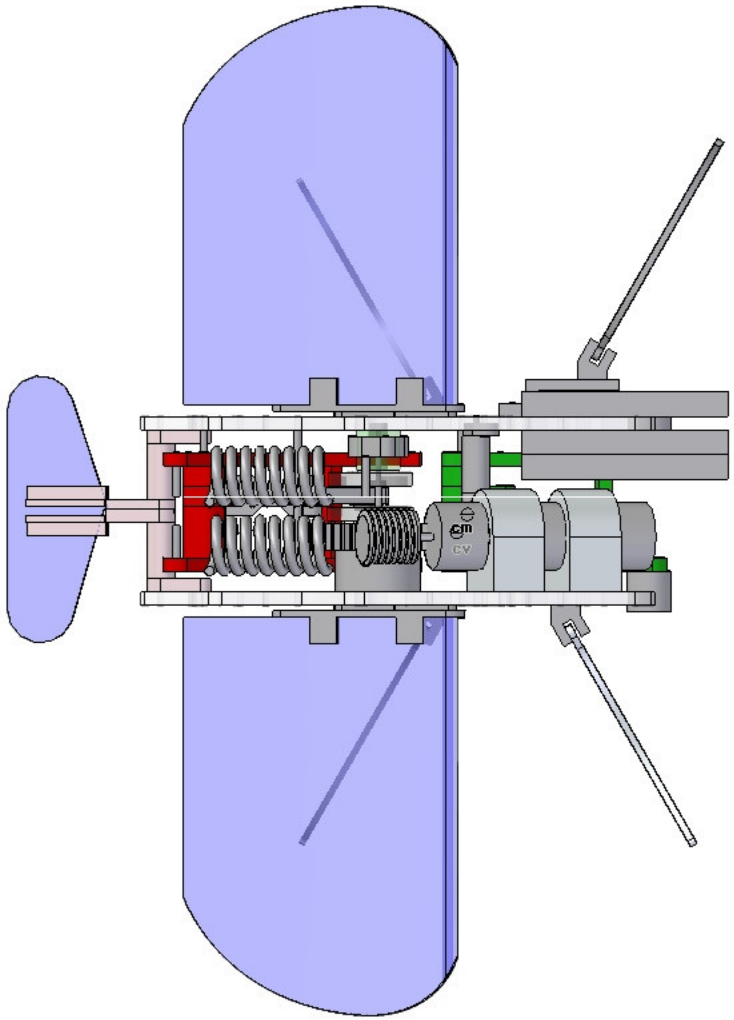
Feet: forelegs

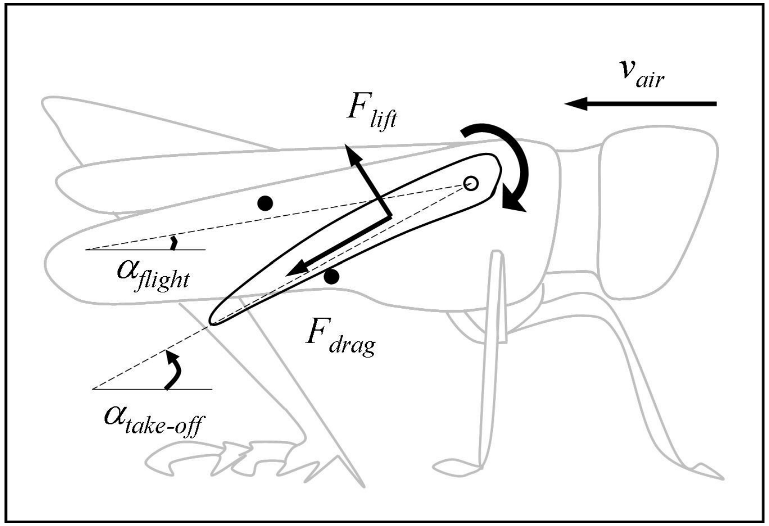


Torsional spring: about the same natural frequency of the rear-legs spring for passive rotation

Roller clutches bearings, mono-directional friction

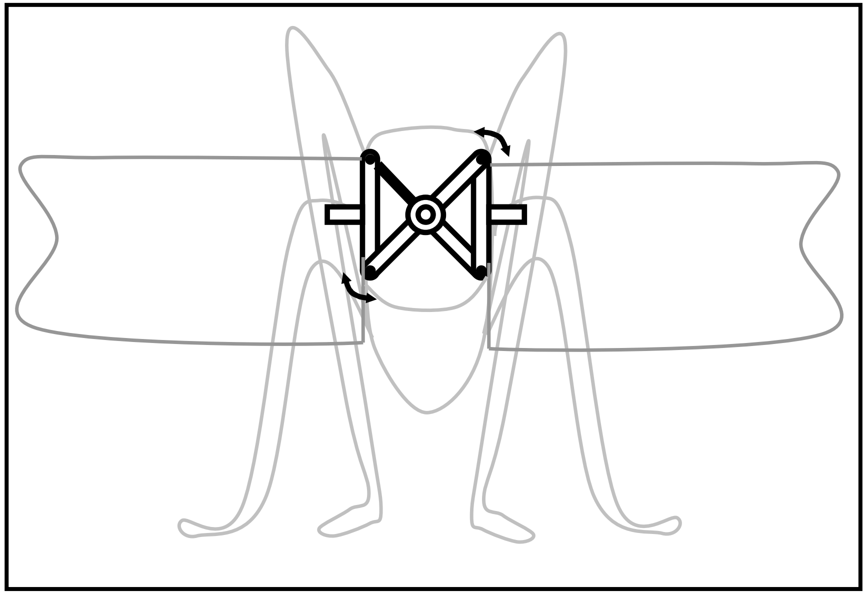
Wings: how big and where?





Passive shape change: different angle and different drag at take-off and during flight

Next step: steering wings using a small servo motor and a 4-bar mechanism



Question?

- How to choose leg elongation?
- Possible different leg design?
- How to dimension the wings?
- Steering wings?
- Non electric actuation? High-pressure pneumatics?
- Feedback control??