A Novel Passive Adhesion Principle and Application for an Inspired Climbing Caterpillar Robot

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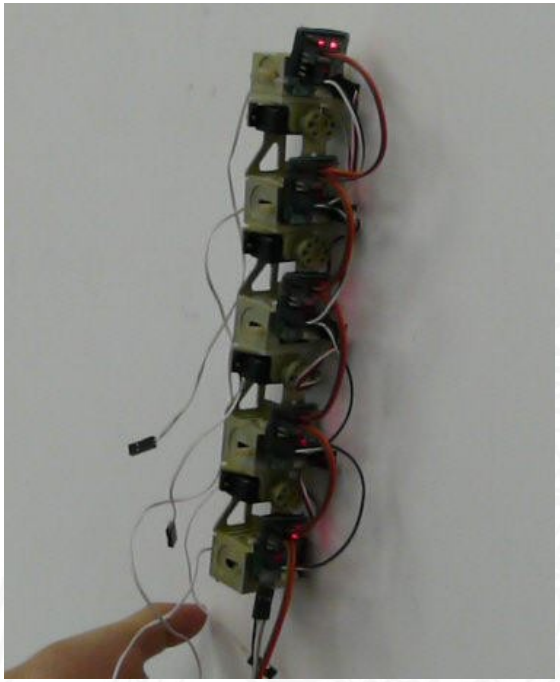

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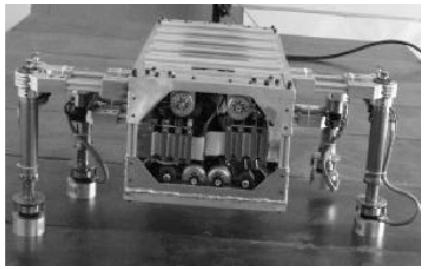
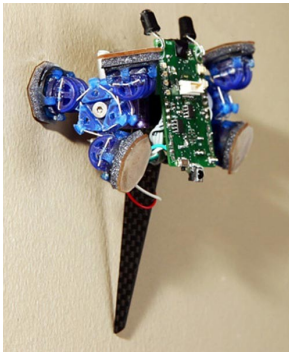
Outline

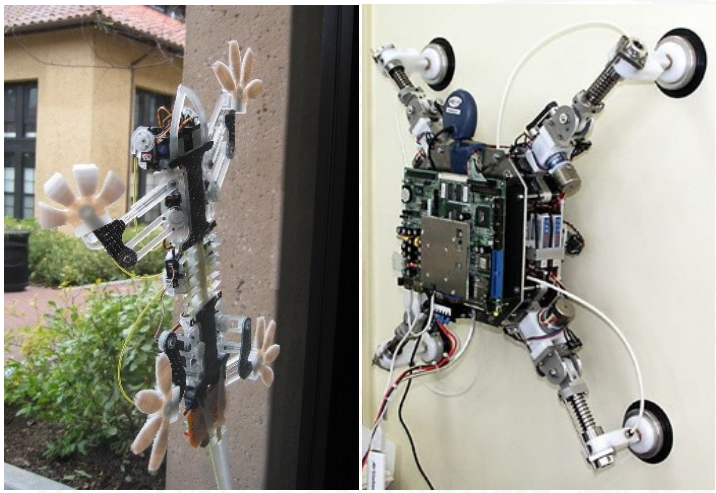
- Review of climbing robots
- Attachment Methods for Climbing Robots
- New Passive Adhesion Principle
- On-site Test on a Climbing Caterpillar Robot
- Conclusions

What is a climbing robot

- A special robot
- A kind of mobile robot
- Works and moves vertically on targets







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Climbing robot technology

- The last decade has seen an increasing interest in developing and employing climbing mobile robots for
  - *Industrial inspection;*
  - *Conducting surveillance;*
  - *Urban search and rescue;*
  - *Building maintenance;*
  - *Inspired research.*

- Two important issues for climbing robots
  - *Attachment principles for climbing robots*
  - *Kinematics of climbing prototypes*

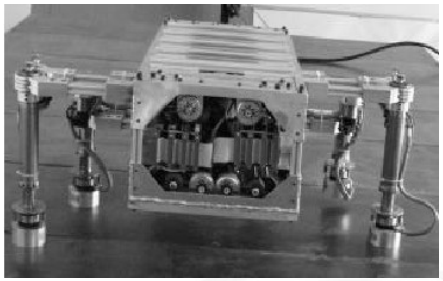
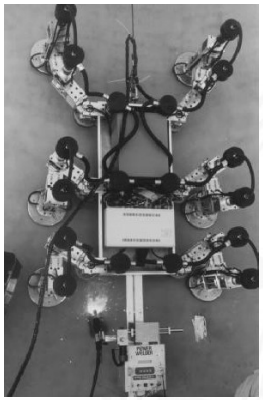
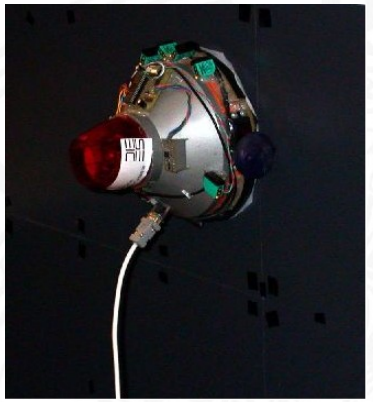
Climbing robots classification

- According to the attachment principles
  - Electromagnetic force
  - Molecular force
  - Mechanical force
  - Vacuum

- *According to kinematics*
  - *Sliding frame robot;*
  - *Legged robot ;*
  - *Wheeled robot and chain-tracks*

Electromagnetic force

- Electromagnetic force is not suitable for general climbing robots because it only works on ferromagnetic surfaces.
- Even if the adhesion is reliable and easy to control, actuating the electromagnet still requires a big and heavy power supply.

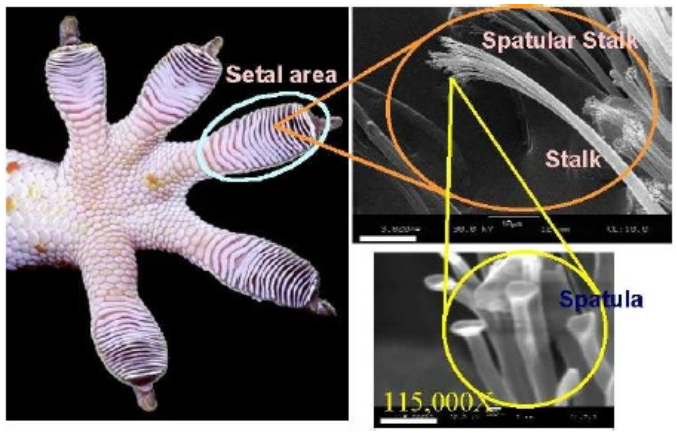





=>impossible to apply on light-weight climbing robots except in some special cases

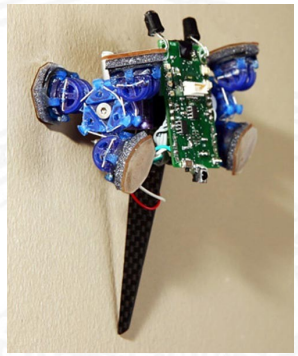
Other examples

Molecular force

- With the development of nanotechnology, molecular force has become a promising reliable attachment principle for climbing from the technical point of view.

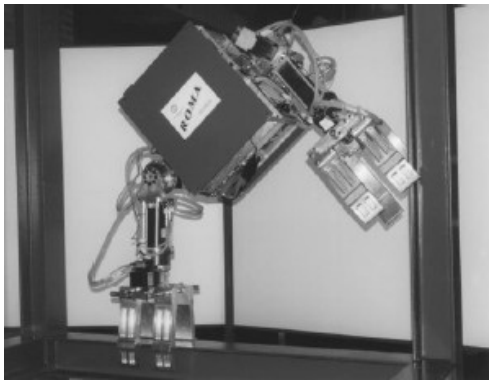


- However, the benefits of this novel adhesive principle are offset by high manufacturing costs and difficulties. Based on the current level of technology, real industrial application is still some way off.

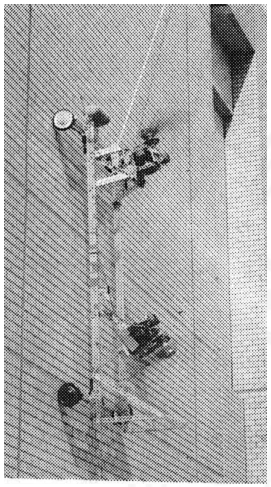


Mechanical force

- Grippers are relatively prevalent. Usually climbing robots based on this attachment method work in a specialized environment such as metal-based buildings.



- A propeller is another way to provide the mechanical attachment force. It is very light, but the level of noise generated is too high.



Vacuum

- Actuated by electrical motors in its negative pressure chamber, the climbing robot can move on the wall flexibly and continuously.

- The vacuum in the suckers is usually established by vacuum ejectors or vacuum pumps.

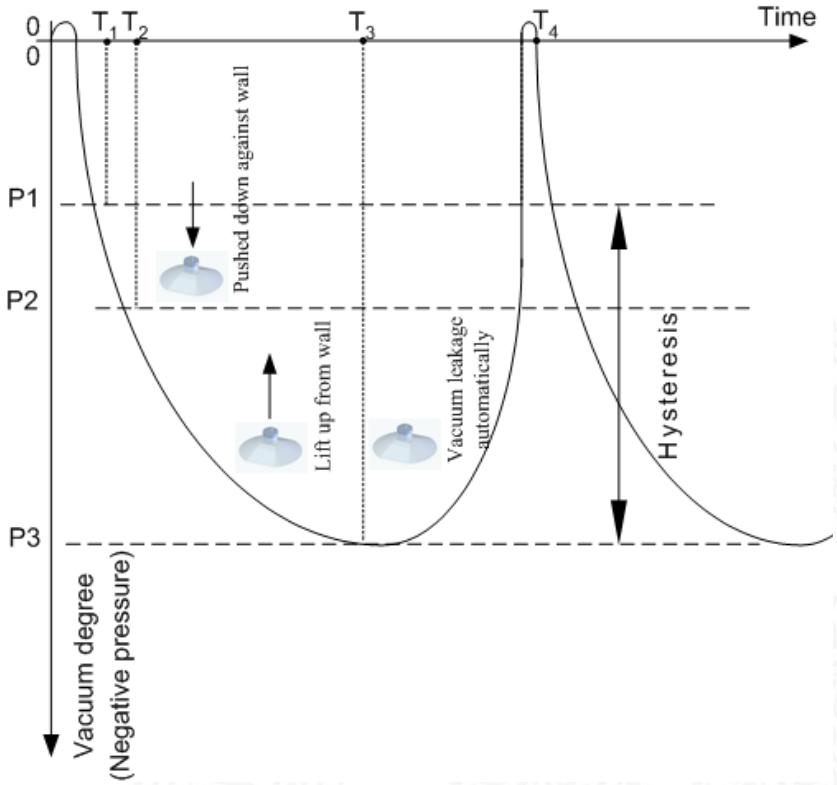
New Passive Adhesion Principle

- Low Frequency Vibrating Adhesion
- Simulation and Rational Testing

Low-frequency vibrating passive suckers

- Keep the merits and eliminate the shortcomings of normal active vacuum suckers
- Make it possible to avoid the usual heavy vacuum ejectors and realize an simple adsorption
- Improve the inspired technological level and flexibility of the locomotion capability

• In principle

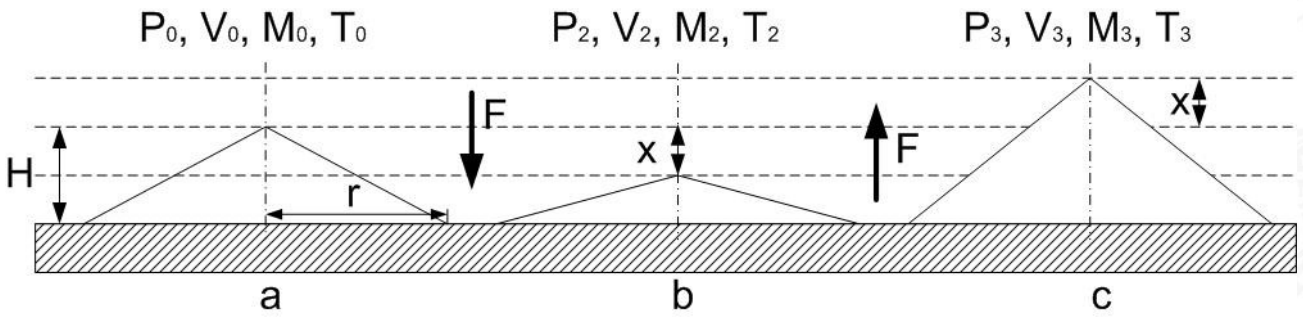


Simulation and Rational Testing

- For idea gas, the following equations represent the passive suckers' attachment principle. In Fig. a, the passive sucker is at the initial state, where *P0, V0, M0, T0* are the inside pressure, volume, mass of air, and temperature respectively; *H* is the initial height of passive sucker; *r* is the radius of the suckers; ρ is the density of the idea air; *F* is the force for squeezing and lifting.

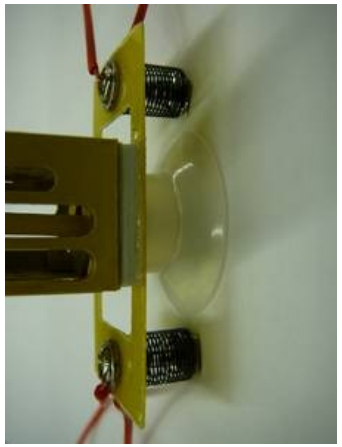
$$P_2 = \frac{P_0 V_2}{V_0} = \frac{P_0 \frac{1}{3}\pi r^2 (H - x)}{\frac{1}{3}\pi r^2 H} = P_0 (1 - \frac{x}{H})$$

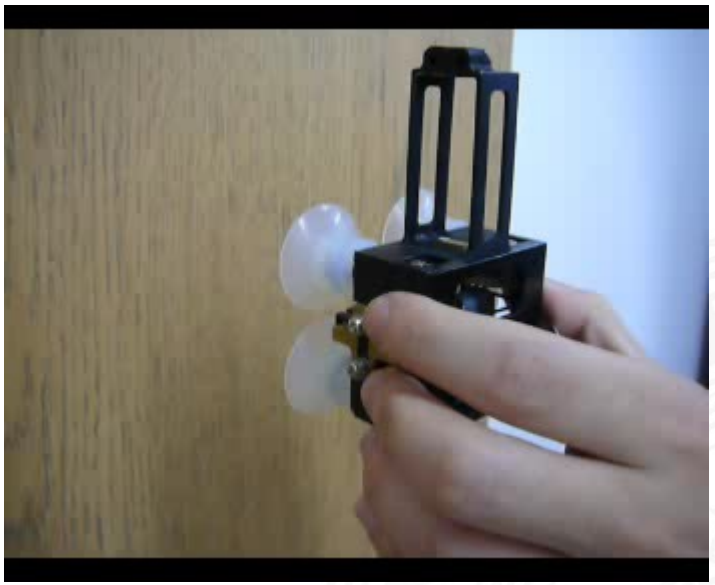
$$P_3 = P_0 (\frac{H - x}{H + x})$$



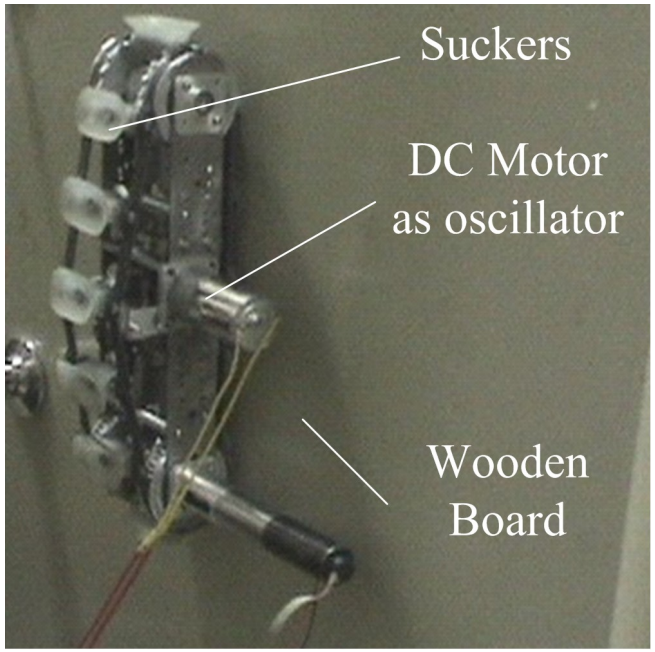
Simulation and Rational Testing

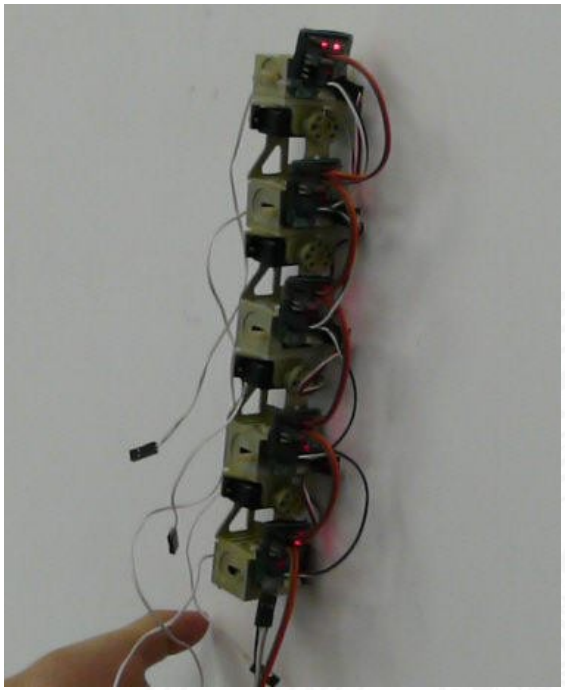
- A DC motor is used as an oscillator to realize the pushing and lifting movement automatically





On-site Test on a Climbing Caterpillar Robot





Conclusions

- This paper introduced a new passive attachment method In order to find an efficient and effective attachment principle which can be adopted by a smart climbing caterpillar.
- This novel passive sucker make it possible to complete our cooperated climbing caterpillar idea which meets all requirements of functionality, safety, flexibility, extensibility and easy handling while being completely automatic and able to learn by the robot itself.
- Still a lot of future work

Thanks for your attention!

Any questions?