Active surfaces, materials and tools for assembly

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• Rationale behind the research work
• The relationship between surfaces, materials and tools
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Definition of the research scope

Active surfaces, materials and tools for assembly

- **Active**: the material is activated by chemical, mechanical, thermal processes. Its properties are radically different from those of unactivated areas.
- **Surfaces**: micro and nano texture, paintings, coatings over the surface can generate strong energy gradient that can be exploited for many purposes.
- **Materials**: SMA, SMP, EAP, PZT, but also super-elastic alloys, palladium, silicon, conductive polymers, etc., rheopetic and tixotropic liquids generate new possibilities for assembly.
- **and tools for assembly**: IR cameras, high speed cameras, ionizers, etc. can increase performances in assembly.
Rationale

• Possibility of manufacturing (and measuring) micro and nano textures on surfaces of different materials.
• Complex patterns and surface textures can be manufactured. It allows to confer different properties (even opposite) to areas bordering each other.
• Such surfaces can be active (chemically, electrostatically, Van der Waals, etc..) or actuated (piezoelectrically, mechanically, etc..) however they can be designed, manufactured and actuated at all scales.

• The characteristics of grasping/feeding surfaces often depend also on the layers beneath the surface itself.
Background for “Surfaces in Assembly”

Keynotes with potential impacts on research about active surfaces for assembly:

**2011 - Replication of Micro and Nano Surface Geometries**  
*H.N. Hansen (1), R.J. Hocken (1), G. Tosello*

**2011 - Biologically Inspired Design**  
*L.H. Shu (2), K. Ueda (1), I. Chiu, H. Cheong*

**2009 - Cooperation of Human and Machines in Assembly Lines**  
*J. Krüger (2), T.K. Lien (2), A. Verl (2)*

**2008 - Advances in engineered surfaces for functional performance**  
*A.A.G. Bruzzone (2), H.L. Costa, P.M. Lonardo (1), D.A. Lucca (1)*

**2000 - Assembly of Micro-System**  

…
Active surfaces have been organised according to the physical principle they exploit for feeding. Some of them work properly at the micro-meso scale while other also at the macroscale.

ACTIVE SURFACES for part feeding

- Cilia
- Nodal Air Nozzles (programmable)
- Hydrophillic Hydrophobic
- Electrostatic Gravitational
- Friction Bounce and fall
- Brushes Underwater
Some of the described feeders (2)

<table>
<thead>
<tr>
<th>Bowl &amp; linear feeder (barely out of scope)</th>
<th>Brush feeder</th>
<th>Nodal lines - feeder</th>
</tr>
</thead>
<tbody>
<tr>
<td><img src="image1.png" alt="Image" /></td>
<td><img src="image2.png" alt="Image" /></td>
<td><img src="image3.png" alt="Image" /></td>
</tr>
<tr>
<td><img src="image4.png" alt="Image" /></td>
<td><img src="image5.png" alt="Image" /></td>
<td><img src="image6.png" alt="Image" /></td>
</tr>
<tr>
<td>Feeder based on microcilia</td>
<td>Electrostatic feeder</td>
<td>Hydrophillic-Phobic Feeder</td>
</tr>
<tr>
<td><img src="image7.png" alt="Image" /></td>
<td><img src="image8.png" alt="Image" /></td>
<td><img src="image9.png" alt="Image" /></td>
</tr>
</tbody>
</table>
## Feeders (3)

<table>
<thead>
<tr>
<th>Active surfaces</th>
<th>Active &amp; Actuated surfaces</th>
<th>Actuated surfaces</th>
</tr>
</thead>
<tbody>
<tr>
<td>Feeder based on hydrophillic and hydrophobic areas</td>
<td>Electrostatically based feeders</td>
<td>Nodal lines over vibrating plates</td>
</tr>
<tr>
<td>Electrostatic “permanent” traps and magazines</td>
<td>Brush feeder</td>
<td>Feeding by bouncing and falling</td>
</tr>
<tr>
<td>Underwater traps and pockets</td>
<td>Microcilia</td>
<td>Gravity traps</td>
</tr>
<tr>
<td></td>
<td>Air feeder</td>
<td>Automated feeding of micro parts based on piezoelectric vibrations</td>
</tr>
<tr>
<td></td>
<td>Externally-resonated micro vibromotor for microassembly</td>
<td></td>
</tr>
</tbody>
</table>
Gripper to grasp (1)

Active surfaces have been organised according to the physical principle they exploit for grasping. Some of them work properly at the micro-meso scale while other also at the macroscale.

ACTIVE SURFACES AND MATERIALS for grasping

- Van der Waals
- Distributed friction
- Thermal Glue
- IR transp. gripper
- Wet adhesion
- Electrostatic
- Universal Gripper
- Deform. membrane
- Hydrophillic
- EAP
- Hydrophobic
- 2 liquids
- Frog
## Gripper to grasp (2)

<table>
<thead>
<tr>
<th>Electrostatic</th>
<th>Electrostatic</th>
<th>Gecko</th>
<th>Self centering SMA</th>
</tr>
</thead>
<tbody>
<tr>
<td>[Hesselbach]</td>
<td></td>
<td>[Lanzetta]</td>
<td>[Shu]</td>
</tr>
<tr>
<td>Flexible cups</td>
<td>Capillary</td>
<td>Universal Gripper</td>
<td>Spini gripper</td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>[Dini]</td>
<td></td>
<td>[Lambert]</td>
<td></td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
<td>Squirrel [Cutkosky]</td>
</tr>
</tbody>
</table>

[Images and diagrams of electrostatic, electrostatic Gecko, self-centering SMA, flexible cups, capillary, universal gripper, and spini gripper are shown.]
## Gripper to grasp (3)

<table>
<thead>
<tr>
<th>Active surfaces</th>
<th>Active &amp; Actuated surfaces</th>
<th>Actuated surfaces</th>
</tr>
</thead>
<tbody>
<tr>
<td>Liquid</td>
<td>Liquid+structured+actuated*</td>
<td>liquid+deformable membrane</td>
</tr>
<tr>
<td>Liquid-liquid manipulation*</td>
<td>Electrostatic</td>
<td>Centering</td>
</tr>
<tr>
<td>Gecko like</td>
<td>Electrowetted</td>
<td>Thermal glue</td>
</tr>
<tr>
<td>Electrostatic</td>
<td>UniversalGripper</td>
<td>Ultrasound</td>
</tr>
<tr>
<td></td>
<td>Flexible vacuum cups</td>
<td></td>
</tr>
</tbody>
</table>
Gripper to release (1) at microscale

<table>
<thead>
<tr>
<th>Type</th>
<th>Principle</th>
<th>Scheme</th>
<th>Description</th>
<th>Force</th>
</tr>
</thead>
<tbody>
<tr>
<td>Conductive material/coatings - Grounded gripper</td>
<td>Conductive materials or coatings (which do not form insulating oxides) reduce static charges. Grounded grippers prevent the charge storage [3, 5]</td>
<td></td>
<td>electrostatic</td>
<td></td>
</tr>
<tr>
<td>Low difference of EV potential</td>
<td>Gripper and object made of materials with a small potential difference reduce “contact interaction” forces [5]</td>
<td></td>
<td>electrostatic</td>
<td></td>
</tr>
<tr>
<td>Hydrophobic coating</td>
<td>Hydrophobic coating reduces surface tension effects: it prevents the adsorption of moisture [6]</td>
<td></td>
<td>surface tension</td>
<td></td>
</tr>
<tr>
<td>Low Hamaker constant Coating</td>
<td>Low Hamaker constant coating reduces van der Waals forces [3]</td>
<td></td>
<td>van der Waals</td>
<td></td>
</tr>
<tr>
<td>Hard materials</td>
<td>Contact pressure causes deformations, increasing the contact area between gripper and object. Grippers made of hard material have to be preferred [5]</td>
<td></td>
<td>van der Waals; electrostatic</td>
<td></td>
</tr>
<tr>
<td>Rough surface - Micro pyramids</td>
<td>The gripper roughness reduces the contact area and sharp edges induce the self discharge effect [5, 6]</td>
<td></td>
<td>van der Waals; electrostatic</td>
<td></td>
</tr>
<tr>
<td>“Spherical” fingers</td>
<td>Spherical fingers reduce the contact area in comparison with planar ones [5]</td>
<td></td>
<td>van der Waals; surface tension</td>
<td></td>
</tr>
<tr>
<td>Active surfaces</td>
<td>Active &amp; Actuated surfaces</td>
<td>Actuated surfaces</td>
<td></td>
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</tr>
<tr>
<td>----------------</td>
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<td></td>
<td></td>
</tr>
<tr>
<td>Conductive Coatings</td>
<td>Invert voltage</td>
<td>Micro heater</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Hydrophobic Coatings</td>
<td>Liquid+structured+actuated*</td>
<td>Varying the gripper curvature</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Superhydrophobic Coatings</td>
<td>EAP based Releasing</td>
<td>Tilting the gripper</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Hard materials</td>
<td>Varying roughness by vibration</td>
<td>Acceleration or vibration</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Rough surfaces</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
</tbody>
</table>
Findings

• New Devices for grasping and releasing microparts
  – At UNIPI
  – In collaboration with DTU

• New research opportunities
Grasping and releasing microparts exploiting liquids with different surface tensions

A novel grasping and releasing strategy for microparts exploiting liquids with different surface tensions

[Fantoni, Porta, Santochi]
Grasping and releasing microparts exploiting liquids with different surface tensions
Active surfaces for grasping and releasing of microparts

Grasping and releasing of microparts by using active hydrophillic-phobic surfaces
[Fantoni, Hansen, Santochi] *in progress*

Programmable hydrophobic surfaces [Fantoni, Zang, Tosello, Hansen] *in progress*
Active surfaces for grasping and releasing of microparts

- hydrophillic
- hydrophobic
Research opportunities: from micro to macro

<table>
<thead>
<tr>
<th>Friction gripper</th>
<th>Jaw gripper</th>
<th>Magnetic Gripper</th>
<th>Vacuum Gripper</th>
</tr>
</thead>
<tbody>
<tr>
<td><img src="image1.png" alt="Friction gripper" /></td>
<td><img src="image2.png" alt="Jaw gripper" /></td>
<td><img src="image3.png" alt="Magnetic Gripper" /></td>
<td><img src="image4.png" alt="Vacuum Gripper" /></td>
</tr>
</tbody>
</table>

<table>
<thead>
<tr>
<th>Capillary G.</th>
<th>Electrostatic G.</th>
<th>Van der Waals</th>
<th>Cryogenic G.</th>
</tr>
</thead>
<tbody>
<tr>
<td><img src="image5.png" alt="Capillary G." /></td>
<td><img src="image6.png" alt="Electrostatic G." /></td>
<td><img src="image7.png" alt="Van der Waals" /></td>
<td><img src="image8.png" alt="Cryogenic G." /></td>
</tr>
</tbody>
</table>

<table>
<thead>
<tr>
<th>Acoustic G.</th>
<th>Laser</th>
<th>Bernoulli</th>
</tr>
</thead>
<tbody>
<tr>
<td><img src="image9.png" alt="Acoustic G." /></td>
<td><img src="image10.png" alt="Laser" /></td>
<td><img src="image11.png" alt="Bernoulli" /></td>
</tr>
</tbody>
</table>

Toward a new adhesive gripper

Toward a new adhesive gripper: skin and pulp

Supehydrophobic surface

Frog Fingerprint (SEM)
Conclusions

• Research activities
  – RobLog (7° EU project)
  – MicroGrippers exploiting structured surfaces
  – Extension of the grasping principles from micro to macro
  – Continue the research on compliant, actuated, hierarchical surfaces

• Search for partners for joint projects and exchange of students

• Keynote paper on “Grasping and handling devices and methods in assembly”
Active surfaces, materials and tools for assembly

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Research opportunities (2): NOT only a surface problem

- The problem is in part more complex, actually the underskin structure plays a key role in mating
- Hyerarchical structures are a solution:
  - Compliant Spines (insects) → Independent and adaptable structures
  - Tree structures (gecko) → Beam-plate structures (Lanzetta, Cutkosky)
- Transition from flexible to rigid is another solution

But we can exploit also non newtonian fluids. Ie. Rheopectic/ Thixotropic liquids increase/decrease in viscosity as stress over time increases.
Toward a new adhesive gripper

• Functions of the skin and side channels:
  – Roughness of the skin → to exert lateral friction
  – Roughness of the skin → supehydrophobic?
  – Side channels → collect, feed and remove water in order to avoid waterplaning
  – Side channels → hydrophillic areas quickly retract water to use it during climbing

• Functions of the pillars:
  – Supply the skin with additional dof in order to mate the pulp with the surface roughness (meso) also in case of corners, sharp edges etc..

• Functions of the pulp:
  – Mate the pulp with the surface roughness (micro)
Feeder (4): References

- Mike Brokowski, Michael Peshkin Ken Goldberg, 1993, Curved fences for part alignment, IEEE International Conference on Robotics and Automation
Gripper to grasp (5): References

- Hesselbach, Jürgen; Wrege, Jan; Raatz, Annika, 2007, Micro Handling Devices Supported by Electrostatic Forces, CIRP Annals - Manufacturing Technology, Elsevier Vol. 56/1, 45-48
- G. Reinhart, J. Hoeppner, Non-Contact Handling Using High-Intensity Ultrasonics, CIRP Annals - Manufacturing Technology, Volume 49, Issue 1, 2000, Pages 5-8
Gripper to release (3) at microscale


Please, find further references in