A short treatise on robots' geometry, kinematics, and dynamics.

Author: Lekan Molu

Dissemination: Microsoft Research RL Group,
New York City, NY 10012

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Standard Texts – Modeling and Control

Robot Modeling and Control

Spong, Mark W., Seth Hutchinson, and Mathukumalli Vidyasagar. Robot modeling and control. Vol. 3. New York: Wiley, 2006.

Mathematical Modeling of Robots

Murray, R. M., Li, Z., & Sastry, S. S. (1994). A Mathematical Introduction to Robotic Manipulation. In Book (Vol. 29). https://doi.org/10.1.1.169.3957

Texts – Modeling, Control, and Mechanisms

Robot Modeling and Control

Lynch, K. M., & Park, F. C. (2017). Modern Robotics Mechanics, Planning, and Control.

Mechanisms' Kinematic Geometry

Hunt, Kenneth H., and Kenneth Henderson Hunt. Kinematic geometry of mechanisms. Vol. 7. Oxford University Press, USA, 1978.

Texts – Screws and Kinematics

Screw Theory

Ball, Robert Stawell. A Treatise on the Theory of Screws. Cambridge university press, 1998.

Mechanisms' Kinematic Geometry

Hunt, K. H. (2019). Structural Kinematics of In-Parallel-Actuated Robot-Arms. 105(December 1983), 705–712.

Topics

Mechanism Components

Freedoms, Constraints, and Mobility.

Kinematic Geometry: Pairs, linkages, and mechanisms.

Motion of linkages: Screws, and spatial motions.

Freedom and Mobility: Freedoms, unfreedoms, connectivity, mobility;

Grübler-Kutzbach's mobility criterion and examples.

Definition of a Mechanism

Definition (Lekan Molu)

A connection of mechanical, magnetic, electrical, hydraulic, or pneumatic components forming an assemblage, meant for moving rigid, semi-rigid or non-rigid bodies via a controlled generation of motion.

Kenneth Hunt (1978)

A means of *transmitting*, *controlling*, or *constraining* the relative movement.

Mechanisms

Joints and links

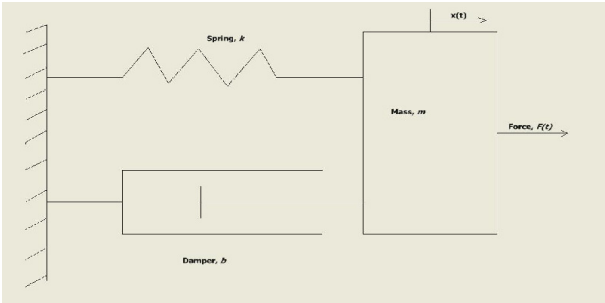
Joints are a result of the connecting points between rigid links. Links may be rigid mechanical parts, elastic, (vulcanized) rubber components, diaphragms, conveyor belts, spring-damper systems e.t.c.

Rigid Mechanism

Our chief focus will be rigid links, pairs, components and mechanisms in general.

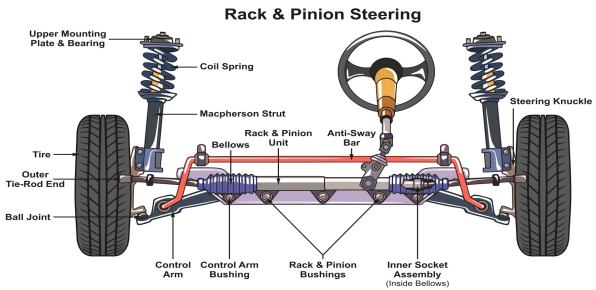
Mechanisms Examples

Spring-Mass-Damper System

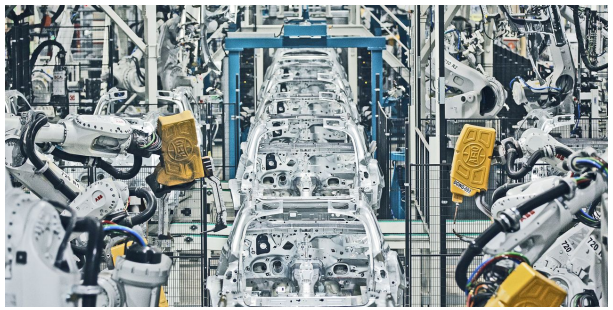


Excavator

Car suspension



Daimler Plant

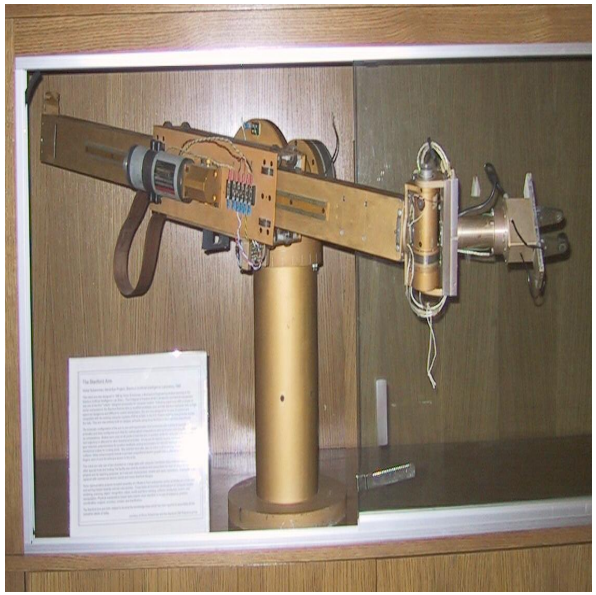


Robot Mechanisms

Definition (Ken Salisbury Jr., 1982)

"*[Robots are] our fascination with constructing mechanical analogues of ourselves... [this fascination] has led us to place all sorts of hopes and expectations in robot capabilities.*"

The Stäubli PUMA Robot (1956).



The Stanford Arm (Infolab 1969).

Long Walk Towards Direct Drive Robot Arms

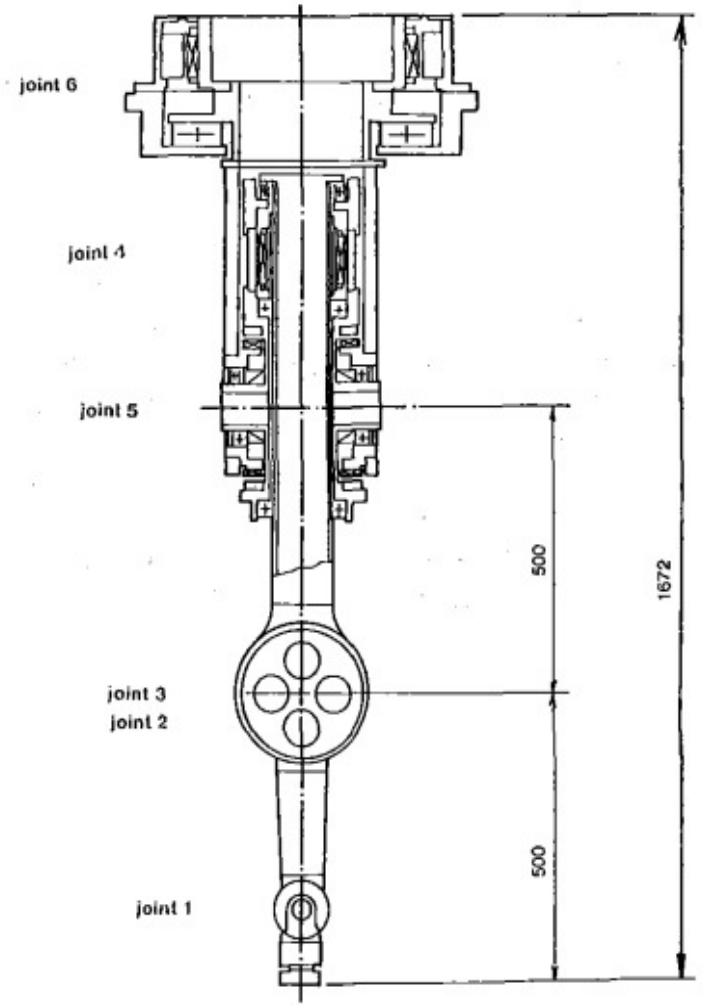
The 50's, 60's nd 70's witnessed use of hydraulics for (feedforward) position control.

For feedback control, force sensors and pressure sensors were used in closed-loop scenarios.

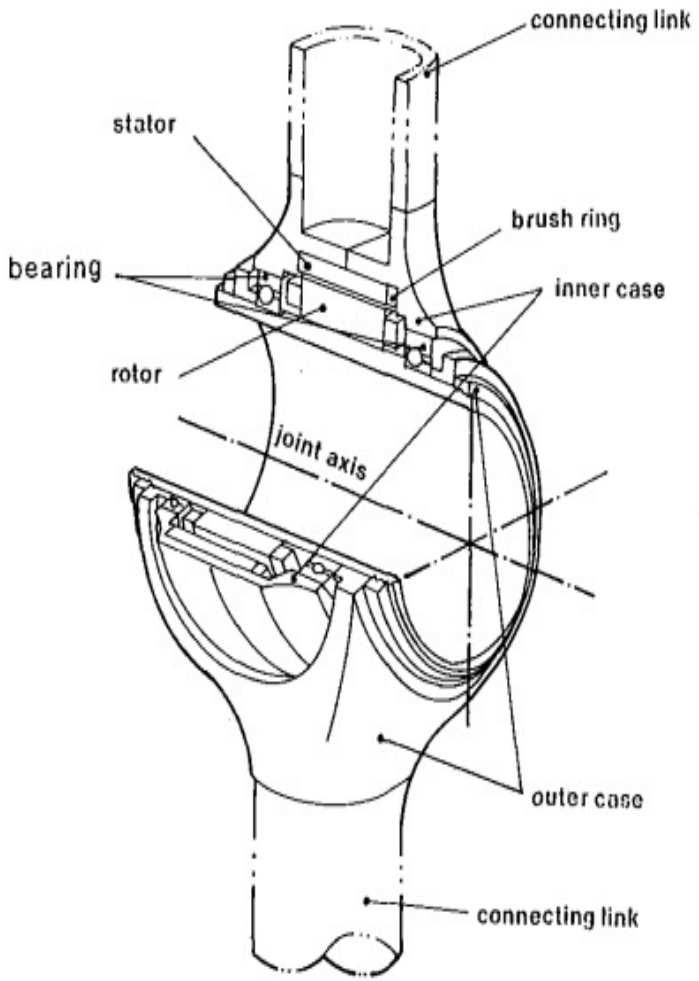
Electrical actuation meant that robots had to be operated at high speeds. Needs for gear reduction for safe operations at low speeds.

With gear reduction came backlash, friction, and associated expense.

Direct Drive Robot Mechanism: CMU DD I Arm

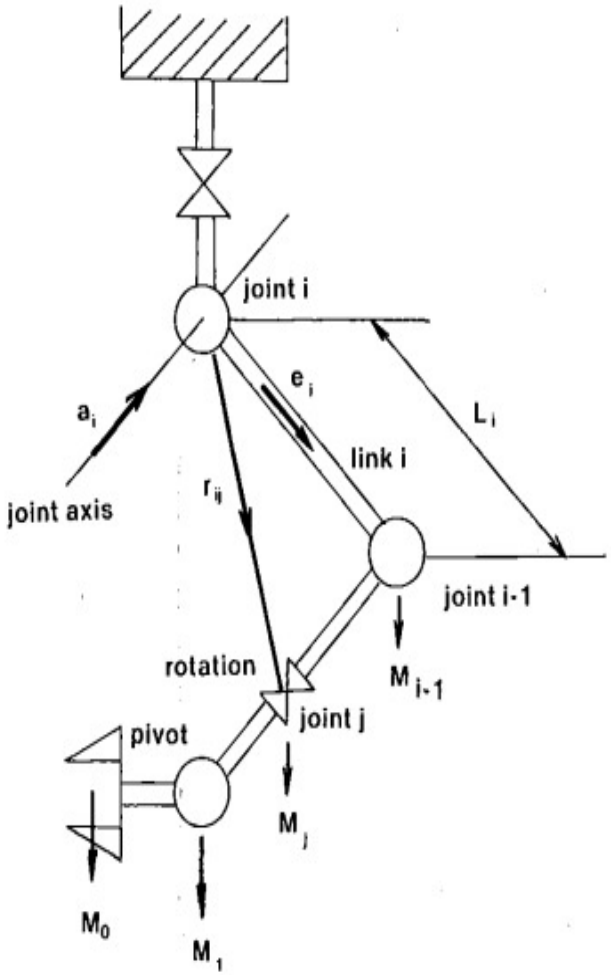


Arm Schematics Transmission

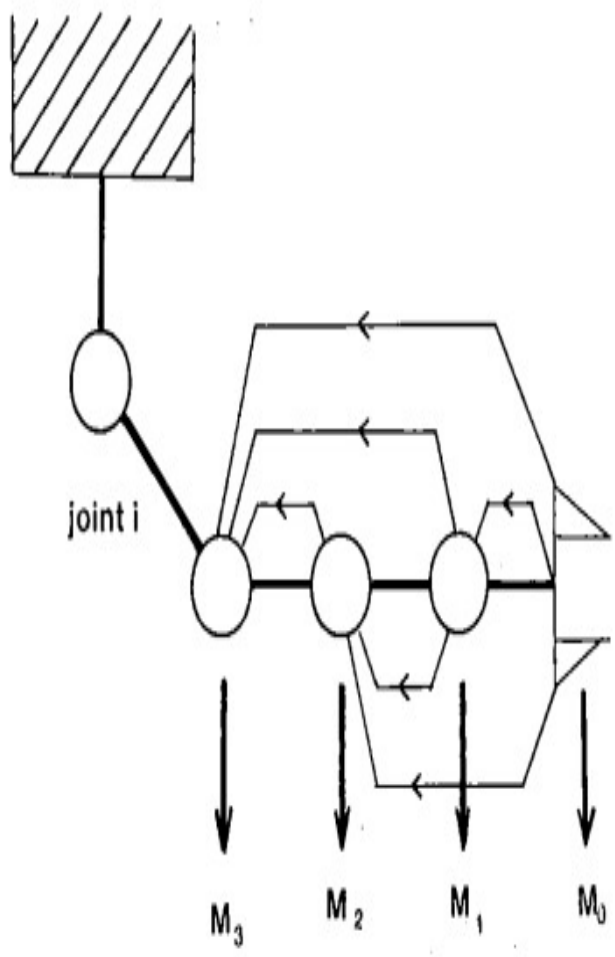


Joint schematic

Direct Drive Robot Mechanism: CMU DD I Arm



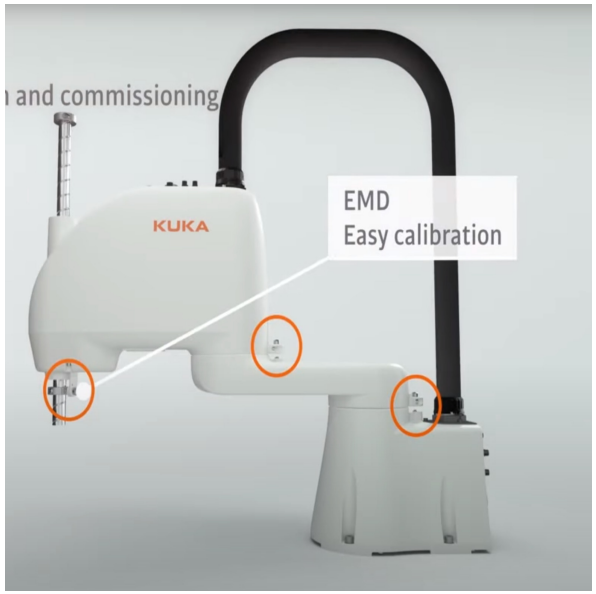
Kinematic model



Errors Transmission

Robot Mechanisms

The Adept One SCARA robot (Debuted 1984).



Kuka's SCARA arm, 2022. ©Kuka Robotics

Open Kinematic Chains

Chains

Open kinematic chains are based off the anthropomorphic construction of the human hand with cantilevered beam structures.

Chain Mechanism

Amplifies errors from waist to tool frame. Control difficult.

Control

Feedforward control: High power and precision hydraulic actuators for servo motors.
Sensory feedback control: Force sensing (Ernst, 1962).

Open Kinematic Chains

- Unstructured environmental interaction;
- Project MAC, MIT;
- Tomovic and Boni's pressure sensed grasp;
- Binary robot vision system (McCarthy et al, 1963).
- Stanford Manipulator;
- Boston arm;
- The AMF (American Machines and Foundry) arm;
- General electric's walking robot (1969)