Bioinspired grasping in Soft Robotics

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Technical Aspects of Multimodal Systems

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Outline

Motivation

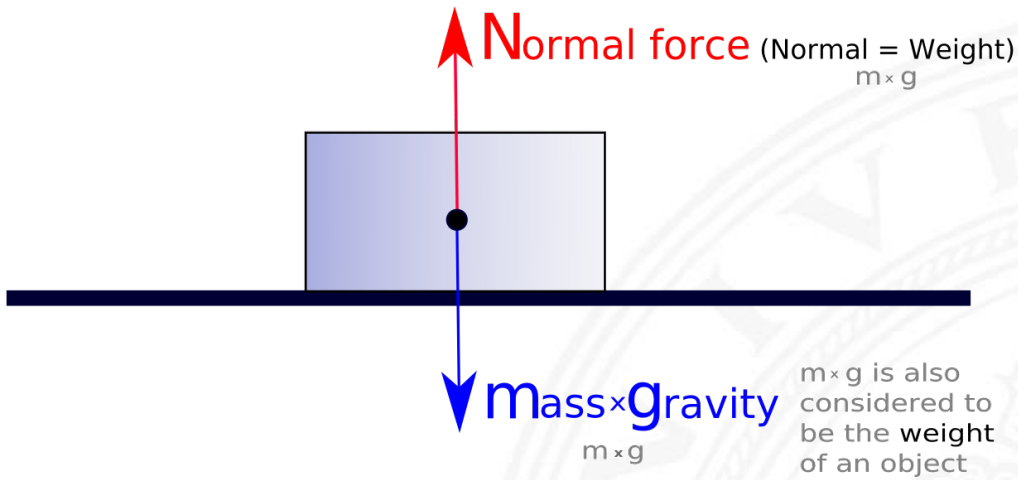
Source: [1]

Grasping - Problem Outline

- N "fingers" on the grasping device
- $\Rightarrow$ N contact points to the object
- **How is the right Grasping Pose calculated?**

Forces involved in grasping processes [3]

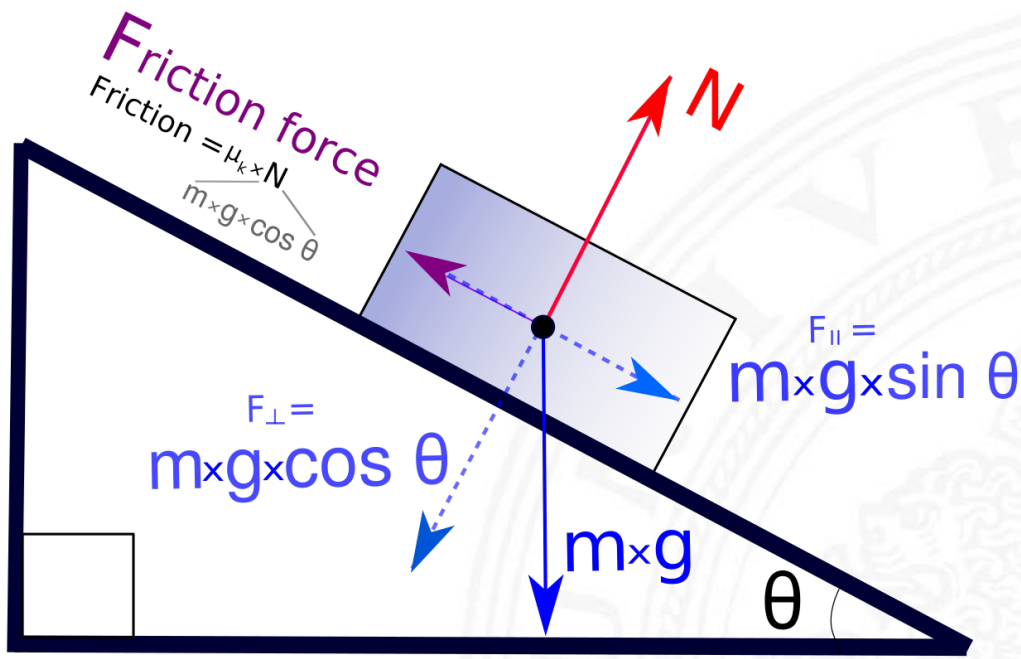
- Normal force ${}^{i}w_n$



Source:[2]

Forces involved in grasping processes [3]

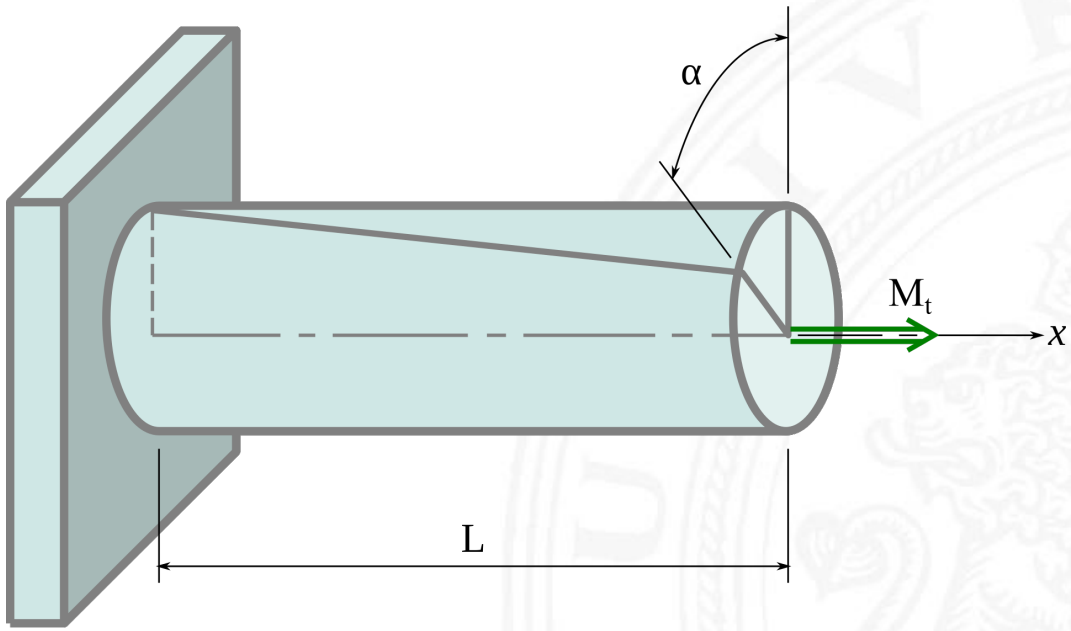
- Normal force ${}^{i}w_n$
- Tangential force ${}^{i}w_t$



Source: [2]

Forces involved in grasping processes [3]

- Normal force ${}^{i}w_n$
- Tangential force ${}^{i}w_t$
- Torsional moment ${}^{i}w_\theta$



Source:[4]

Contacts [3]

- Frictionless contact: ${}^{i}w_n$
- Frictional contact: ${}^{i}w_n \wedge {}^{i}w_t$
- Soft contact: ${}^{i}w_n \wedge {}^{i}w_t \wedge {}^{i}w_\theta$

Equilibrium Grasp - Definition [3]

A grasp is considered in equilibrium when:

$$Wc + g = 0, c \neq 0$$

- W := Wrench matrix
- c := Wrench intensity vector
- g := External wrench

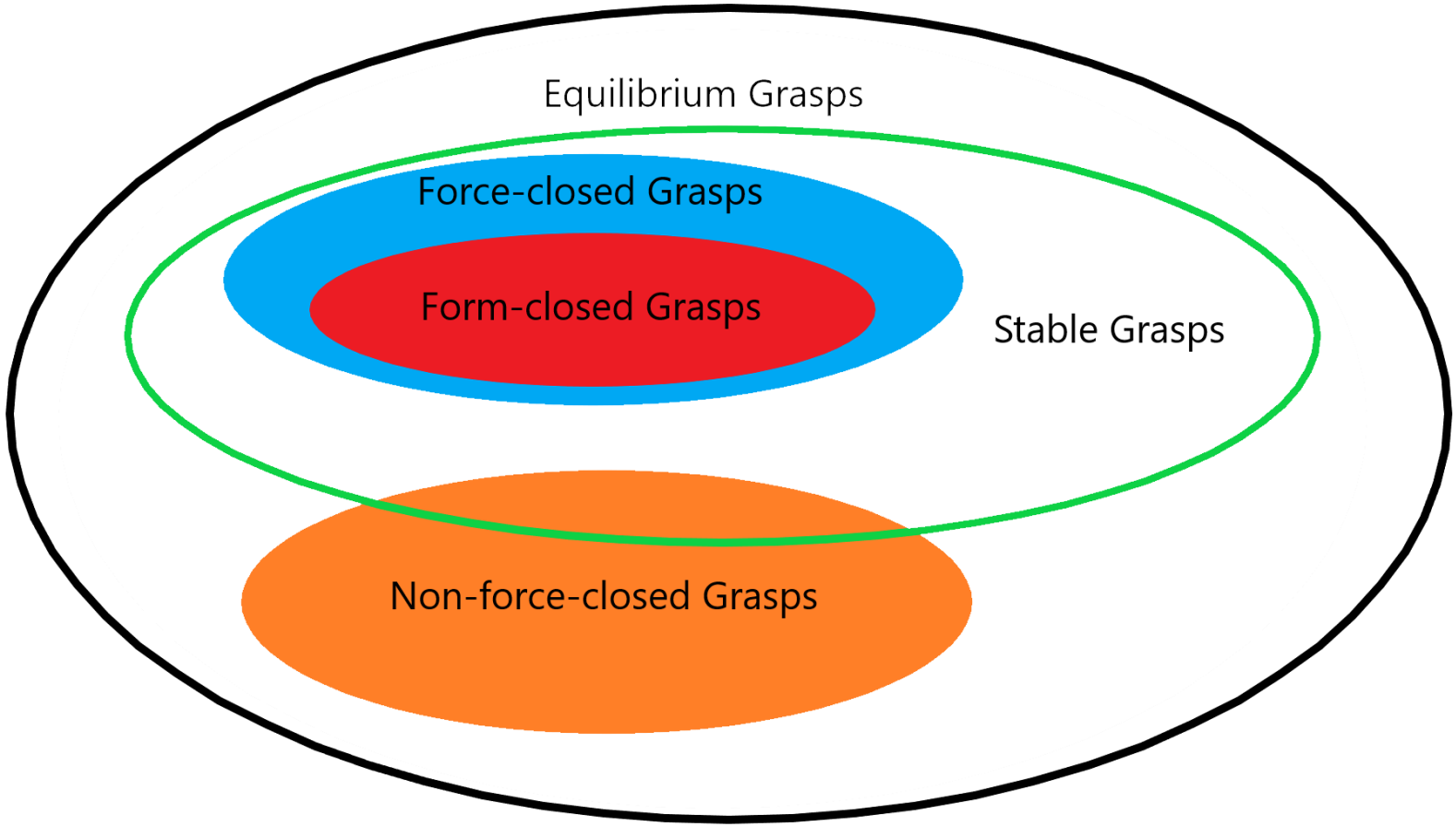
Force-closed Grasp - Definition [3]

A grasp is considered to be force-closed, when for every wrench $\hat{w}$ there is an λ that fits the constraints of a equilibrium grasp so that:

$$W\lambda = \hat{w}$$

- Note: Every force-closed grasp is a stable grasp

Categorization of Grasps



Classes of grasps based on [3]

Properties [3]

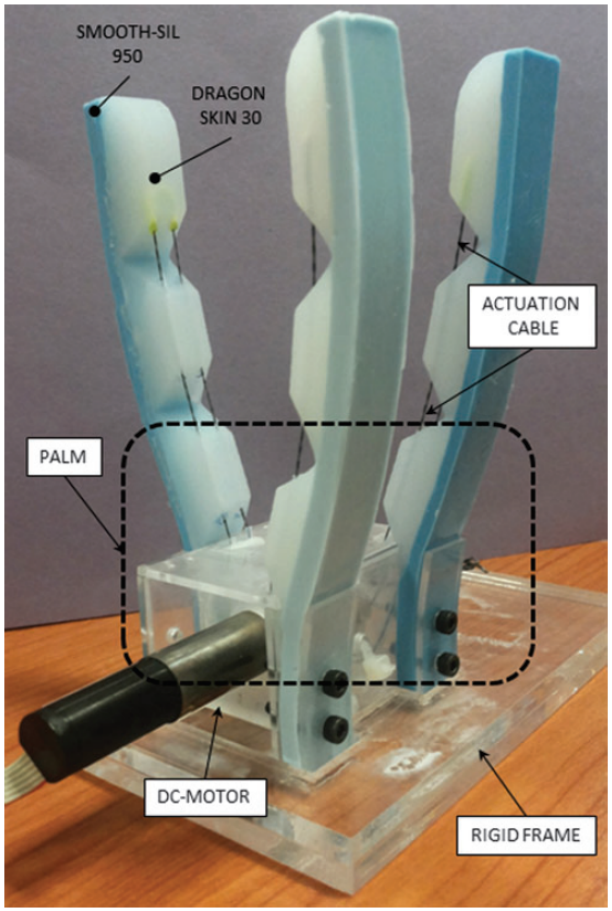
- Properties of the grasp process:
  - Dexterity
  - Equilibrium
  - Stability
  - Dynamic behaviour

- Problems in grasping:
  - Slipping detection
  - Fracture of grasped object

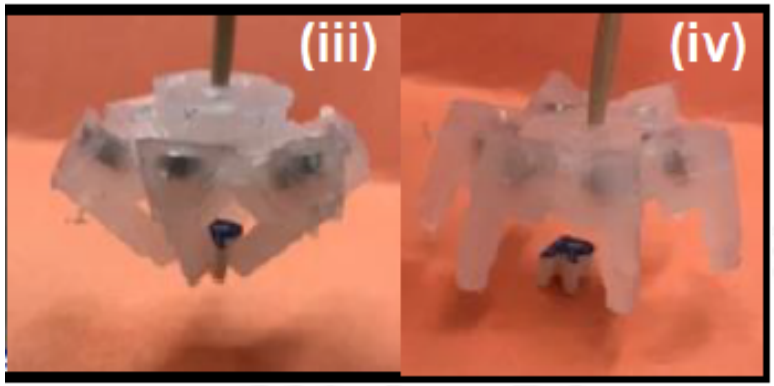
Charakteristics of Soft Robotics [5]

- Humanoid Soft Robotics
  - Skeletton
    - Metal
    - Synthetic polymer
  - Soft "skin" out of:
    - Active elastomer
    - Hydrogel
    - Shape memory polymers
    - e.g. GelSight, Dragon Skin, uSkin
- Animal-inspired Soft Robotics
  - "CAN" be completely out of soft material

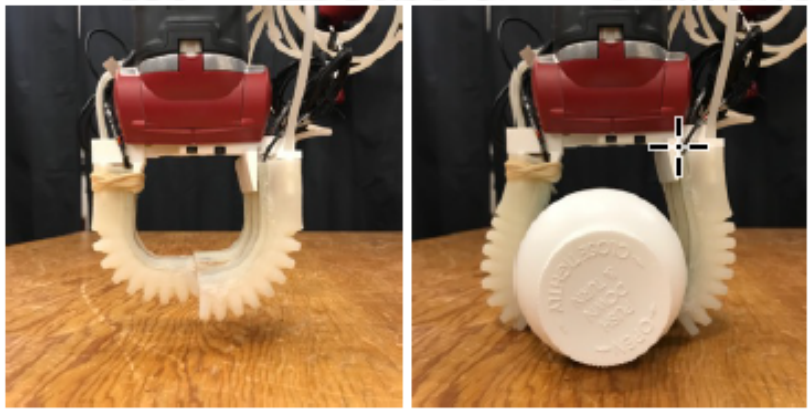
Charakteristics of Soft Robotics: Examples



Source: [6]



Source: [5]



Source: [7]

Grasp Synthesis [8]

- Two kinds of approaches:
  - Analytical
    - Objective: Calculate possibly best configuration of position and angles
    - Constrained optimization problems
    - Based on 3D-models
  - Data-driven
    - Objective: Reusing existing grasp experience
    - Heuristic
    - Knowledge-based

Sensors [9]

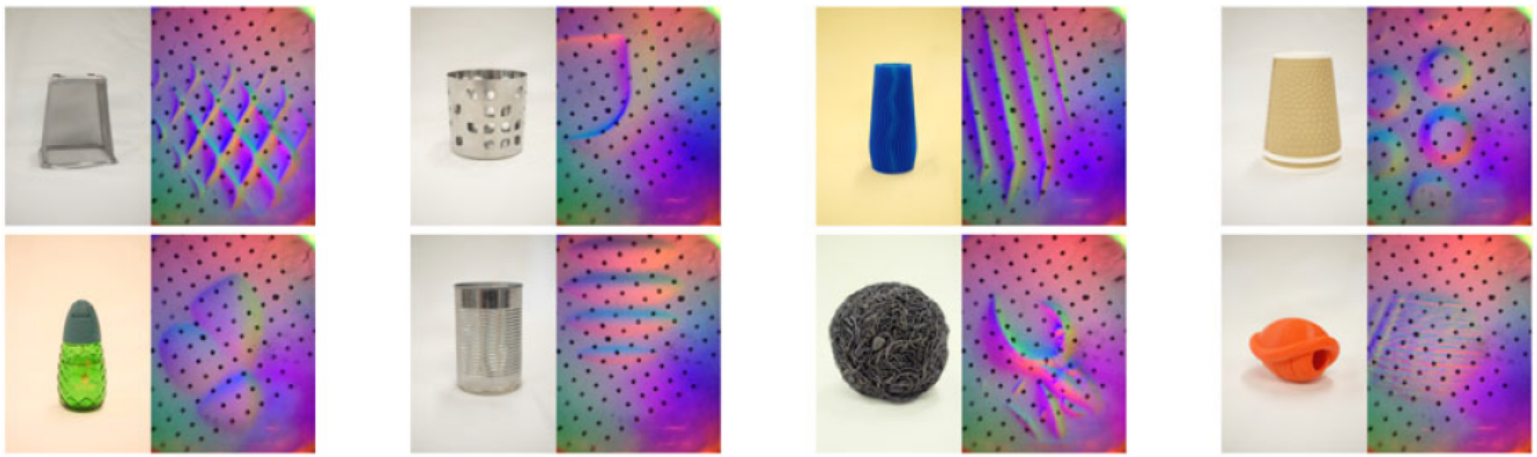
- Visual
  - Depth sensing
  - Pattern recognition
  - $\Rightarrow$ Stereo Camera Sensor
- Tactile
  - Force sensing
  - Surface exploration
  - Slipping detection
  - $\Rightarrow$ GelSight, TacTip, etc.

Action-conditional model [10]

Source: [10]

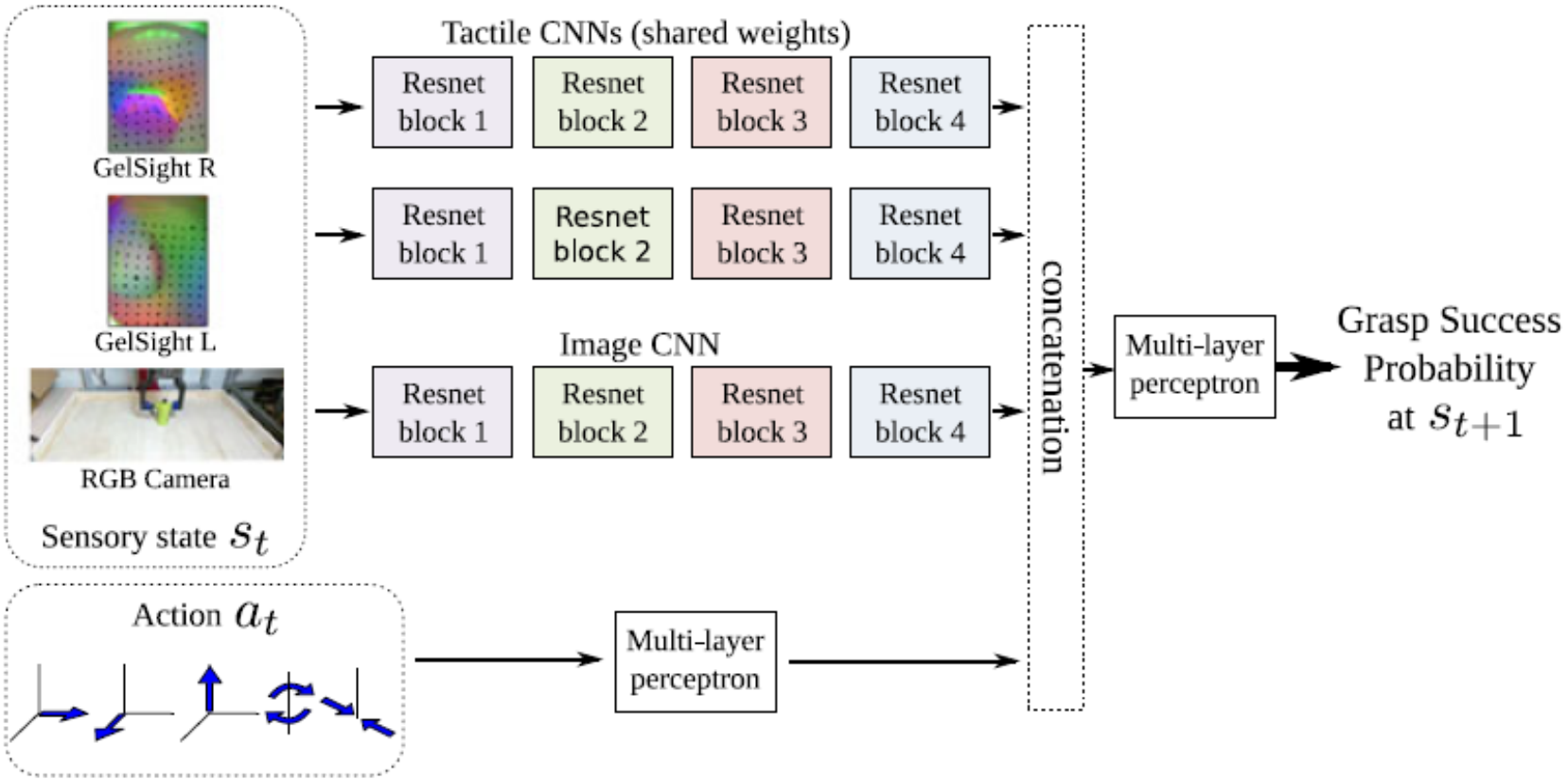
- Objective: Combine visual and tactile sensing
- Sensors: GelSight tactile sensor, Microsoft Kinect v2.0
- Operating with raw input data
- Self supervised Deep Learning approach to predict grasp success
- Adjusting grasps (Regrasping)
- Optimizable for gentle grasps

2D tactile-sensor input



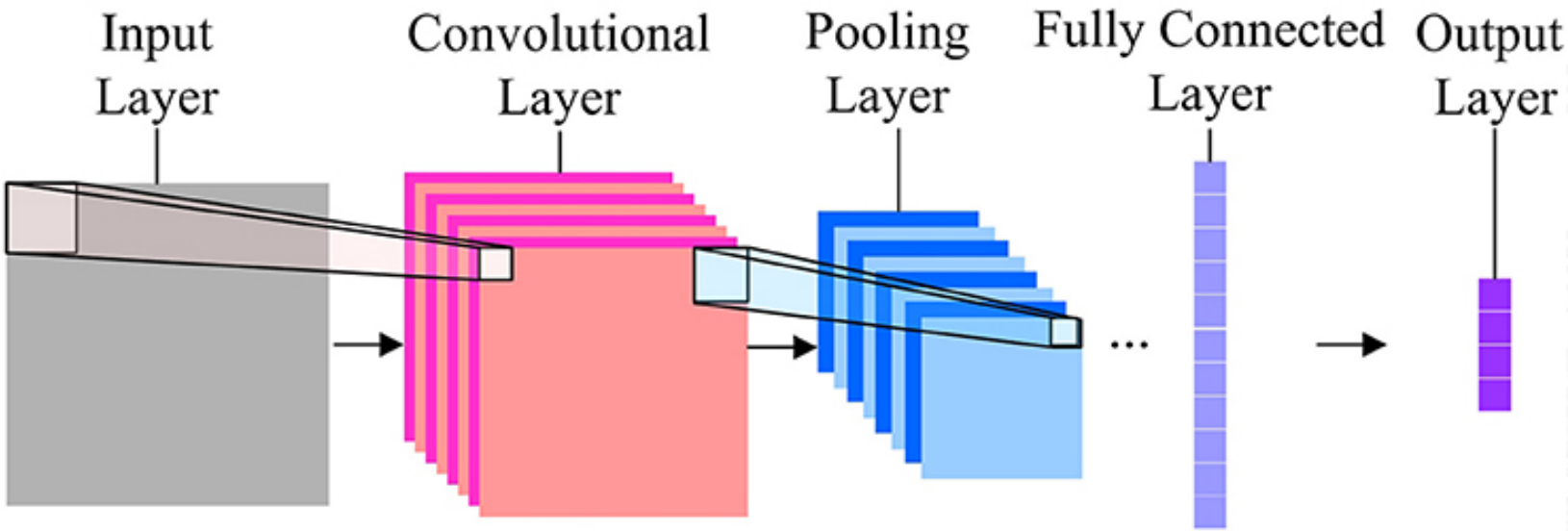
Source: [10]

Calculation of success probability



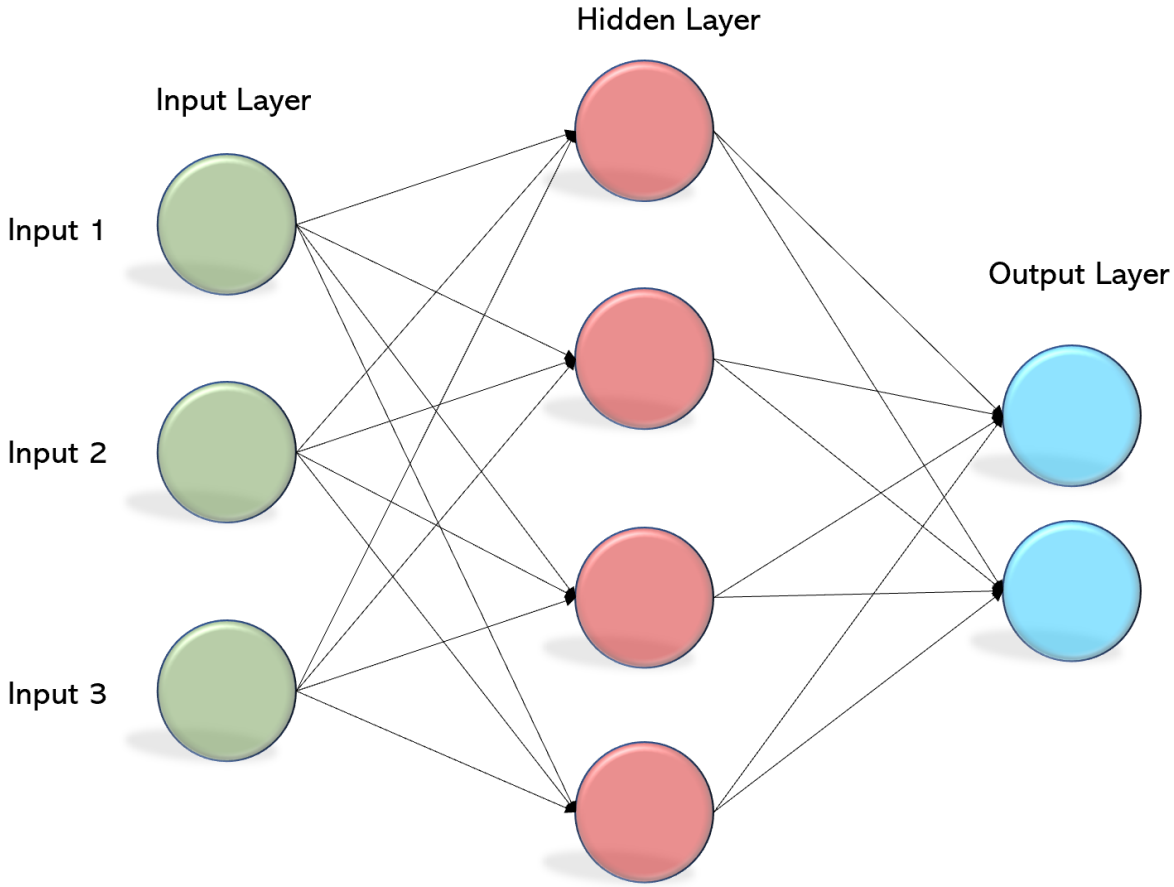
Source: [10]

Convolutional Neural Network



Source: [11]

Multi-layer Perceptron



Source: [12]

Regrasp Optimization

$$\boldsymbol{a}_t^* = \arg\max_{\boldsymbol{a}} f\left(\boldsymbol{s}_t, \boldsymbol{a}\right) .$$

Source: [10]

Results

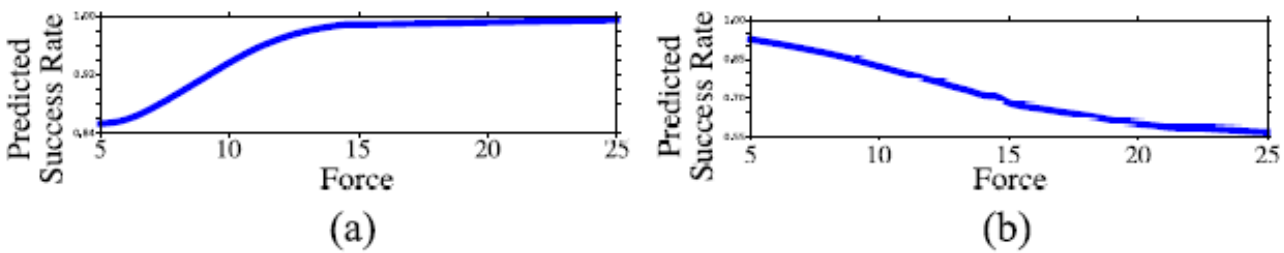
- Absolute sucessful Grasps

Model	Accuracy (mean ± std. err.)
Chance	62.80% ± 0.85%
Vision (+ action)	73.03% ± 0.24%
Tactile (+ action)	79.34% ± 0.66%
Tactile + Vision (+ action)	**80.28%** ± **0.68%**
Tactile + Vision (no action)	76.43% ± 0.42%

Source: [10]

Results

- Predicted success in relation to the applied force

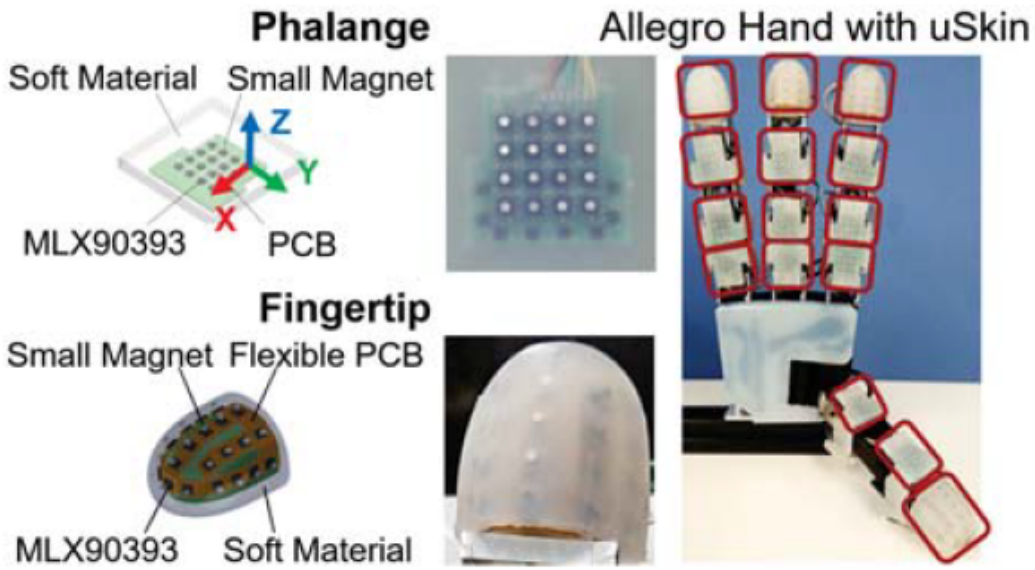


Stable Grasp Unstable Grasp

Source: [10]

Outlook

Multi-finger hand with uSkin:



Source: [9]

- Recognizing objects based on tactile sensing with 95% success

Conclusion

- Soft Robotics are supportive for dynamic grasping tasks
- Visuo-tactile sensing is highly valuable for future grasping research
- But, more research is needed on:
  - The combination of visual and tactile data
  - Tactile sensors
  - Suitable learning models for grasping

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