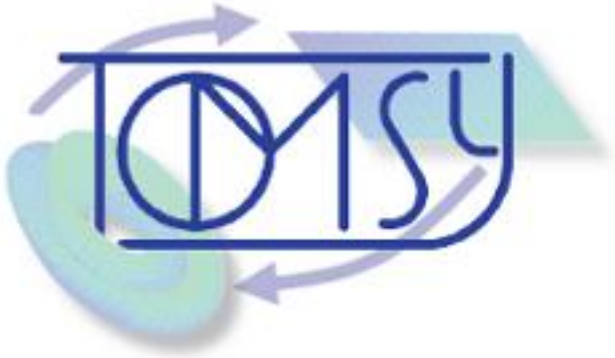

CogSys
Cognitive Systems

# TOMSY

## Topology Based Motion Synthesis for Dexterous Manipulation

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# TOMSY

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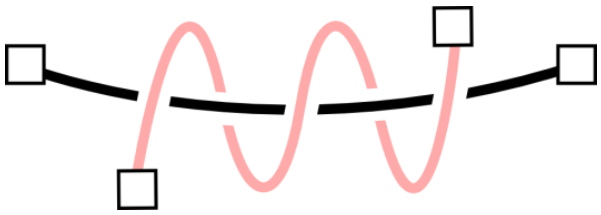
# TOMSY: Motivation and Idea

- Human performance currently beyond state of the art of robotics: carrying a person, tying shoes, putting on a shirt, complying to a dance partner.
- Humans are able to execute these tasks even in cases when one of our arms/hands/legs is injured or not functioning properly.
- Fundamental problem: classical approaches generate motion in a complete configuration or state space that do not scale.
  - This results in a computationally expensive state space optimization and exploration in very large search spaces.
  - Lack of generalizability of solutions.
  - Does not capture invariances.

**Using topology-based representations can address these problems.**



representing

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# TOMSY: Novelty and Approach

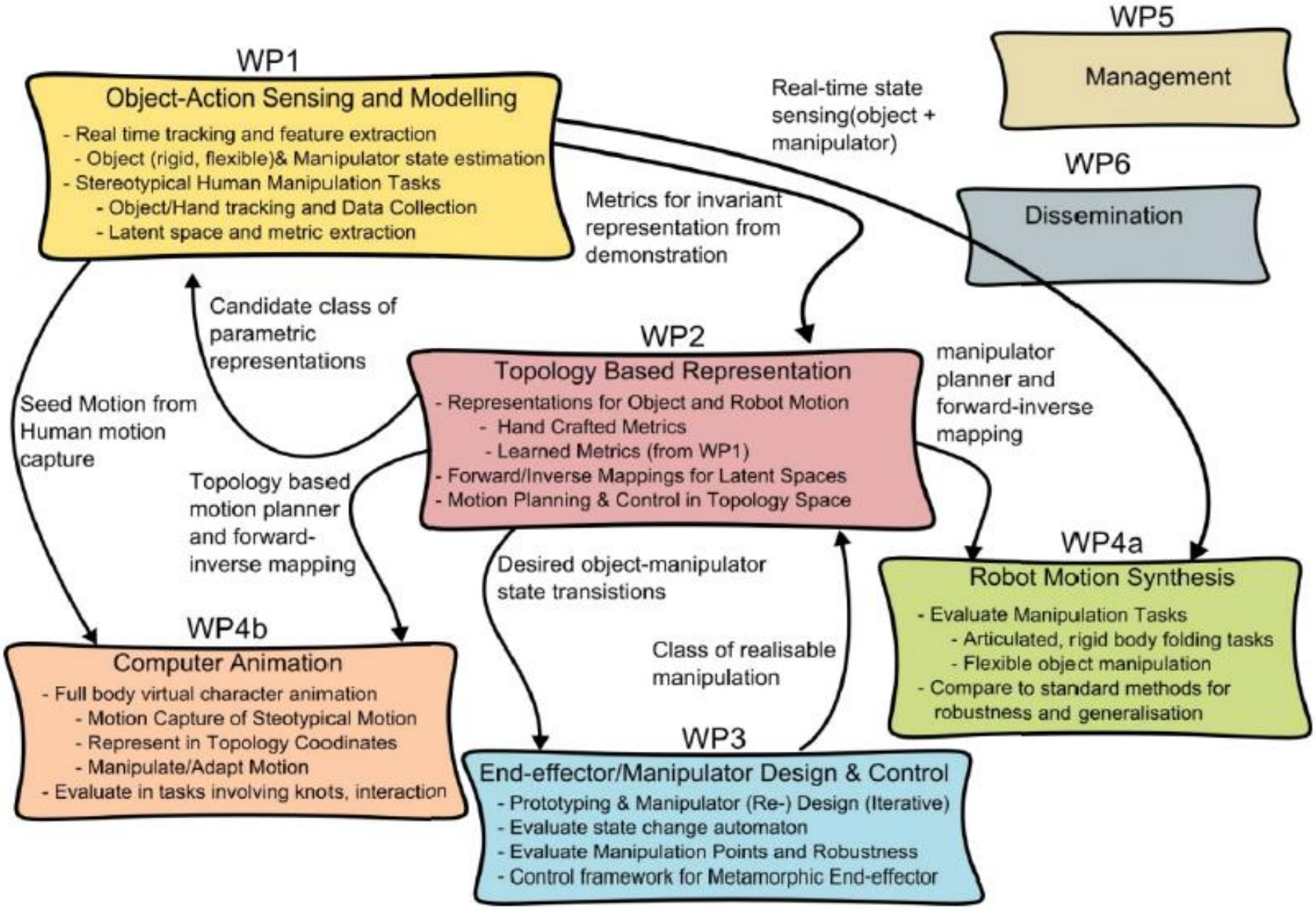
- Examples of topological constructs include
  - knot invariants for describing tangled object manipulation,
  - homology (measures of connectivity) of high-dimensional configuration spaces,
  - the discrete space of local plans.

Thus, representations based on topological equivalence classes are used to represent state-action dynamics in a way that exploits invariances.

- **The key novelty** is achieving flexibility at the level of:
  - Efficient sensor representation (for state estimation and action synthesis)
  - Development and learning of alternative metrics for planning and control
  - Actuator morphology for optimizing the action space

- Aim is to demonstrate robots, in physical world and simulation, that are capable of dexterous manipulation of flexible and articulated objects

# WP organisation



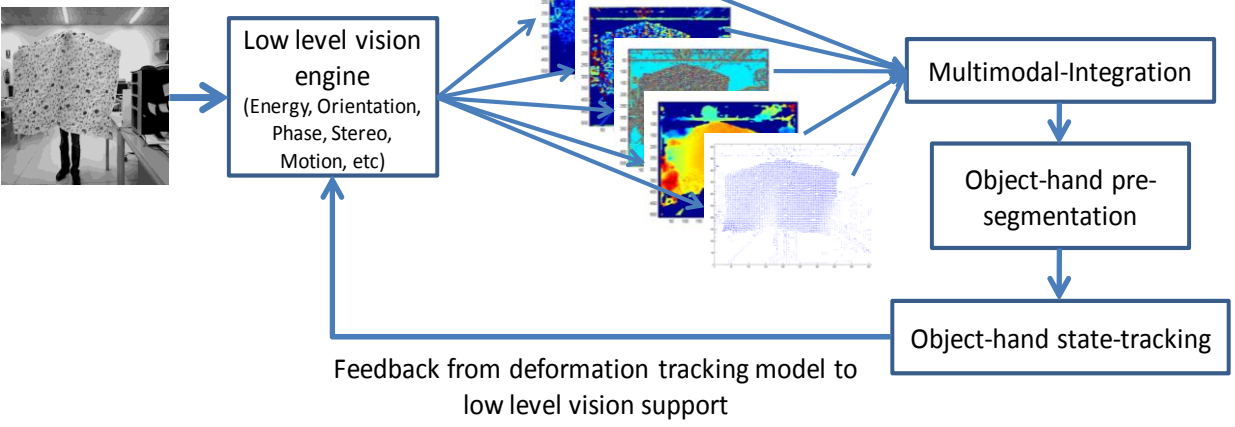
# TOMSY: Objectives

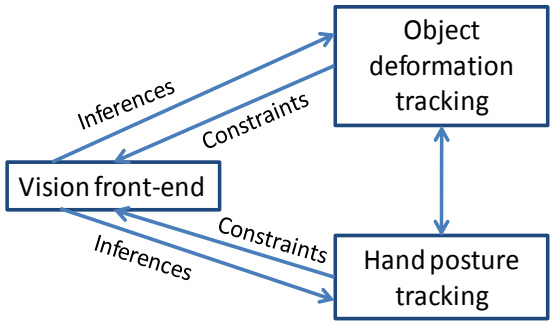
- **Objective 1:** Development of methodology of motion synthesis that distinguishes between the topology of the object from the detailed geometry – using the former to reduce the complexity of problems solved in the latter space.
- **Objective 2:** Embedding of this methodology in several robotic systems of variable topology involving sophisticated visual sensing and state of the art manipulation systems; and develop control strategies for animated characters.
- **Objective 3:** Understanding how people solve such problems, with the goal of trying to inform representations and problem formulation, and also to suggest primitives that will be used at the lower-level control system.
- **Objective 4**: Embedding of these methodologies in state-of-the-art methods for stochastic optimal control and planning under uncertainty – aiming towards a coherent integrated planning and motion control system coupling representations on all levels of abstraction.
- **Objective 5:** Development of methods that relate task topology with object features to end-effector/manipulator synthesis, leading to development of metamorphic end-effector/manipulator with variable topology.

# WP1: Efficient Object-Action Sensing and Modelling

**Scientific objectives and progress beyond state of the art:**

- Real-time deformable object tracking (based on multimodal low level cues, such as optical flow, stereo, local contrast descriptors, etc).
- Inferences and constraint integration engines for cross-validating extracted primitives with model-based structures



# WP1: Efficient Object-Action Sensing and Modelling

## Scientific objectives and progress beyond state of the art:

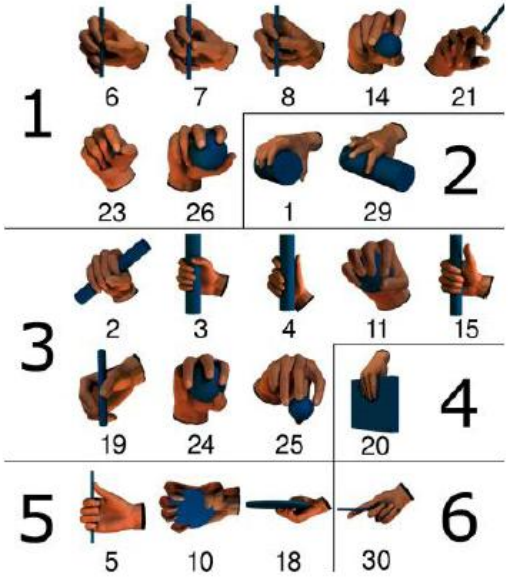
- Topological, generative, low-dimensional models of (dual) hand motion
- Topological, generative, low-dimensional models of (dual) hand action
- Contextual models of hand motion, hand action and objects in the hand

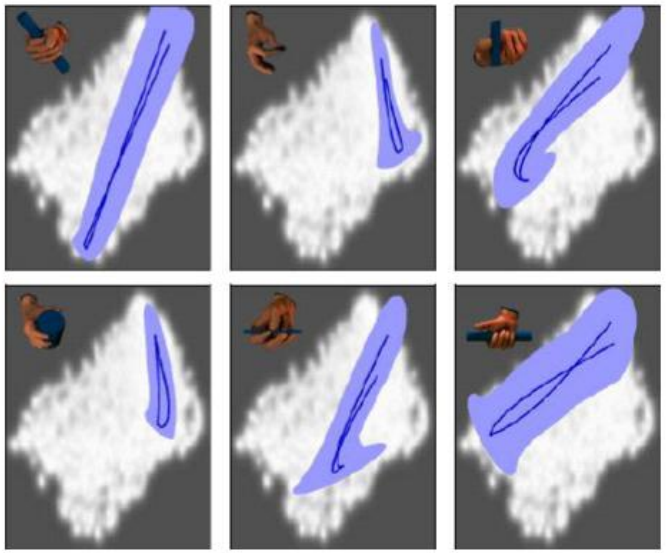
Lower-level

Interaction

Higher-level

Topological motion-action-object state spaces

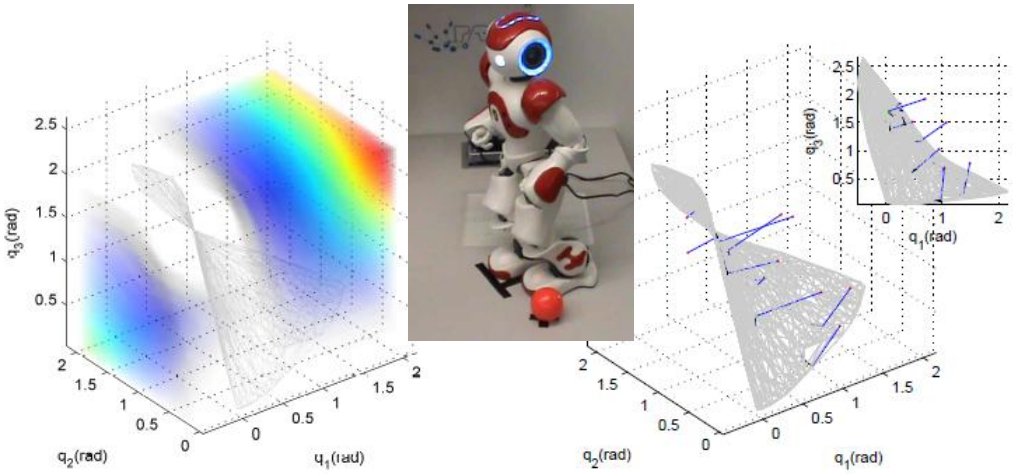


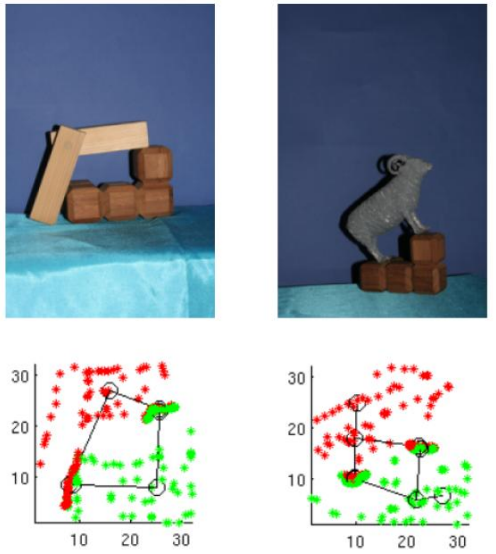
# WP2: Topological Representations for Motion Synthesis

- Develop and learn topology based representations for object and robot motion.
  - Start with existing metrics
  - Use learned metrics from WP1
- Develop forward/inverse mappings for latent spaces.
- Realize control and planning in topology space.

Reactive control on humanoid skill manifolds



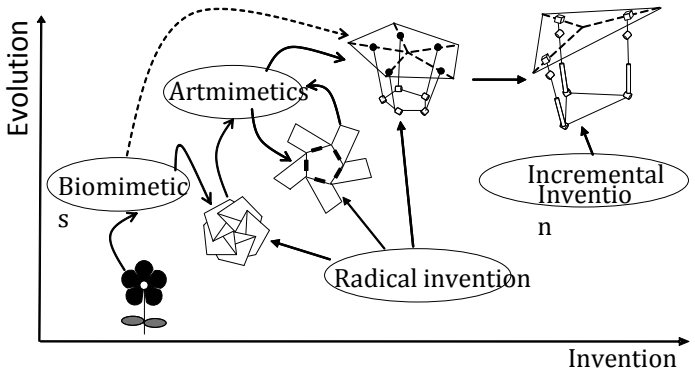

Semantic representations for complex manipulation

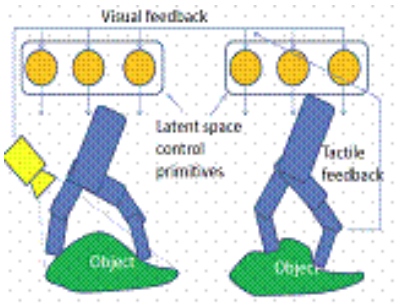


# WP3: End-effector/Manipulator Design and Control

## Scientific objectives and progress beyond state of the art:

- Mapping from topology space to actuator space and optimized control leading to high dexterous manipulation
- Generic mathematical approach for reconfigurable manipulator synthesis oriented from the task space
- Dexterous and evolutionary manipulator with variable topological phases




Design, Analysis

Control, Evaluation

**Manipulator synthesis framework** → **Prototyped End-effectors/Manipulator** → **Dexterous manipulation** → **Objects**

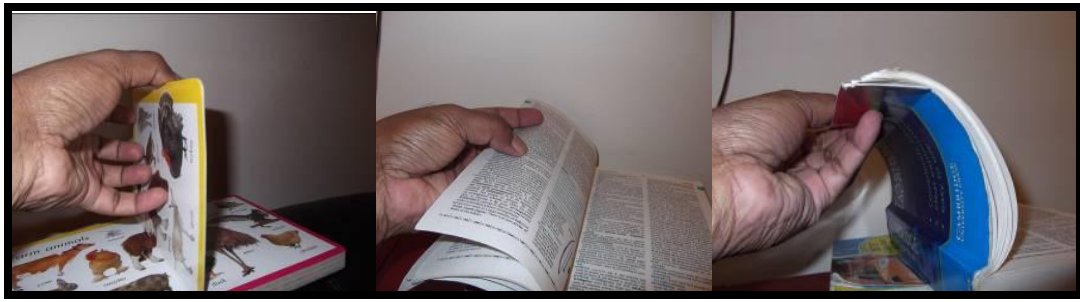
**Task Space**

# WP4: Integration, evaluation, benchmarking

Evaluation of:

- motion planning on **alternative representations** (topology-based)
  1. wrt handle **inherent redundancies** - arise when coupling different task representations
  2. wrt handle **uncertainties** - arise from noisy sensors and underspecified task constraints, e.g., **unspecified timing** of a manipulation task

- In tasks that include estimation, control and planning for:
  - Rigid blocks-world
  - Articulated objects
  - Flexible objects



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