Note Title 11/29/2007

Control :

1) Independent joint control

2) "Centralized" control taking

SISO into account full Dyn. of the robot

MIMO $\underline{\tau} = M(\underline{\theta})\,\ddot{\underline{\theta}} + \underline{V}(\underline{\theta}, \dot{\underline{\theta}}) + G(\underline{\theta})$

$+ F(\underline{\theta}, \dot{\underline{\theta}})$

Partitioned Control + Traj following control

(INVERSE DYNAMICS Controller)

$$\underline{\tau} = \alpha \, \underline{\tau}' + \underline{\beta}$$

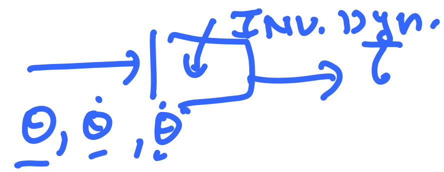
matrix

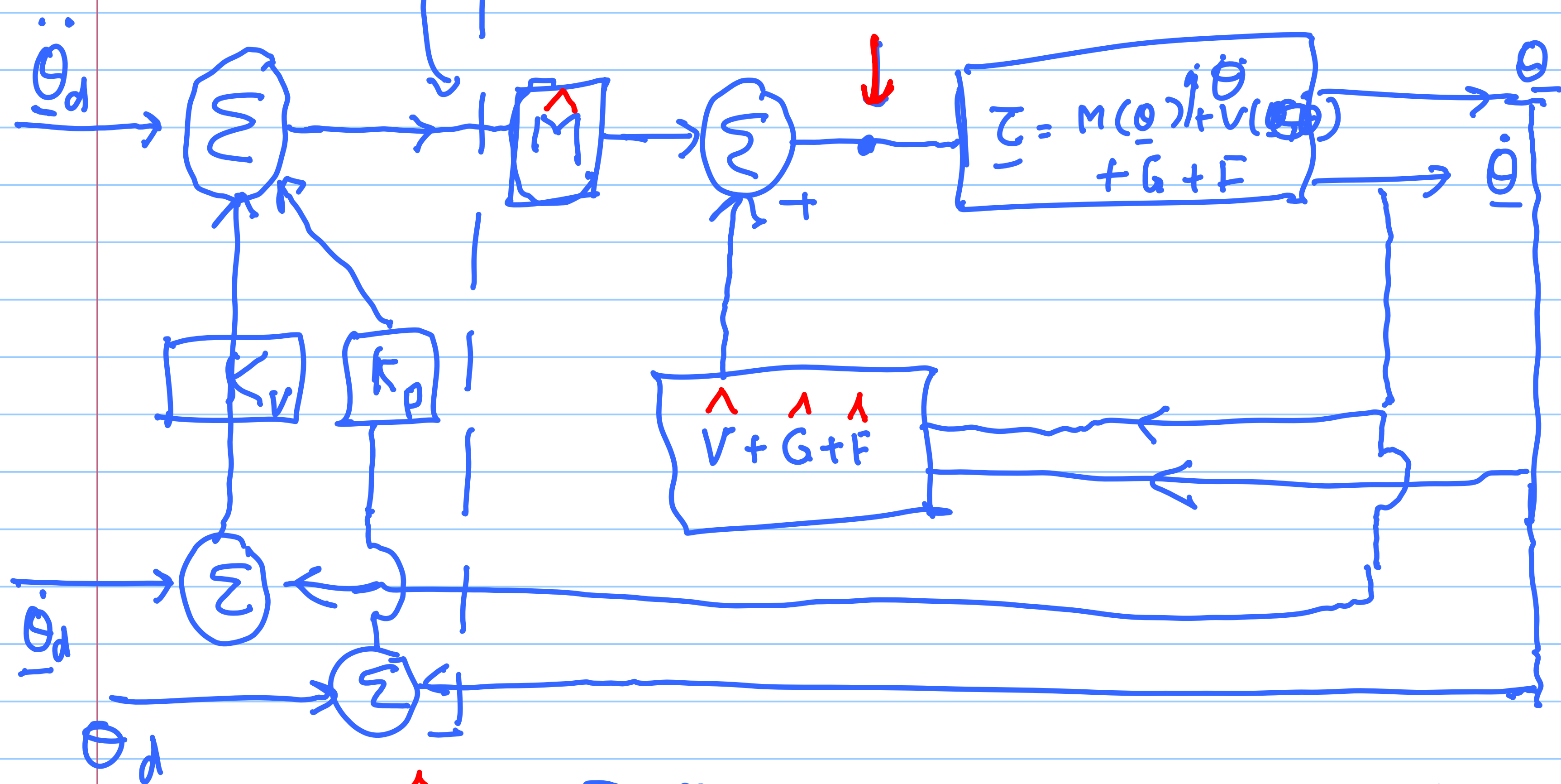
$$\alpha = M(\underline{\theta}), \quad \underline{\beta} = \underline{V} + \underline{G} + \underline{F}$$

$$\tau' = \begin{pmatrix} \ddot{\theta}_1 \\ \ddot{\theta}_2 \\ \vdots \\ \ddot{\theta}_n \end{pmatrix}$$

Controller

$\underline{\tau}' = \underline{\ddot{\theta}}$





$$\hat{M}(\underline{\theta}) \left[\underline{\ddot{\theta}}_d + K_p (\underline{\theta}_d - \underline{\theta}) + K_v (\underline{\dot{\theta}}_d - \underline{\dot{\theta}}) \right]_{\tau'}$$

↑ Looking at the red arrow:

$$+\cancel{\hat{V}} + \cancel{\hat{G}} + \cancel{\hat{F}} = M(\underline{\theta})\ddot{\underline{\theta}} + \cancel{V} + \cancel{G} + \cancel{F}$$

$$\underline{E} = \underline{\theta}_d - \underline{\theta}$$

$$\Longleftrightarrow \quad M(\underline{\theta})\left[\ddot{\underline{E}} + K_v \dot{\underline{E}} + K_p \underline{E}\right] = \underline{0}$$

$$\Longleftrightarrow \quad \ddot{E} + K_v \dot{E} + K_p \underline{E} = 0$$

$\Big\Vert$ Choose K_v & K_p to be diagonal matrices

$$\xrightarrow{i=1,N} \quad \ddot{e}_i + k_{v_i}\dot{e}_i + k_{p_i}\dot{e}_i = 0$$

choose k_{v_i}, k_{p_i} for critical damping.

(1) <u>Key assumption:</u> | precise knowledge of syst. dynamic models.

if the (known / estimated) values are indicated by ^ quant.

closed loop eqn will be:

$$\hat{M}\left[\underbrace{(\ddot{\theta}_d - \ddot{\theta})}_{\ddot{E}} + K_v \dot{E} + K_p E\right]$$

$$= (M - \hat{M})\,\ddot{\theta} + (V - \hat{V}) + (G - \hat{G}) + (F - \hat{F})$$

$$\Longleftrightarrow \quad \ddot{E} + K_v \dot{E} + K_p E = \hat{M}^{-1} [\qquad]$$

error dyn. are complicated,
may not even be stable.

(2) Computation: inv. dyn. controller requires full inv. dyn. comp. to be carried out at "servo" rates.

that may be problematic …

Answers

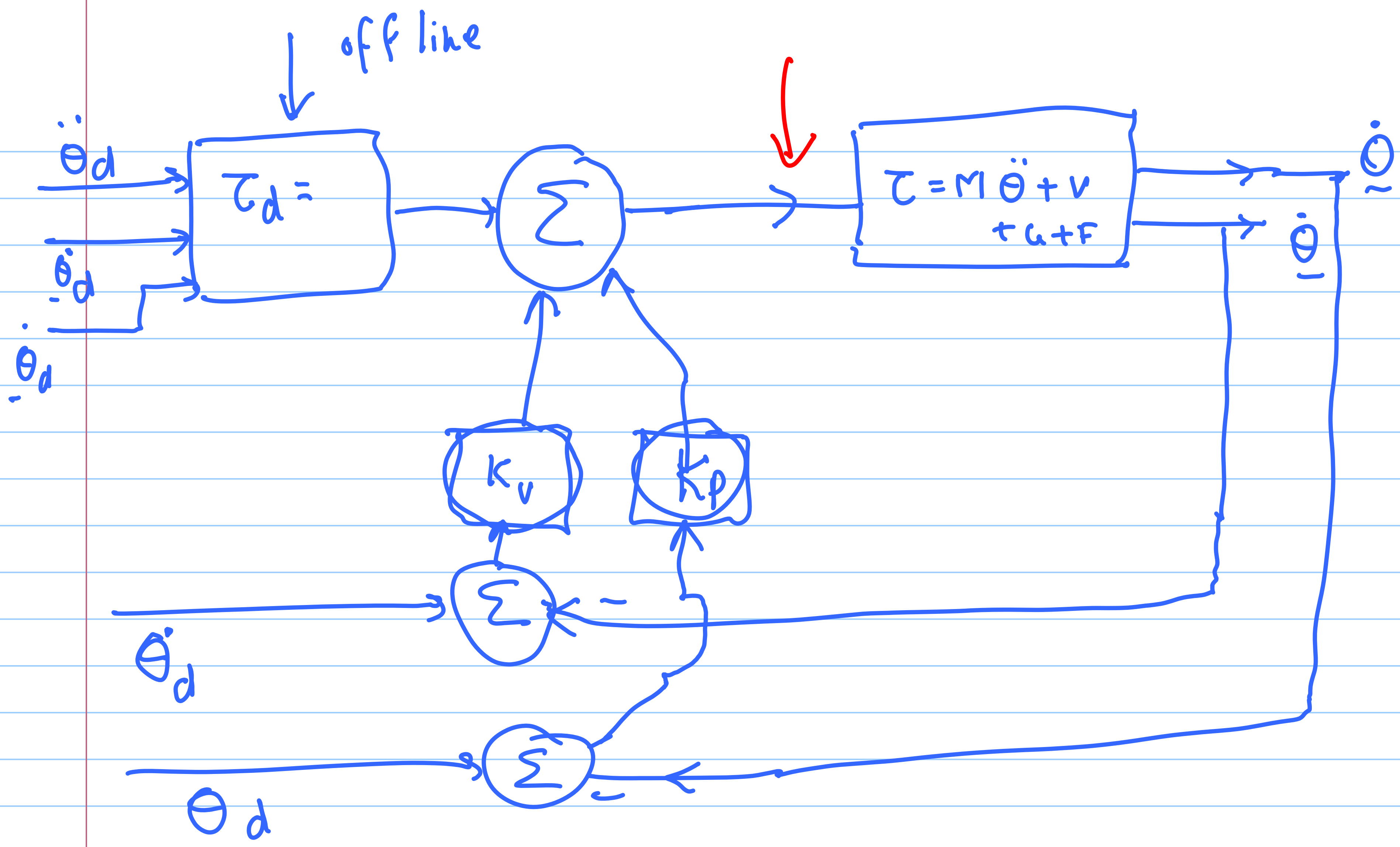
"will compute" a subset of Dynamic terms

$\underline{G}(\underline{\theta})$

will be computed

off line

$$\tau_d = M\ddot{\underline{\theta}}_d + V(\underline{\theta}_d, \dot{\underline{\theta}}_d) + G(\underline{\theta}_d) + F(\underline{\theta}_d, \dot{\underline{\theta}}_d)$$


off line
$\ddot{\theta}_d$
$\dot{\theta}_d$
θ_d
$\tau_d =$
Σ
$\tau = M\ddot{\theta} + V + G + F$
$\dot{\theta}$
θ
K_v
K_p
$\dot{\theta}_d$
θ_d
Σ
Σ
-
-

error dynamics will be "complex"

$$\boxed{\ddot{E} + M^{-1} K_v \dot{E} + M^{-1} K_p E = 0}$$

Off-line Robot Programming

Robot Prog. Lang

1) joint-level

2) Cartesian level

moveXY(x, y, ϕ)

3) "WORLD MODEL"

Computer m/c Anewb high level obj...

"ease of interaction"

"GRASP"

Pick ~~sq~~ Cube object at (x, y, ϕ)

place at (x_1, y_1, ϕ_1)

Gave demos of "Path planning / obs. avoidance"

→ sensor based path planning

mainly to illustrate "autonomous" / higher levels of robot interaction with its environment.