A Small, Insect Inspired Robot that Runs and Jumps

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Motivation for Small Robots

- Platform for autonomous or intelligent control research
- Distributed robotics
- Search and rescue
- Exploration
- Surveillance
- Insect inspired research
Wheels + Legs = Whegs

**Wheels:** smooth, firm terrain, continuous ground contact

**Legs:** broken, uneven terrain, discontinuous contact, climbing

**Whegs:**
- multiple spokes
- climbs like leg
- rolls like wheel
- constant motor speed
Whegs I (2001)

- Runs at 3 body lengths per second
- Climbs obstacles >1.5 leg length

Quinn et al., (2001), CLAWAR
Mini-Whegs

- Small
- Mechanically simple
- Fast
- Less expensive
- Scalable
- Large payloads

Mini-Whegs 5 with *Blaberus gigantius*
Obstacle Clearance

Composite of video frames showing Mini-Whegs 5 traversing two 3.5 × 9 cm boards while running at 3 body lengths per second
Froghopper Jumping

- Specialized rear legs
  - Not used during walking
  - Ridge on femur locks onto coxal protrusion

- Jumping
  - Muscle contracts slowly with legs locked in position
  - Femur and coxa disengage
  - Insect leaps over 100 body lengths high
Jumping Mini-Whegs

Four-bar jumping mechanism concept

Mini-Whegs 4J
Proof-of-concept
Mini-Whegs 4J Layout

- Drive motor
- Jump mechanism
- Slip-gear mechanism
- Power switch
- Jump spring
- Front axle
- Drive chains
- Drive-to-jumping mechanism connection chain
- Rear axle
- Parallel four-bar jumping mechanism (retracted)
Slip-Gear Jumping Activation

A-B: Slip-gear pinion retracts jumping mechanism
C-D: Teeth disengage, and the jumping mechanism springs out
A softer, preloaded spring stores more energy for the same displacement
Mini-Whegs 4J Results

Composite of video frames showing Jumping Mini-Whegs surmounting a 15 cm step
Improving Existing Components

- **Steering mechanisms**
  - Mini-Whegs 1, 2, and 3 use various flexible couplings for transmitting torque to the whegs
  - Springs unwind or collapse
  - Delrin® fatigues and snaps

- **Wheg appendage design**
  - Thin spokes provide little traction…or they get stuck and make the robot flip over.
Appendage Development

A: Mini-Whegs 1
B: Mini-Whegs 2,3
C: Mini-Whegs 5
D: Mini-Whegs 7

Short feet improve traction and smooth walking
- Rounded heel smoothes transition between steps
- Scalable design works for other size Whegs robots
Too Large, Too Heavy

- Mini-Whegs 6J is 32% longer and 50% heavier than Mini-Whegs 4J
Goals for a New Mini-Whegs

- Lighter
  - Less than 100 grams
- Cheaper
  - Half the cost of Mini-Whegs 5
- Easier to Build
  - More off-the-shelf components
  - Fewer fasteners
Weight Savings

- Modified servo drive vs. Maxon Motor
- Hollow aluminum axles
- Plastic sprockets and gears
- Single plastic chain
- Nylon fasteners
- All Delrin® frame
- Single 6V 2CR-1/3N cell
A single, acetal plastic drive chain saves space and weight in Mini-Whegs 7.
Exploded View of Mini-Whegs 7

- assembly screws
- receiver
- drive servo
- bearing
- upright
- steering cup
- ball stud with pin
- steering servo
- single drive chain
Bottom View

- **switch**
- **antenna**
- **Plasti Dip rubber coating on feet**
Results

- Small: 6 x 9 cm
- Light: < 90 grams
- Cheap: < $180
- Mobile
  - Single 6V 2CR-1/3N cell
    - 2.7 body lengths per second
  - Pair of 3V CR2 cells in series (adds ~18 grams)
    - 3.8 body lengths per second
    - Obstacles > 1.25 leg length
    - Incline up to 25 degrees
Mini-Whegs 8: Enclosed Batteries

- ABS body shell is lighter than Delrin®
- Same weight as Mini-Whegs 7 despite slightly larger size
- Easily carries a 50-100g payload
Goals for New Jumping Mini-Whegs

- Lightweight
  - Maintain weight reduction techniques of Mini-Whegs 7
  - Reduce weight in jumping mechanism components
  - Target weight < 200g
- Small
  - Pack components closely
  - Single drive chain
Components Selection

- Same sprockets, drive servo, and materials as Mini-Whegs 8
- Smaller steering servo, receiver, and speed controller by Cirrus
- Maxon jumping motor from Mini-Whegs 6J
Layout of Mini-Whegs 9J

- radio receiver, speed controller, and antenna
- jumping motor and transmission
- jumping mechanism axle
- steering servo
- batteries
- drive chain
- drive servo
Assembled Mini-Whegs 9J

- removable battery lid
- jumping spring
- aluminum brace for spring
- power switch
Mini-Whegs 9J – Jumping
Results

- Weight
  - 191g
- Walking speed
  - ~3 body len./second
- Jumping:
  - 15-18cm
Future Work

- Alternative motors and transmissions
  - More force for higher jumps
  - Faster walking
- Torsion springs could fit entirely inside chassis
- FDM or injection molded chassis construction
- Improved control system for jumping
- Sensor integration
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Questions?