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Development of Modular and Active Impact Protection System for Humanoids Falling

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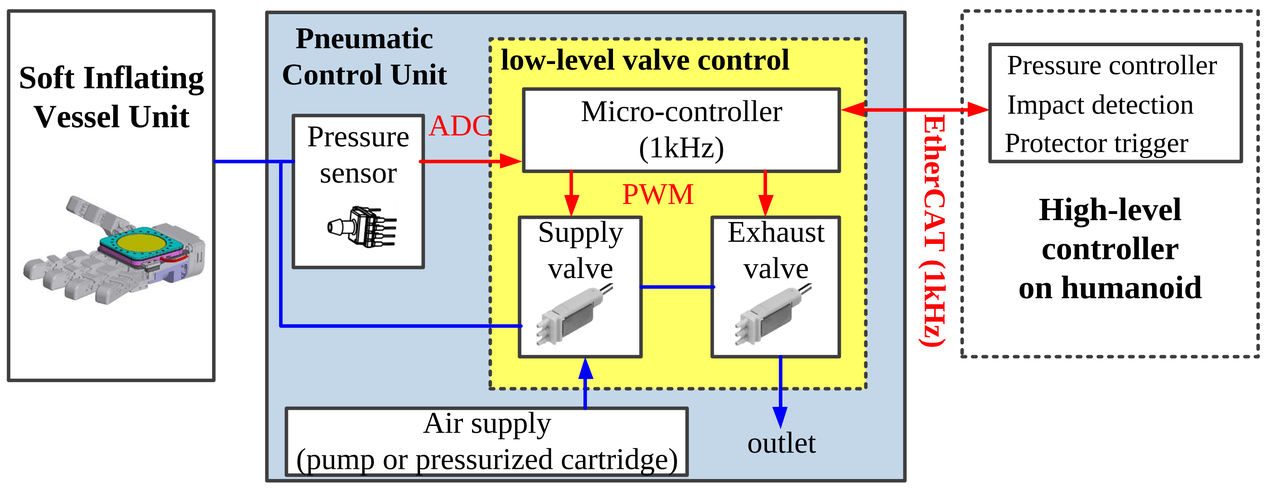
INTRODUCTION

- We report on the development of a pneumatically-controlled soft impact protection system that may be applied to a variety of practical humanoid robots.
- Inspired both by the control and the soft robotics design approach, the following requirements are defined and set as a goal of the development:
  - * softness to protect from the impact
  - * sensorized and active control
  - * modular, customizable, and light weight design
  - * cost effectiveness: low-cost, reusable, easily repairable
- We develop a pneumatically-controlled impact protection system consisted of two modular units:
  ** a soft inflating vessel* and ** a pneumatic pressure controller*
  which can be flexibly designed so as to be easily mounted at the point of interests and consolidated with a high-level controller through EtherCAT.

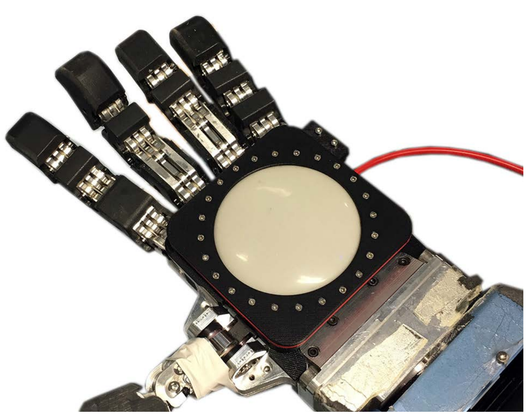
SYSTEM OVERVIEW: ACTIVE-SOFT IMPACT PROTECTION SYSTEM



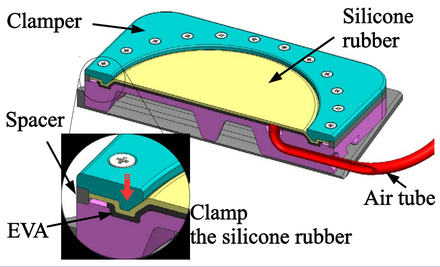
- Targeted features

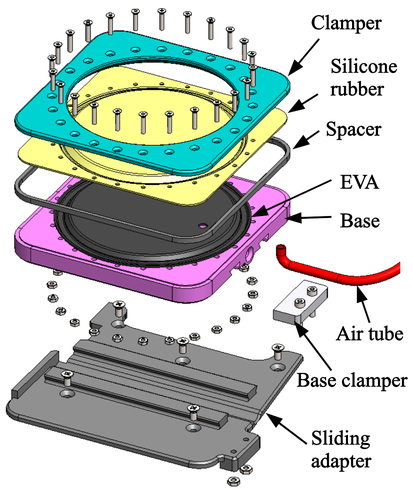
1) *Trigger from a high-level controller:* the soft vessel is able to inflate and remain in a stable inflation mode when the action is requested.
2) *Impact detection:* the actual impact instance can be automatically detected.
3) *Pressure control of soft vessel:* once the impact is detected, the vessel is able to deflate to dissipate the impact energy and oscillations.

DEGISN OF SOFT INFLATING VESSEL UNIT



Frame: 100 x 100 x 13.5 mm, 86.6g
Silicon Rubber: 1mm thickness, Shore A50



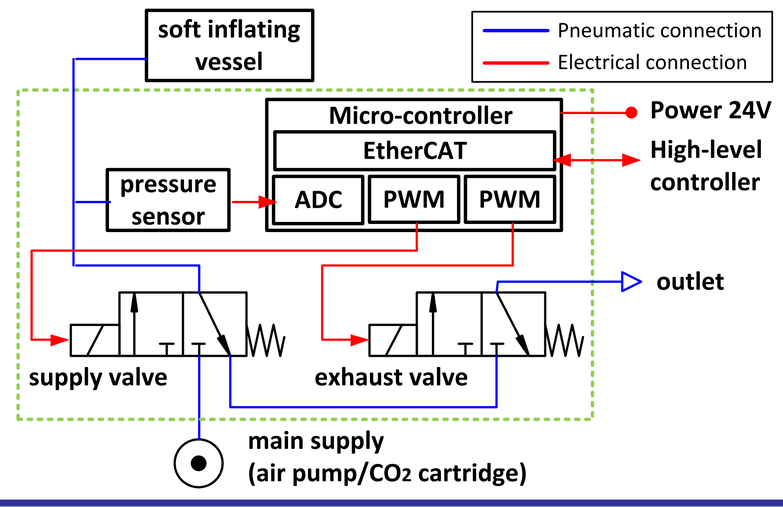


- 3D-printed Rapid Proto-typing
- Light weight and compact size
  (Design example for WALK-MAN Hands)
- Soft material (Silicon rubber) is capable to - inflate 40mm height (without yielding)
  - endure max. 3000 N
- Minimum number of parts, easy to maintain
- No air leakage

ACITVE PRESSURE CONTROL UNIT

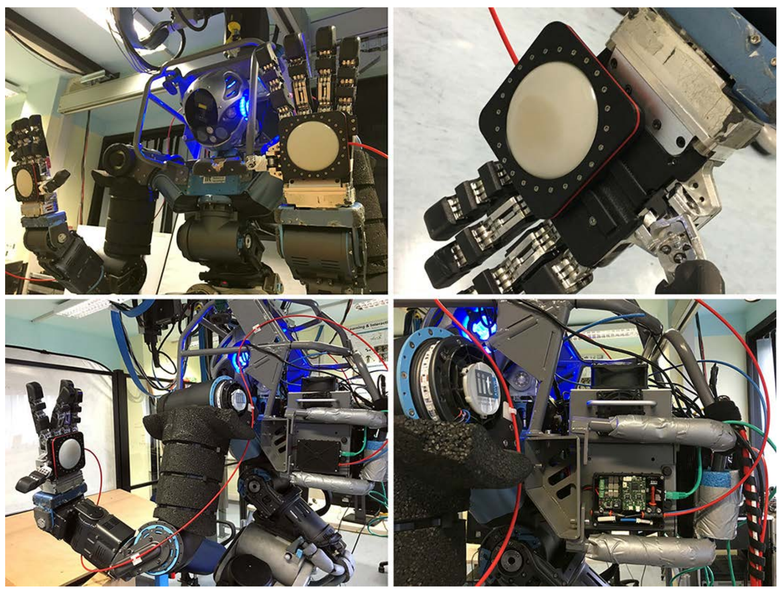
[redacted]

150x80x30mm, 120 g

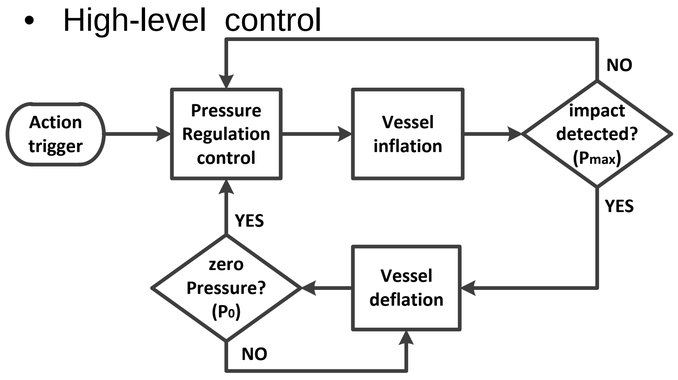


- Light, compact, and sensorized
- General use for pneumatic devices
- Micro-controller (ARM Cortex-M4F)
- Low-level pressure control by PWMs
- Pressure sensing by a 16-bit ADC in the range between 0-150 psi (0.23×10^{-2} psi)
- High-level control through
  1 kHz EtherCAT communication

IMPLEMENTATION ON WALK-MAN HANDS



- High-level control



Bang-Bang pressure control with dead-zone

$$V_{\text{action}} = \begin{cases} inflate & ,if\ (P_{ref} - P_{sensed}) > \delta_{threshold} \\ deflate & ,if\ (P_{ref} - P_{sensed}) < -\delta_{threshold} \\ valve\ off & ,if\ -\delta_{threshold} \leq (P_{ref} - P_{sensed}) \leq \delta_{threshold} \end{cases}$$

- Realtime control in high-level PC (1kHz)
- Inflating action controlled by pressure
  - ✓ Inflating speed: min. 0.6s
- Impact detection triggers deflating action
  - ✓ Damp out impact energy
- Impact reduction capability:
  - ✓ More than 30% impact reduction compared with a passive rubber protection (WALK-MAN hand)