Human behaviour modelling for teleoperation

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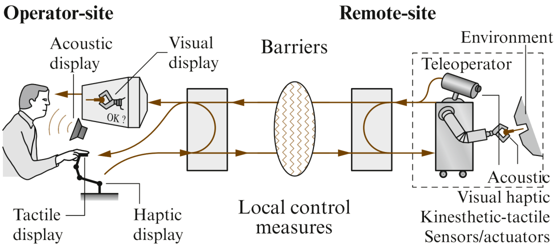
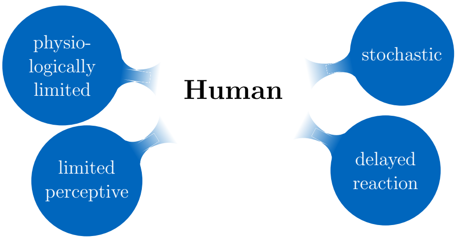
Human aspects in teleoperation

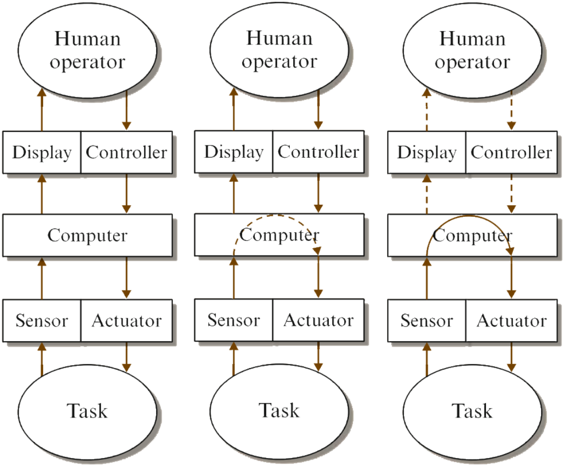
Telerobots allow for complex tasks in unstructured environments



Human behaviour is relevant for control design [She92]



Levels of human-in-the-loop involvement



Direct - Shared - Supervisory Control

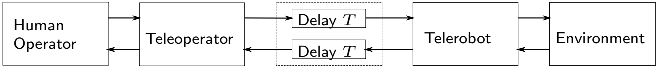
Human actuation in bilateral telemanipualtion

Haptic interface: Human is an impedance
Human motion is inherently dissipative [RIM99]
The passivation of delayed communication leads to a distorted environment display

A dissipative system is locally stable for a negative semidefinite supply rate $s\left(u(t), y(t)\right)$

$$\dot{V}(x(t)) \leq s(u(t), y(t)),$$

The interconnection of dissipative systems is again a dissipative system with supply rate $s(t) = \sum_i s_i(t)$



A closed-loop dissipative system with a non-passive communication channel has reduced environment distortion [HB12]

Human Perception Resolution

Passivation of delayed communication:

- Hard contacts are displayed softer
- Telerobot seems to be more inert

Just noticeable difference (JND) for inertias: 21%; for stiffness: 8%

Displayed impedances for free motion and hard contact

$$Z_{\mathrm{m}}^{*} = \frac{bT}{2} s \ , \quad Z_{\mathrm{k}}^{*} = \frac{2k_e b}{2bk_e T} \frac{1}{s}$$

Tuning the wave impedance b gives conflictive results

Just not noticeable deviation in stiffness

$$b > (1 - \mathsf{JND}_k) \frac{k_e T}{2}$$

Perceived stiffness is not compromised, inertia display becomes more realistic [HB12]

Human trajectory planning: Zero-order hold

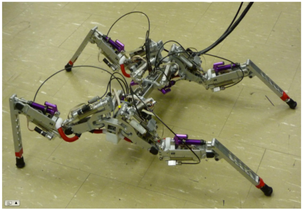
Forward-looking planning requires few changes in direction

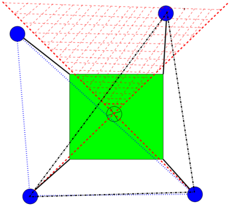
Shared control of quadruped robot: Human controls front legs

Automatic positioning of rear legs to achieve

- Gait stability during rear leg change
- Gait stability for the next front leg steps

Prediction of the next step allows for a large step size



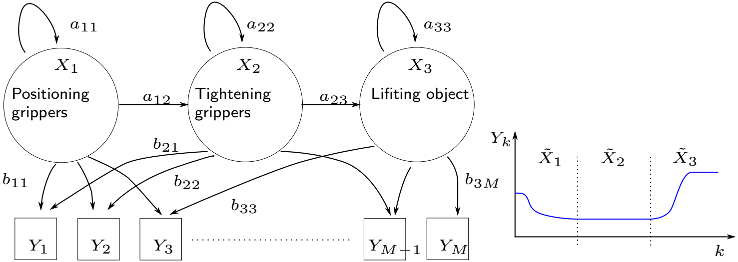


Zero-order hold extrapolation is suitable for a small prediction horizon [CDE13]

Human motion sequence learning

Traded control: robot automatically executes repetitive tasks
Learning "good" motion sequences by demonstration
Human motion is a doubly stochastic process: Hidden Markov Models
States (intention) are estimated from the observations (motion)
Selection of the best learned trajectory

$$\max P(\lambda_r \mid O^*) = \frac{P(O^* \mid \lambda_r)P(\lambda_r)}{P(O*)}\ ,\ \forall r = 1...R$$



Elimination of minor uncertainties, trading of control not perceivable [YX94]

Human actuation with pointing interfaces

A passive human ensures stability with delayed communication and correct positioning in partially controlled robot-swarms

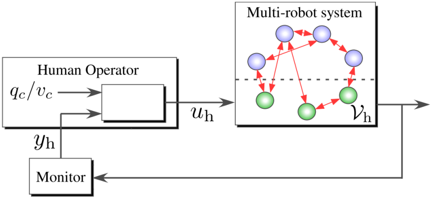
The *VITE* model generates human arm trajectories

$$\dot{\nu} = \gamma(-\nu + x_{\mathrm{d}} - x)$$
$$\dot{x} = G(t)\max(0, \nu)$$

Target position x_{d}, actual position x, gains γ, G

Passive for no position overshoot $\nu \geq 0$ [VZ13]

System identification: passive at low frequencies $f < 1$[rad/s] [HCF15]



Forced-choice decision making

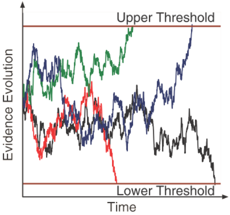
Supervision of multiple surveillance agents

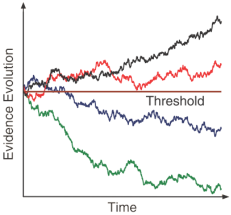
Modelling of human decision making for incident identification and estimation of the evaluation time

Choice between two alternatives by accumulation of evidence x

$$dx(t) = \mu dt + \sigma dW(t),$$

with the accumulation rate μ, the diffusion rate σ and the Wiener process $W(t)$





Pre-selection and scheduling of tasks reduces human resource allocation [PST+15]

Conclusion

Human modelling in teleoperation can

- ensure stability with a human-in-the-loop
- achieve a more realistic display of the environment
- improve manipulation skill
- support decision making

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