

Progress Report on Human-robot Team Attitude Synchronization



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Human-Robot team Control

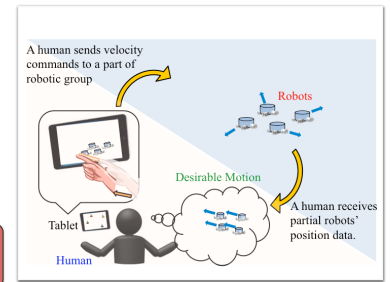
Computer, Robot

Data processing

Human

Flexibility

Human-Robot team



Position and velocity synchronization

Attitude Synchronization on SO(3)

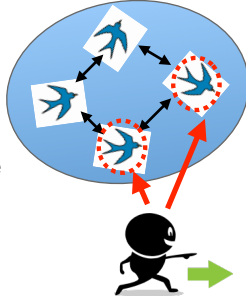
Previous Topic

Assumption

- Human Passivity

Previous Discussion

Attitude Synchronizaiton can be achieved theoretically



Problems

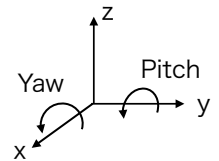
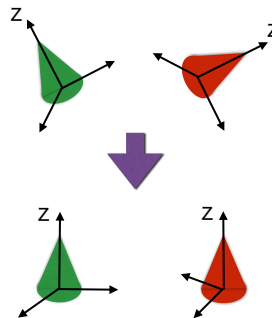
- Complexity of Human Command
- Difficulties in experiment

Reduction to 2 DOF

3 DOF → 2 DOF

Yaw, Pitch, ~~Roll~~

z-axis synchronization

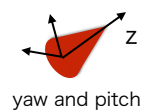
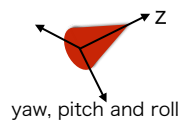


Human just need to consider z-axis

more simple problem

Algorithm

- Arbitrary orientation
- Describing z-axis by yawing and pitching
- Average of yaw and pitch angles of all operational agents
- Reconstructing average orientation of all operational agents
- Generating control input to synchronize average orientation with world frame
- Iterating 2. to 5.



z-axis synchronization

Arbitrary orientation

$$R = \begin{bmatrix} r_{11} & r_{12} & r_{13} \\ r_{21} & r_{22} & r_{23} \\ r_{31} & r_{32} & r_{33} \end{bmatrix}$$

z-axis

$$\xi_z = \begin{bmatrix} r_{13} \\ r_{23} \\ r_{33} \end{bmatrix}$$

Arbitrary orientation by yawing and pitching

$$R_{yp} = R_{y,\theta} R_{x,\psi}$$

$$= \begin{bmatrix} \cos \theta & 0 & \sin \theta \\ 0 & 1 & 0 \\ -\sin \theta & 0 & \cos \theta \end{bmatrix} \begin{bmatrix} 1 & 0 & 0 \\ 0 & \cos \psi & -\sin \psi \\ 0 & \sin \psi & \cos \psi \end{bmatrix}$$

$$= \begin{bmatrix} \cos \theta & \sin \theta \sin \psi & \sin \theta \cos \psi \\ 0 & \cos \psi & -\sin \psi \\ -\sin \theta & \cos \theta \sin \psi & \cos \theta \cos \psi \end{bmatrix}$$

z-axis

$$\xi_{ypz} = \begin{bmatrix} S_\theta C_\psi \\ -S_\psi \\ C_\theta C_\psi \end{bmatrix}$$

🏠 Average yaw and pitch angles

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Arbitrary z-axis is realized by only yawing and pitching

$$\text{from } \xi_z = \begin{bmatrix} r_{13} \\ r_{23} \\ r_{33} \end{bmatrix} \quad \xi_{ypz} = \begin{bmatrix} S_\theta C_\psi \\ -S_\psi \\ C_\theta C_\psi \end{bmatrix}$$

$$\begin{aligned} r_{13} &= S_\theta C_\psi & \theta &= \arctan\left(\frac{r_{13}}{r_{33}}\right) \\ r_{23} &= -S_\psi & \psi &= \arcsin(-r_{12}) \\ r_{33} &= C_\theta C_\psi \end{aligned}$$

Average of operational agents' yaw and pitch angles

$$\tilde{\psi} = \frac{1}{|N_h|} \sum_{i \in N_h} \psi_i \quad \tilde{\theta} = \frac{1}{|N_h|} \sum_{i \in N_h} \theta_i$$

N_h : set of operational agents

$|N_h|$: the number of elements

🏠 Reconstruction of Average Orientation

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Average Orientation

$$\tilde{R} = R_{y, \tilde{\theta}} R_{x, \tilde{\psi}}$$

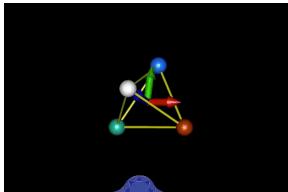
Control input to fit \tilde{R} to world frame

$$\tilde{\omega} = \text{sk}(\tilde{R})^\vee$$

z-axis synchronization can be achieved by $\tilde{\omega}$ even though x and y-axis are not synchronized with world frame

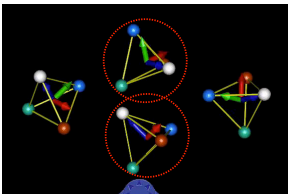
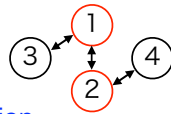
🏠 Simulation

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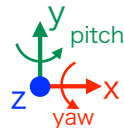
Average orientation

Human tries to synchronize this orientation with world frame



Real orientation

All z-axis achieved synchronization



🏠 Next task

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- Perfect synchronization by simple command
- \tilde{R} and average orientation in human brain might not agree completely
 - ➡ Stochastic disturbances?
- Not simple enough for human
 - ➡ Human cannot deal with many agents