Legged Capsule Robots In Medicine

Intelligent Robotics Seminar, Group TAMS, University of Hamburg

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Outline

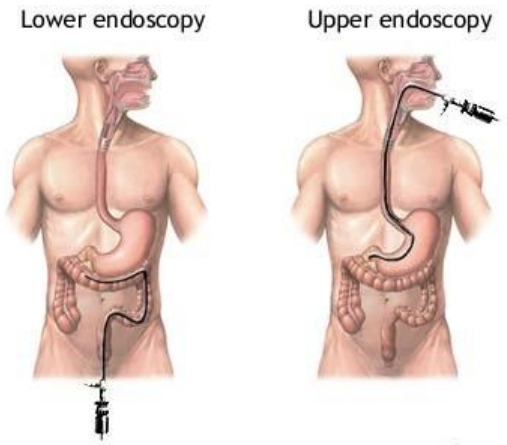
- Motivation
- Medical Consideration
- 12-legged capsule robot and The spiral leg robot
- ✓ Design overview
- ✓ Robots structure
- ✓ Kinematic analysis
- Conclusion

Motivation

Endoscopy means looking inside and typically refers to looking inside the body for medical reasons using an endoscope, an instrument used to examine the interior of a hollow organ or cavity of the body.

Issues:

- Pain and discomfort
- Not feasible to capture image from small intestine



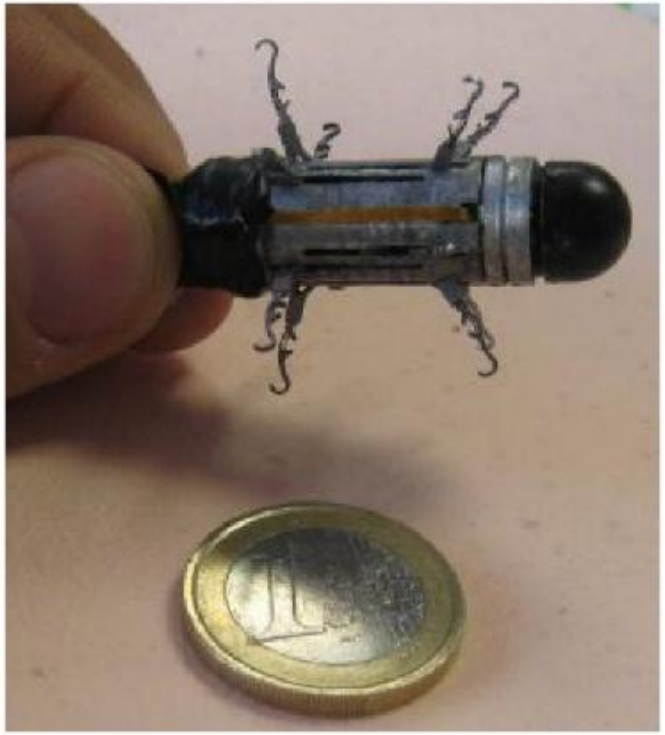
From [1]

Medical Consideration

- **Size:** a swallowable cylindrical shape
- **Speed:** a standard colonoscopy is complete in approximately 20-min-1 hour
- **Safety:** no more damage than a standard endoscope
- **Painless:** the capsule has to be provided with a locomotion system able to propel the capsule forward without insufflation
- **Functionality:** need to visually observe the interior of the GI

12-Legged Endoscopic Capsule Robot

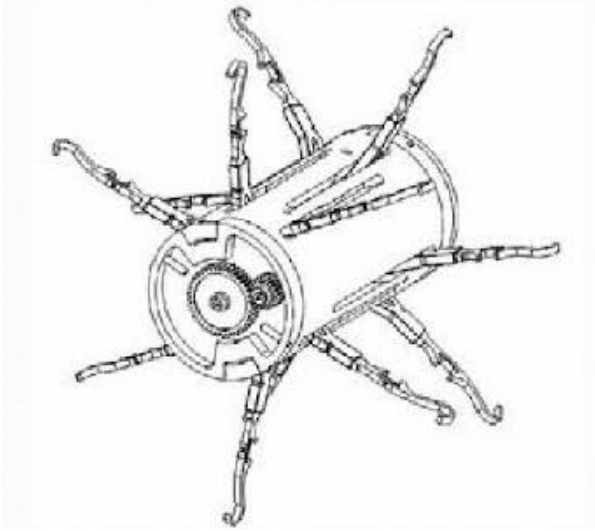
- Number of legs: 12
- Size: 11mm diameter by 25 mm long
- Force at each leg tip: 2.3 N



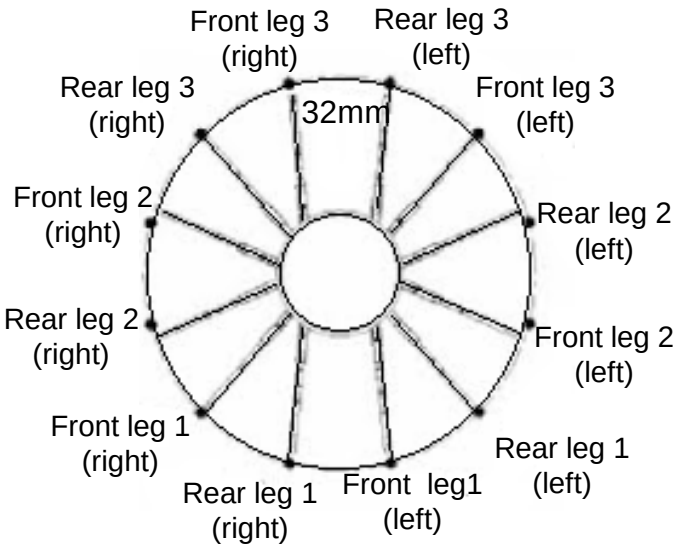
From[2]

Design overview

- The number of legs to use
- The gait they should follow
- Their placement positions on the capsule wall.

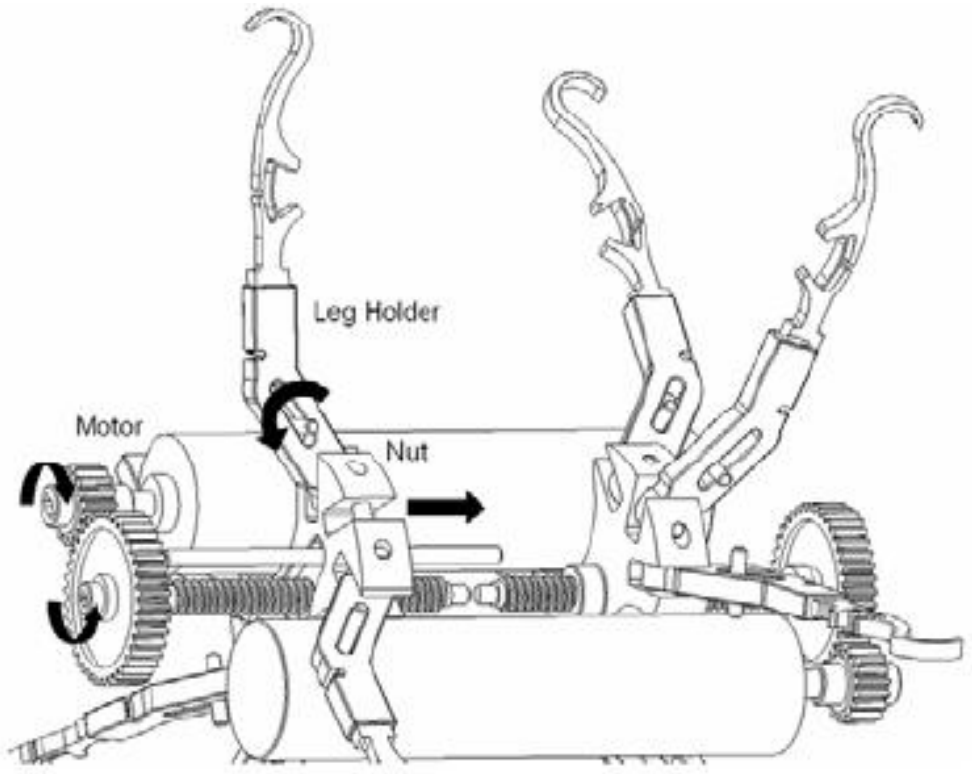


The disposition of the two sets of legs[4].



Front view of the capsule showing a 32 mm diameter circle[4].

Robot Structure



- Side view of capsule showing motor, gear, lead screw, leg-holder, leg and pins, the arrows show the direction of translation of the nut and the rotation movement impart to the leg holder.[4]

Kinematic Analysis

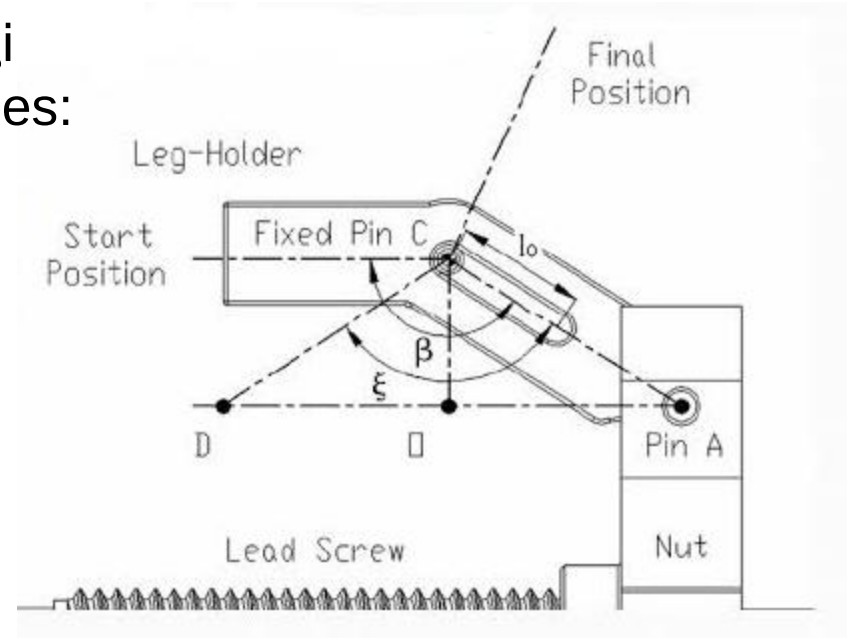
Constrains :

1. Overall size must be at most 11 mm diameter by 26 mm in length
2. Leg opening angle must be at least 110 degree
3. Maximum possible foot force of 2.3 N
4. Legs must all Simultaneously react within the capsule
5. Sufficiently large and thick enough to withstand the force

Kinematic Analysis

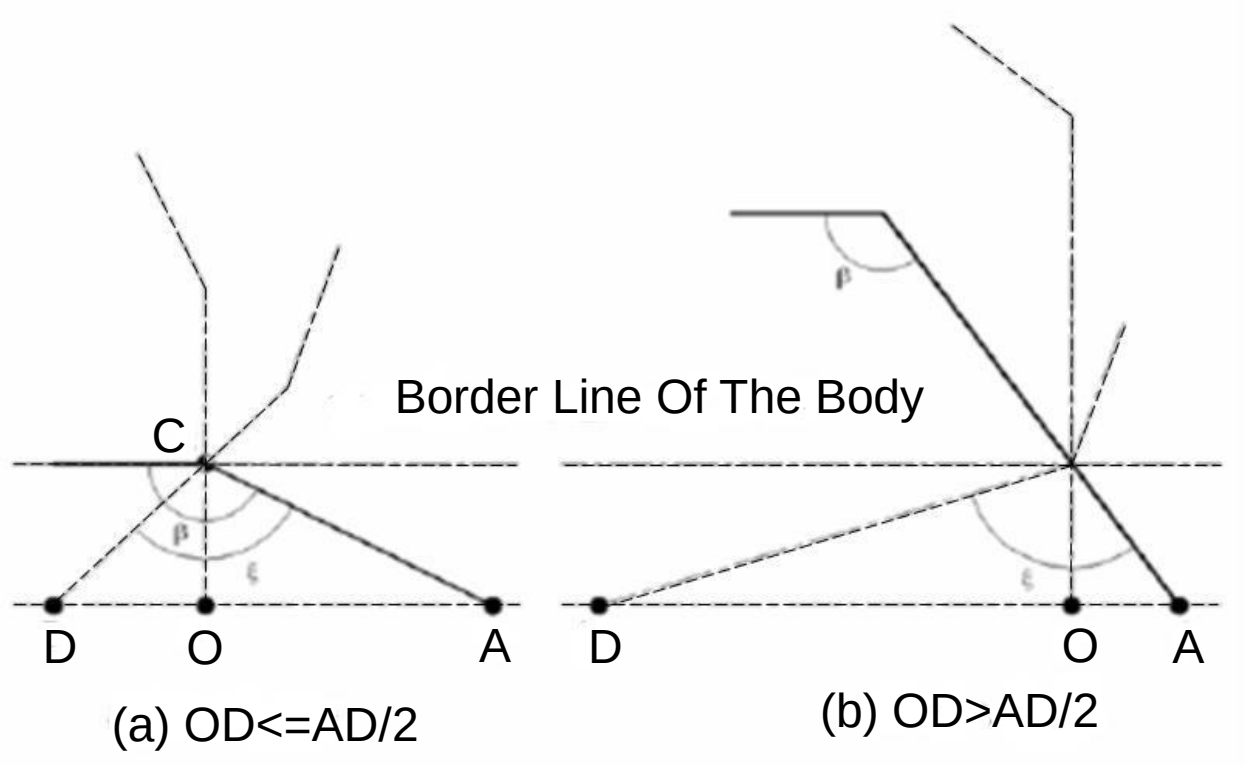
The values AD, OD, OC and ξi are related by the law of cosines:

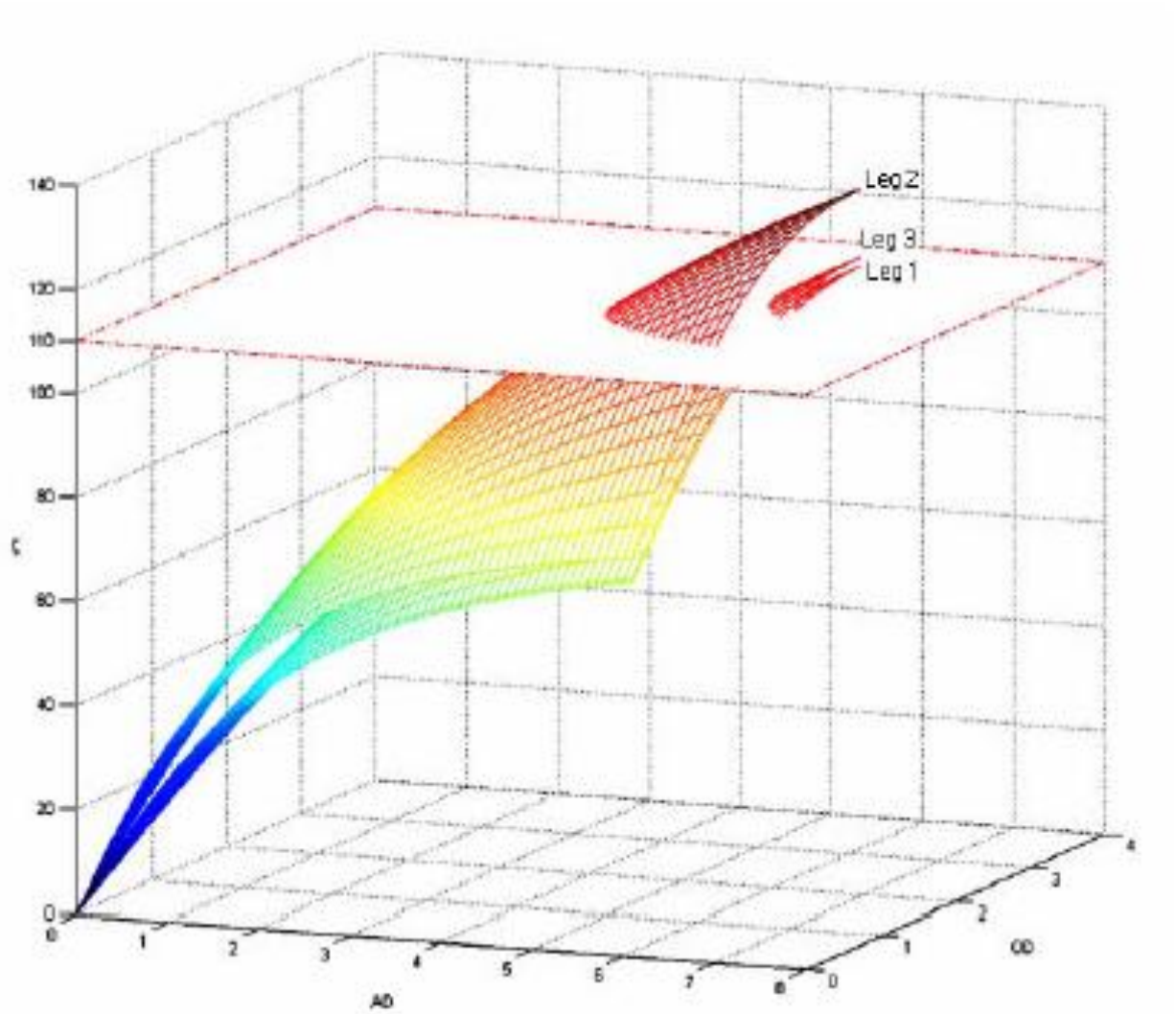
$$\xi = \cos^{-1}\left\{\frac{\overline{AD}\cdot\overline{OD}-\overline{OC}^2-\overline{OD}^2}{\left[\left(\overline{AD}-\overline{OD}\right)^2+\overline{OC}^2\right]^{\frac{1}{2}}\left[\overline{OD}^2+\overline{OC}^2\right]^{\frac{1}{2}}}\right\}$$



- Side view of the slot-follower mechanism showing all its design parameters[4]

- (a) In the closed position the leg is completely inside the body.[4]
- (b) In the case in the ‘closed’ position the leg remains outside the body.[4]

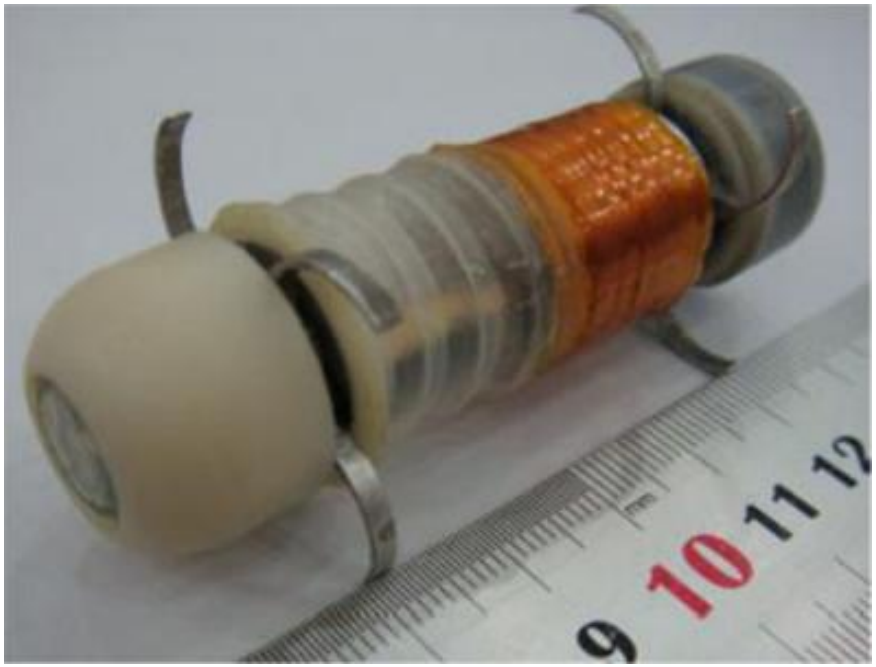




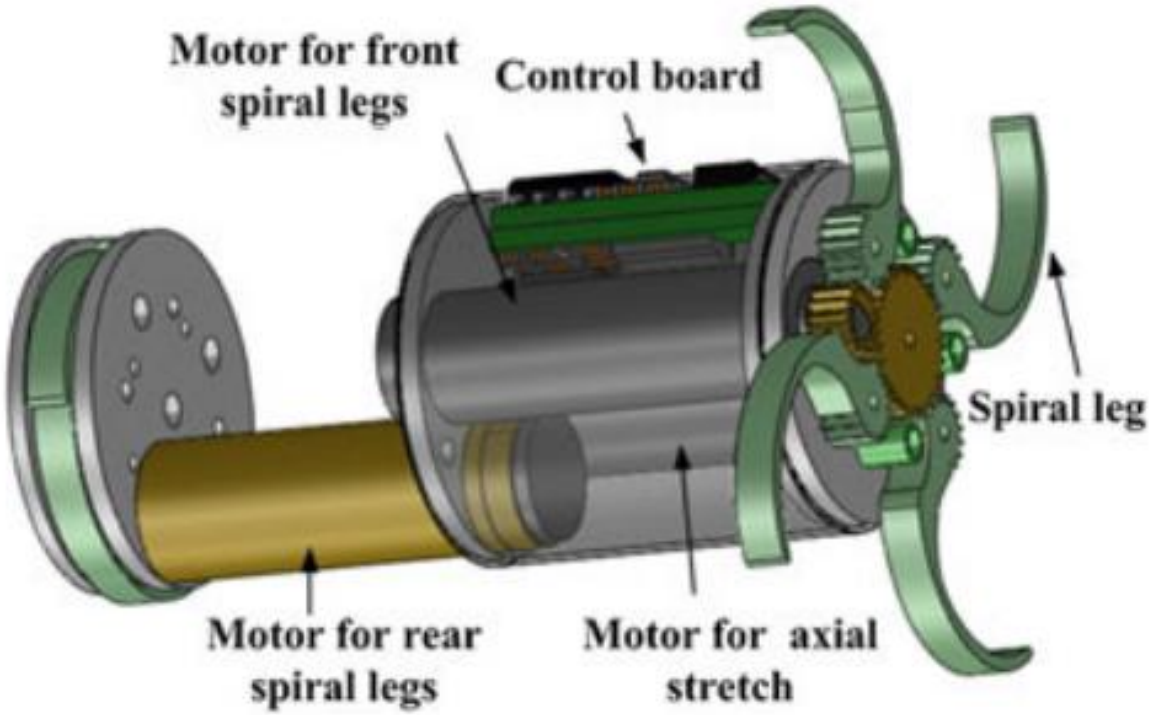
The Matlab plot showing the permissible AD and OD

The spiral leg robot

- Number of legs: two sets of four legs
- Size: 16mm diameter by 45mm length
- Force: 2.6 N on each leg, it was improved to 1.489 with textured legs.



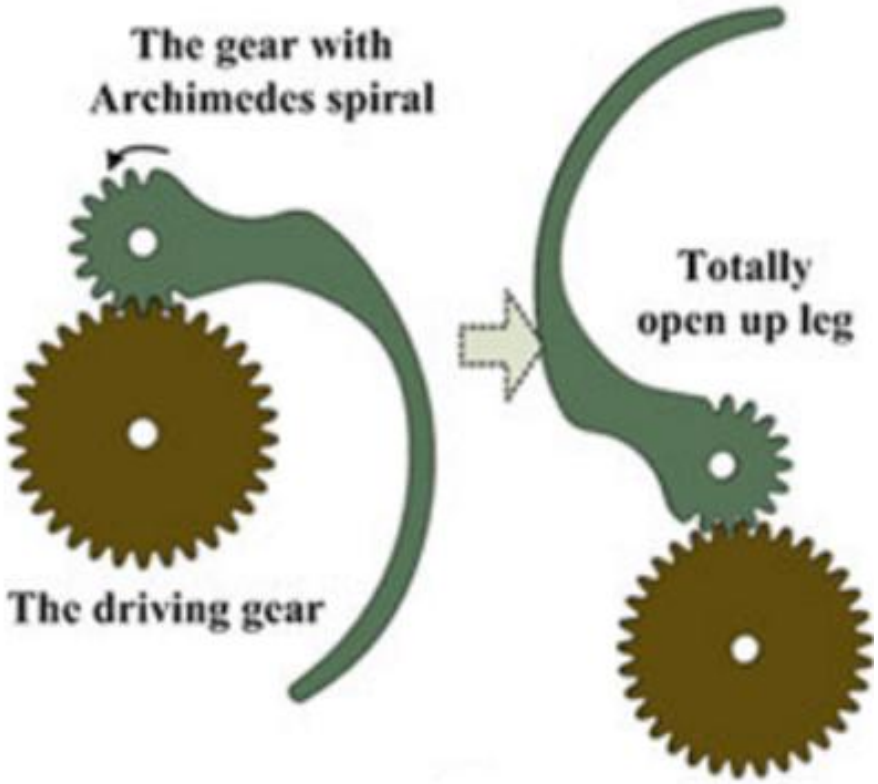
Robot structure



Side view of the robot with the body hidden to reveal internal components.[3]

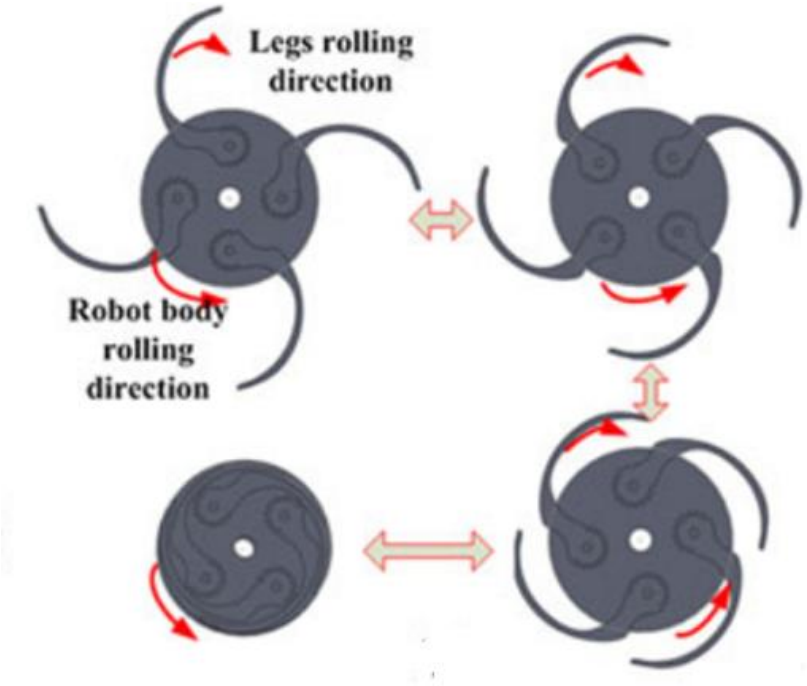
Design overview

- Single leg shape[3]



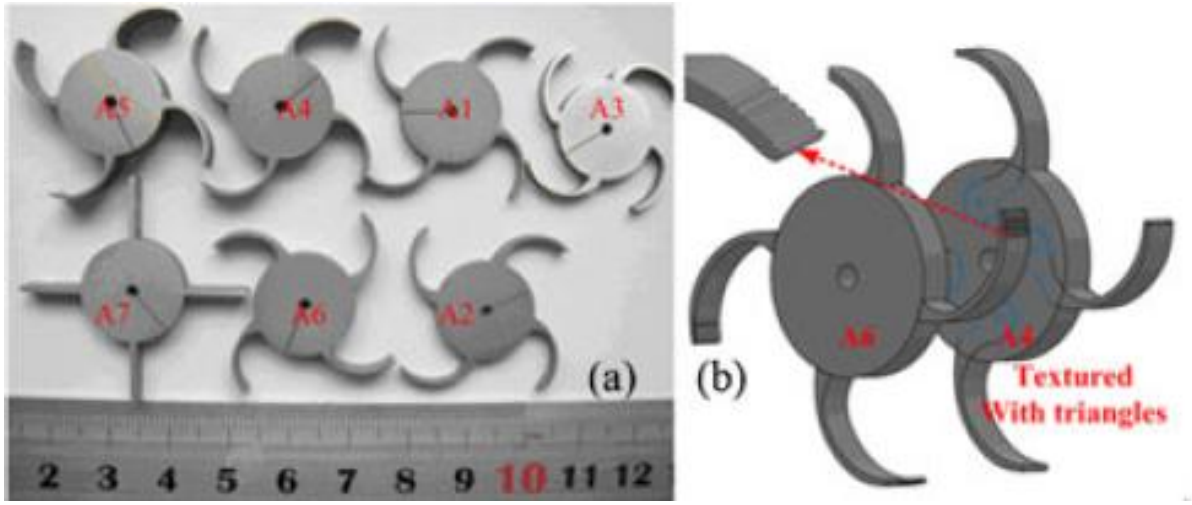
- Using clamper mechanism
- Design with a gear shape, rotating with the driving gear

Opening process of spiral leg



- The rolling force of the gear meshing will turn the robot body in the verse direction.[3]

Experiment Result



(a) Seven different sample of legs [3]

(b) Texture on sample[3]

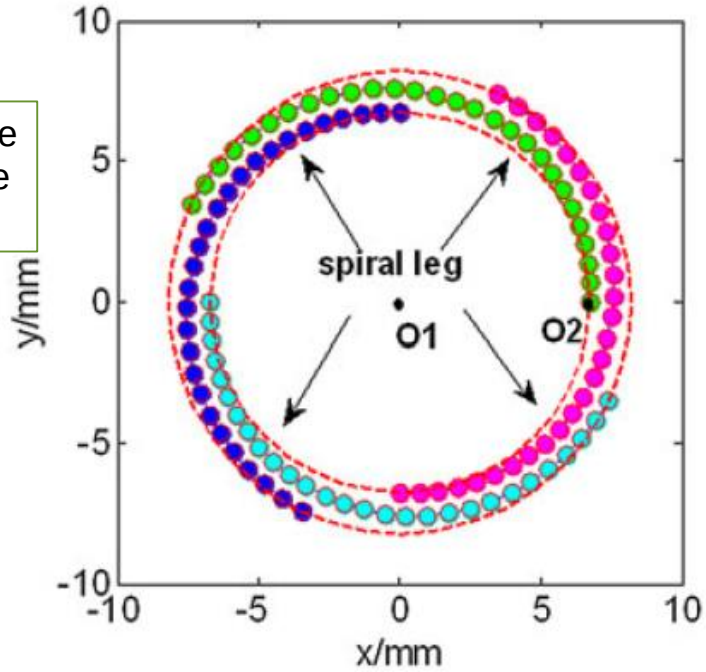
Mechanism Kinematic

- The Archimedes spiral

turn the spiral

controls the distance between successive turnings

$$\begin{cases} r = \alpha + \lambda \cdot \theta \\ x = r\cos\theta \\ y = r\sin\theta \end{cases}$$



- Four Archimedean spiral legs in the radial plane.[3]

geometry of the spiral leg mechanism

The torque of motor:

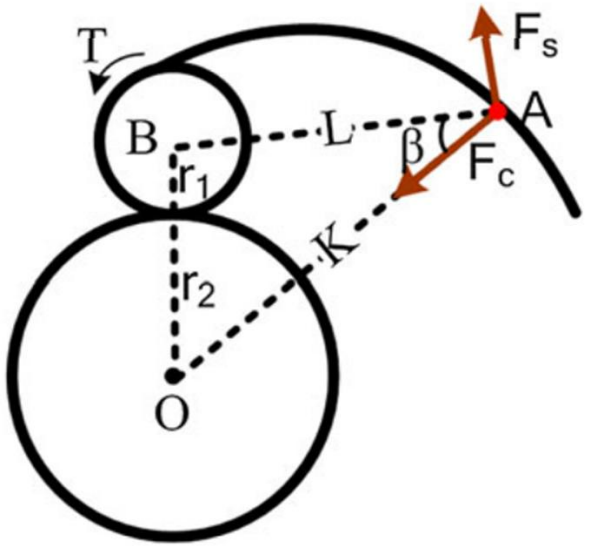
$$T = F_s \cdot L$$

Open force:

$$F_c = F_s / \sin\beta$$

Related between L and K by the low of cosines:

$$\cos\beta = \frac{L^2 + K^2 - {r_1}^2}{2LK}$$



Front view of the spiral leg mechanism showing its design parameters.[3]

Conclusion

- Stronger anchoring and safer contact with the colon due to texture tip
- Smaller size and diameter
- The size and diameter would be reduce in spiral leg capsule robot.
- In vivo experiments will be conducted to verify improvements in performance and controllability of capsul movement.
- Obtaining a biopsy sample

References:

1. http://www.beverlyoakssurgery.com/colonoscopy/endoscopy
2. http://www.hindawi.com/journals/jr/2012/412816/fig3
3. Chen, Wenwen, et al. "A wireless capsule robot with spiral legs for human intestine." *The International Journal of Medical Robotics and Computer Assisted Surgery* 10.2 (2014): 147-161.
4. Quirini, Marco, et al. "Design of a pill-sized 12-legged endoscopic capsule robot." *Robotics and Automation, 2007 IEEE International Conference on*. IEEE, 2007.
5. Valdastri, Pietro, et al. "A new mechanism for mesoscale legged locomotion in compliant tubular environments." *Robotics, IEEE Transactions on* 25.5 (2009): 1047-1057.

Thank you for your Attention!!!

Any Questions?