Generating Control Hierarchies through Real World Experience

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Can Hierarchies Be Derived?

Hierarchical Control structures are commonly applied in robotics but built inconsistently. Different engineers may use different hierarchies for the same problem, producing inconsistency.

A clear understanding of what a hierarchy is and the semantics of what makes a hierarchy correct remain largely undefined. A unified theory would prove for more consistent and effective control.

DOSA (The Dependency-Oriented Structure Architect) uses an understanding of dependencies to build hierarchies. The methodology identifies possible dependencies through input-output relationships and then derives an order to explore hierarchical possibilities in. Then, DOSA builds the hierarchy and tests the possibilities that meet the dependency constraints.

Stage 1: Input-output Relationships

By exploring the range of effects of specific outputs, whether it affects a specific input can be determined. A table can be built like the one below, where the inputs are on the left and the output actuators above.

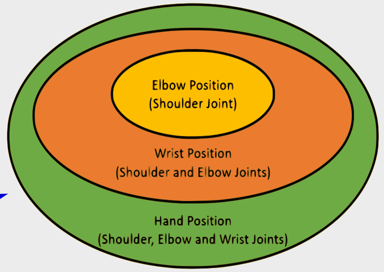
	Shoulder Joint	Elbow Joint	Wrist Joint
Elbow Position	Yes	No	No
Wrist Position	Yes	Yes	No
Hand Position	Yes	Yes	Yes

In control, a closed loop which controls a specific output must contribute to every input. Therefore, initial insight into possible hierarchies can be gleamed. Inputs with no crossover will have no relationship directly, for example.

Many tools can be used to determine an effect on an input by an output such as using a listener, sensitivity analysis or input-output analysis.

Stage 2: Derive Progressive Order

Possible hierarchies can exist where the actuators required for one input are a subset of the actuators of another. There, a hierarchy would keep to the closed-loop rule. The possible lowest candidates in a hierarchy should be resolved first.

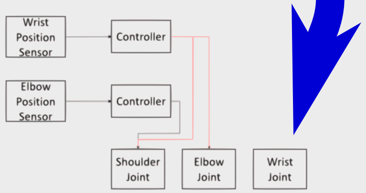

Elbow Position
(Shoulder Joint)
Wrist Position
(Shoulder and Elbow Joints)
Hand Position
(Shoulder, Elbow and Wrist Joints)

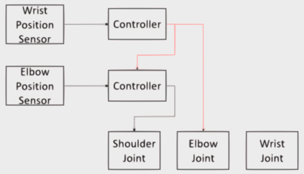
Order: Elbow Position, Wrist Position, Hand Position.

An input should only be added to the hierarchy when all possible subordinate hierarchical candidates have been considered first. This allows one to derive a simple logical order, which for the example table in step 1 is shown above.

Stage 3: Build and Optimise

Now, a hierarchy can be progressively built in the order derived in stage 2. Each input is added and possible connections for a controller that meet the closed-loop requirements are tested against each other. The one that best minimises error is kept. Below is an example of some possibilities. The controller at the top is added and the red lines indicate the possible control outputs for that controller.

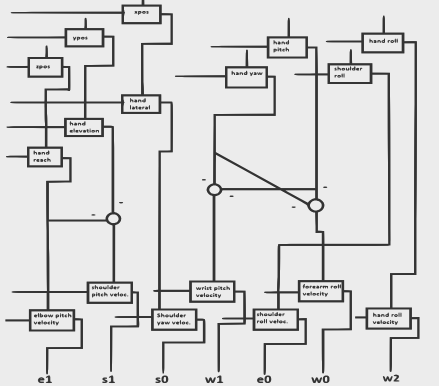




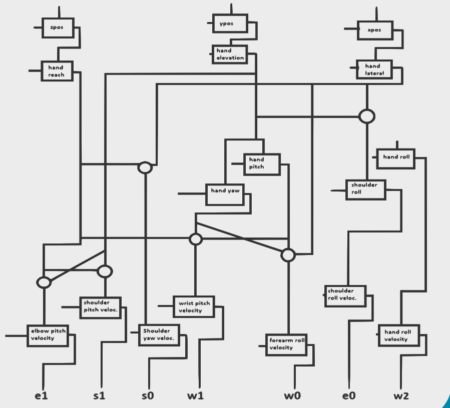
DOSA's hierarchy For a robot arm

DOSA was performed by hand to produce an alternate hierarchy for LCS III's arm. The hierarchies have many similarities, sharing most connections.

Living Control Systems III



DOSA


zpos
ypos
xpos
hand elevation
hand reach
hand lateral
hand pitch
hand roll
hand yaw
shoulder roll
shoulder pitch veloc.
wrist pitch velocity
shoulder roll veloc.
elbow pitch velocity
Shoulder yaw veloc.
forearm roll velocity
hand roll velocity
e1
s1
s0
w1
w0
e0
w2