



Aalto University  
School of Electrical  
Engineering

# Combining Information Across Perceptual Domains

Ville Kyrki  
Aalto University  
Finland

# Combining Tactile and Visual Perception

- **Why?**
- **Timescales and Perceptual Domains**
- **Real-Time View**
- **Discrete Time View**

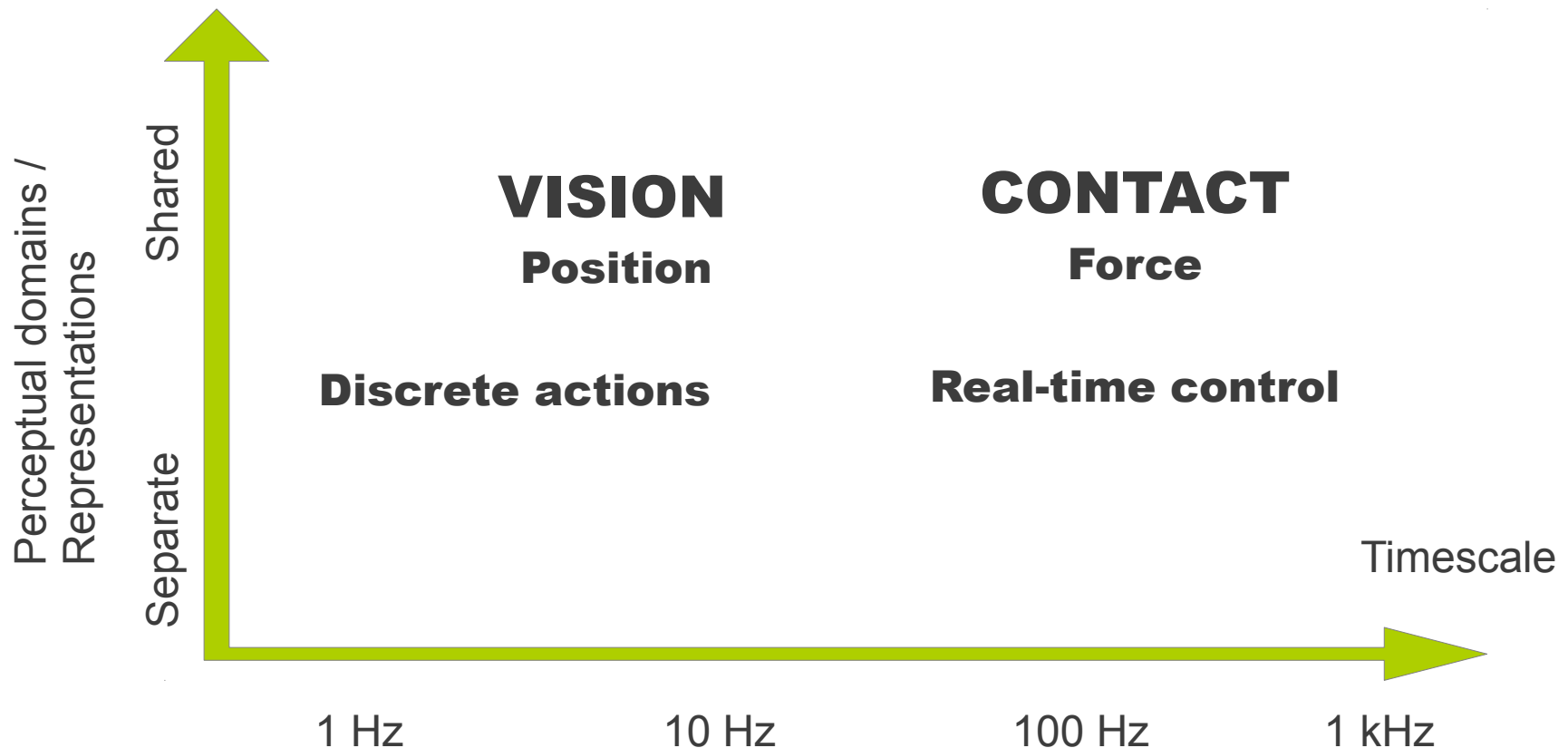
# Why?

- **Visual and contact sensors are very complementary**
- **Visual (non-contact) sensors**
  - Global, measure large area, relatively low accuracy
- **Contact sensors (e.g. F/T, tactile/pressure)**
  - Very local, accurate
    - E.g. tactile exploration slow

# Timescales and Relationship between Perceptual Domains



# Timescales and Relationship between Perceptual Domains



# Combining Vision and Contact in Real-Time Control

- **Switching / traded control**
  - “Time-multiplexing”
  - E.g. taking contact smoothly using visual sensor to anticipate contact before force control (Alkkiomäki et al. ICARCV 2006)
  - No need for shared representations.
  - Switching point dynamics often highly non-linear.

# Combining Vision and Contact in Real-Time Control

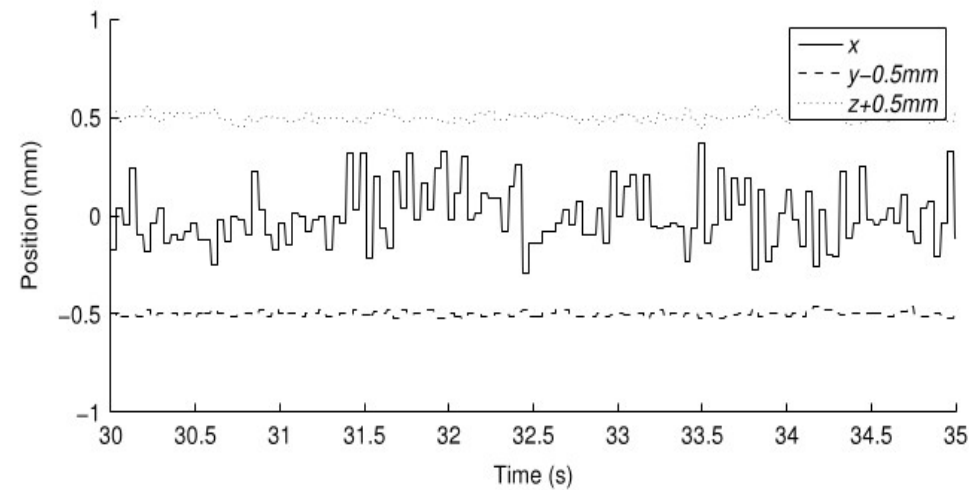
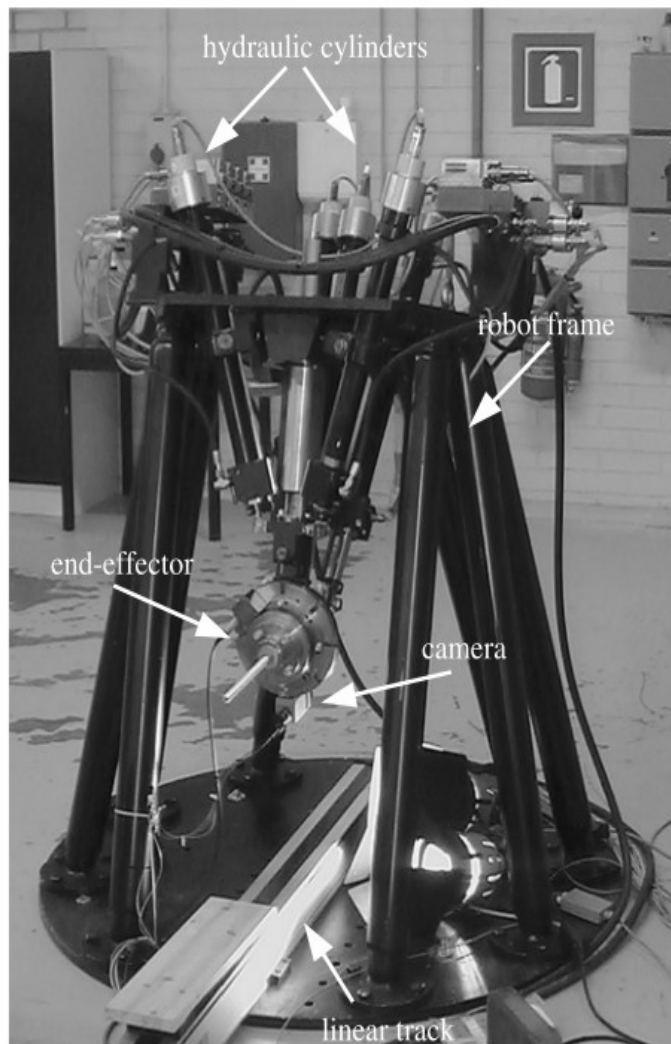
- **Hybrid control**
  - Using different sensors to control different DOFs
  - E.g. separate control of perpendicular force from tangential motion
  - Still no need for shared representations.



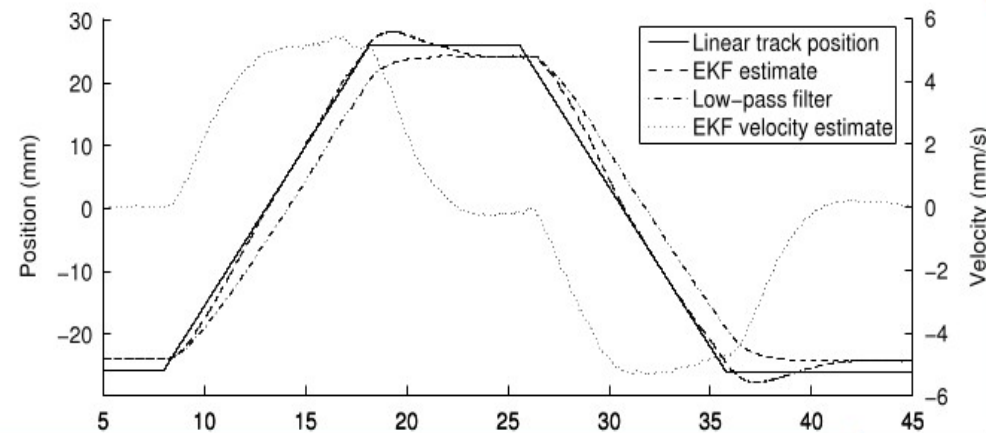
Alkkiomäki et al. ICAR 2009

# Combining Vision and Contact in Real-Time Control

- **Shared control**
  - Using several sensors for the same DOF
  - Challenging
    - Shared model needed
    - Different sampling rates, different latencies
    - Different **uncertainty** structure (actually reason why this is useful)
  - But worthwhile, can greatly improve e.g. position accuracy (typically 2x - 5x)



**Fig. 6.** Effect of measurement noise.



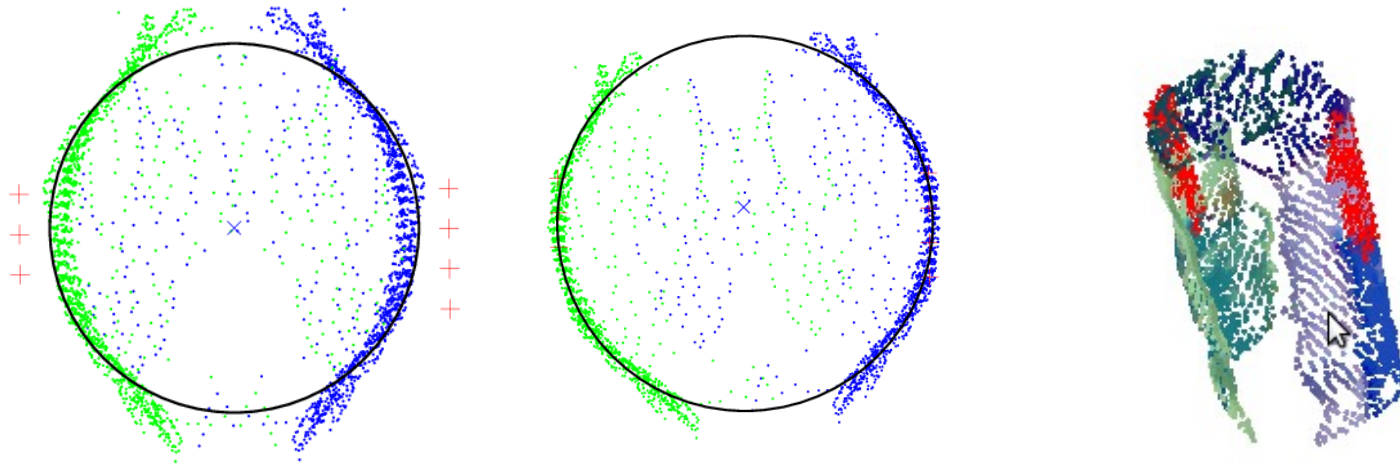
# Combining Vision and Contact in Discrete Actions

- **Temporal division**
  - E.g. grasping by initial visual localization and tactile corrections
  - Surprisingly little vision is needed



# Combining Vision and Contact in Discrete Actions

- **Shared representation, no loop closing**
  - E.g. Object shape modeling with symmetry assumptions
  - Major advantage not in local improvement but in increased accuracy for the global structure (symmetry)



# Combining Vision and Contact in Discrete Actions

- **Shared representation with loop closing**
  - E.g. Object localization to maximize grasp stability or information gain
  - Model for dynamics needed
    - Leads towards POMDPs
    - Approximate solutions
  - Uncertainty modeling crucial



Nikandrova, Laaksonen, Kyrki  
RAS 2014

# Conclusion and Challenges

- **Important ingredients**
  - Complementary sensors
  - Uncertainty modeling
- **Shared representation not always necessary**
- **Learned models of complex dynamics might be needed**



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# Thank You!

Ville Kyrki  
Aalto University  
Helsinki, Finland  
[Ville.Kyrki@aalto.fi](mailto:Ville.Kyrki@aalto.fi)