Climbing Walls with Microspines

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Climbing in Nature

Advantages
- Low profile: Each toe has to engage or disengage
- Robot can hang for extended periods with a single toe on a平面 or hasp, or a system of legs
- Works on a wide range of outdoor building surfaces (comparable to 61+50µm per surface)
- Unaffected by modest amounts of dirt or moisture
- Spines on forepaws and hind legs damage hard surfaces because spines do not penetrate.

Limitations
- Cannot be used on glass or similarly smooth surface.
- Sensitive to surface normal distribution (works less well on surfaces with smooth bumps or pits).
- Payload to lean on weak or soft surfaces (e.g. cacti, leaf edges) because spines do not penetrate.
- Wear occurs on abrasive surfaces (e.g., spines can be damaged on concrete).

Spine scaling for hard surfaces

Concrete, Masonry, Rock, Stucco

Spines catch on asperities (bumps or pits) on surfaces.

For effective engagement, we require that $r_a \times r_f$, where $r_a$ is the spine tip radius and $r_f$ is the average asperity radius.

Spinybot

Long tail prevents pitching back
Sprawled posture, COM close to wall
Legs pull inward slightly
COM well within polygon of wall contacts—very stable

Climbing buildings with Microspines

Surfaces able to climb

Stucco
Brick
Concrete
Wood planks
Treas

Mechanical Design

Alternating tripod motion – fixed servo pattern
3 Controlled DOF
Body-level load sharing via mechanical compliance
Baita frame
PIC microprocessor

RiSE

Common features facilitating climbing

Fabricating compliant spined toes

Spines for heavy robots

Effect of Scaling Parameters on Toe Compliances

Spines for heavy robots

Effect of Scaling Parameters on Toe Compliances

Spinybot

Spinybot toe:
Shoe 60D (low) or 80D Shore D (high) urethanes + embedded stainless steel spines

RiSE toe:
Shoe 80D (low) or 80D Shore D (high) urethanes + embedded stainless steel spines

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RiSE toe:
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Scaling spines from Spinybot to RiSE

Adaptations:
- Foot width increased, length decreased to avoid interference
- Spine count increased
- Toes redesigned with tougher materials, stronger spines
- Compliance in normal, tangential directions adapted for higher load, different stroke length
- Overload-release mechanism reduces spine damage
- Heterogeneous spine/toe population for wide range of surfaces

Design requirements for feet and toes

Masonry surfaces:
- Have many small asperities per unit area,
- Requires small ($r_a \times r_f$) spines,
- With small ($f < 0.30$) loads per spine.
Therefore the foot must:
- Ensure that many spines independently attach to asperities,
- Promote load-sharing among spines. [82]

Each toe in a compliant, multior bar linkage designed to:
- Increase probability that spines will catch asperities,
- Become a share of the load, avoid premature slip-off.

Stability
Mass: 400g
Max. payload: 400g
Speed: 2.3 cm/sec

RiSE
Mass: 3kg
Max. payload: 1.5kg
Speed: 1.5 cm/sec

References

Rise Consortium Members

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Spinybot: Climbing Hard Surfaces with Compliant Microspines,

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