AIC-Automatisation avancée, intelligence artificielle et cognitique

7. Commande multimodale

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AIC-Automatisation avancée, intelligence artificielle et cognitique

Contenu

Contenu des *Exposés et exercices*

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Sur demande, l'étudiant peut échanger l'une des manipulations ci-dessus par un autre sujet (cf. manipulations LaRA)	

AIC-Automatisation avancée, intelligence artificielle et cognitique

Contenu

- Introduction
- Notion de modèle ; métrique pour le traitement d'information et pour la cognitique
- Choix d'une structure de commande
- Intelligence artificielle et « machine learning »
- Commande à logique floue
- Commande neuronale, yc. « deep learning »
- **Commande multimodale**
- Commande à algorithme génétique
- Robots mobiles autonomes
- Robot humanoïde NAO
- Conclusion

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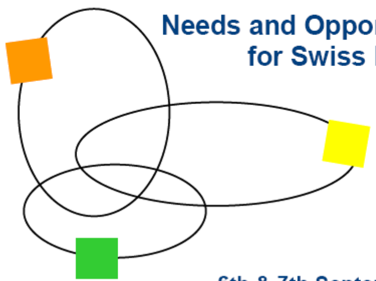
IPLnet Integrated Production and Logistics WORKSHOP **2005**

Needs and Opportunities
for Swiss Industry



6th & 7th September 2005

Schloss Böttstein

Schlossweg 20, 5315 Böttstein, Switzerland

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Largement basé sur l'article suivant:

Novel Modal Control for Strongly Non-stationary Systems

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Content

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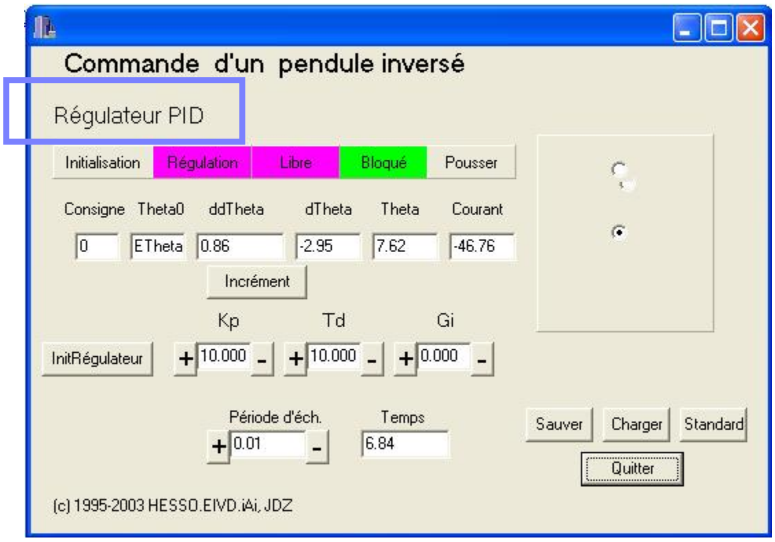
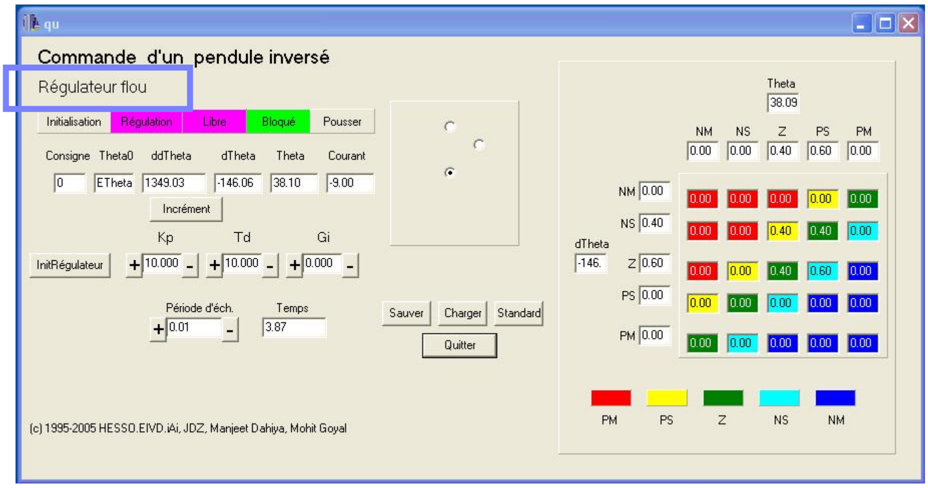
1. Introduction (1 of 2)

- **Classical control theories have been developed for many years.**
  - **Work well when systems are stationary and linear**
- **How to tackle non-stationary, non linear systems?**
- **Core idea:**
  - **divide the state space in smaller domains (local modes, as required by applications) where controllers can be individually, specifically designed by classical approach**
  - **Perform a feature-space based, dynamically changing, weighted average of all controller outputs**

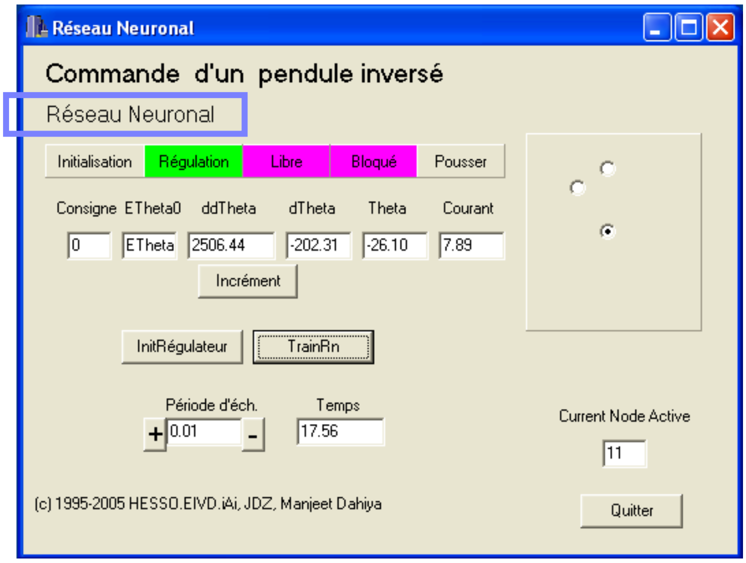
…PID Controller…



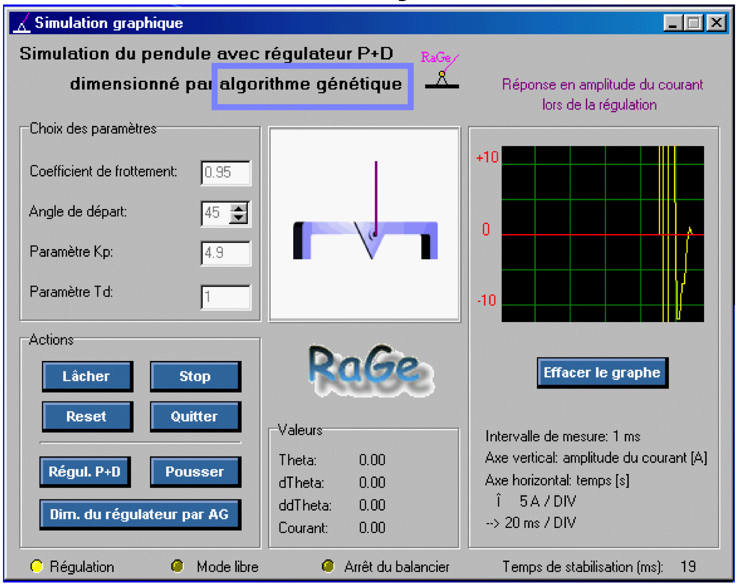
...Fuzzy Controller...



...Neural Controller...



...Evolutionary Controller...



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1. Introduction (2 of 2)

- **Particular motivation behind this study**
  - **Printing machines at high speed (20 m/s) and high resolution (<0.02mm)**
  - **Robotized handling systems with large changes in inertia and high requirements in terms of dynamics and precision**

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2. Multimodal Controller (1 of 2)

- **Principle, at design time**
  - **Divide the state space into domains sufficiently homogeneous, along one or more discriminant dimensions (features)**
  - **Design classic controllers in each domain**
    - **e.g. PID, Ziegler-Nichols method**
  - **Define weighting functions, typically distance dependant in feature space (e.g. w=1/(1+d))**

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2. Multimodal Controller (2 of 2)

- **Procedure, in operation**
  - **"Simultaneously" evaluate the output commands of individual controllers in each domain**
  - **Evaluate instantaneous, local weight values, for all controllers**
  - **Average the weighted contributions from all controllers**

Mathematically:

$$U_m(t) = \frac{\sum_{n=1}^{N} w_n(t) \bullet U_n(t)}{\sum_{n=1}^{N} w_n(t)} = \frac{\sum_{n=1}^{N} w_n(v(t)) \bullet U_n(t)}{\sum_{n=1}^{N} w_n(v(t))}$$

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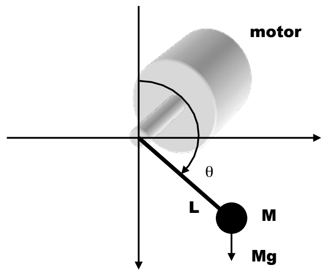
3. Example of MMC (1 of 3)

Control of an inverted pendulum



$$J\ddot{\theta} = C_m + MgL\sin\theta$$

$$C_m = kI_m$$ ***Driving torque***

$$J = ML^2$$ ***Inertia of load***

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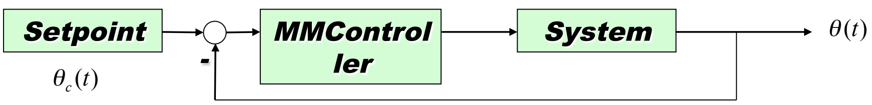
3. Example of MMC (2 of 3)

Main components of the specific MMC



Error signal: $\varepsilon(t) = \theta_c(t) - \theta(t)$

-180°..180° : domain broken into 5 regions

Output of one elementary controller (e.g.PID with a priori term):

$$I_n(t) = K_{pn} \cdot \varepsilon(t) + G_{in}\int \varepsilon(t) + T_{dn}\frac{d\varepsilon(t)}{dt} + A_n$$

Weighted average of all controller outputs:

$$I_m(t) = \sum_{n=1}^{N} w_n(\theta) \bullet I_n(t) \Big/ \sum_{n=1}^{N} w_n(\theta)$$

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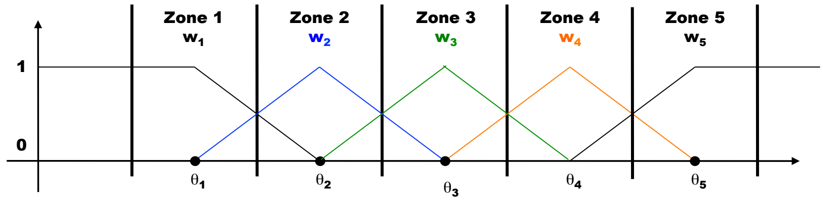
3. Example of MMC (3 of 3)

Computation of weights (ex. linear, 1-dimensional)



$$For \quad \theta_n \le \theta \le \theta_{n+1} \quad \begin{cases} w_n = \dfrac{\theta_{n+1} - \theta}{\theta_{n+1} - \theta_n} \\ w_{n+1} = 1 - w_n \end{cases}$$

$$For \quad \theta \le \theta_1 \qquad w_1 = 1$$

$$For \quad \theta_N \le \theta \qquad w_N = 1$$

θ_1	*-135°*
θ_2	*-30°*
θ_3	*0°*
θ_4	*30 °*
θ_5	*135°*

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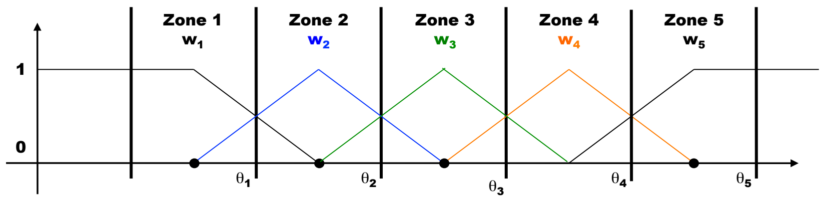
3b. Remarque



Il n’est pas nécessaire que la somme des poids vale 1 partout immédiatement. Si ce n’est pas le cas, on peut très simplement obtenir un nouveau jeu, normalisé, en divisant les premiers par la somme en chaque point.

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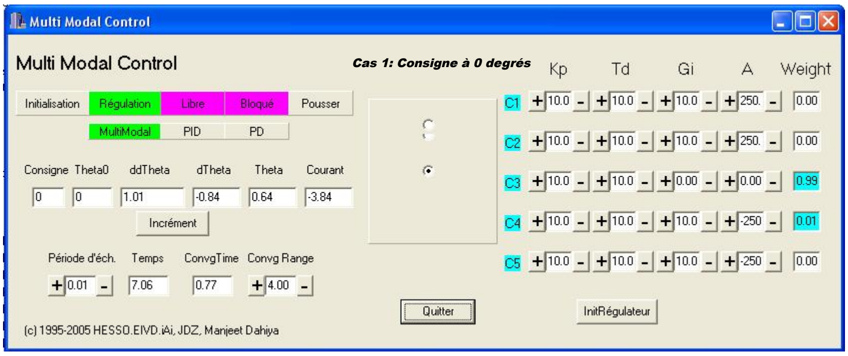
4. Implementation and tests (1 of 3)

Graphical interface, C++ implementation



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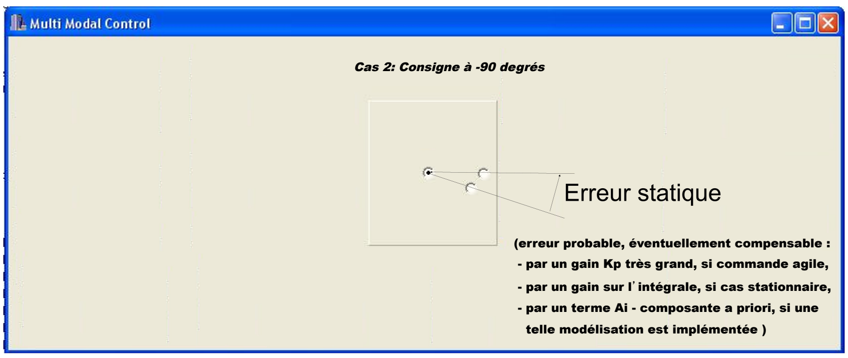
4. Implementation and tests (1 of 3)

Graphical interface, C++ implementation



4. Implementation and tests (2 of 3)

Benchmark with PD controllers

	Residual error (asymptotic value)	
Set point	***PD***	***Multi - PD***
-90°	*30.4°*	*9.8°*
-30°	*30.2°*	*<2°*
0°	*<2°*	*<2°*
30	*30.8°*	*<2°*
45°	*34.7°*	*<2°*
80°	*32.6°*	*10.3°*
90°	*30.4°*	*9.8°*
135°	*16.7°*	*<2°*

4. Implementation and tests (3 of 3)

Benchmark with PID controllers

	Convergence Times in seconds	
Set point	***PID***	***Multi - PID***
-90°	*217*	*7.7*
-30°	*112*	*8.5*
0°	*18*	*1.6*
30	*98*	*6.4*
45°	*133*	*5.2*
80°	*196*	*4.1*
90°	*207*	*3.9*
135°	*182*	*0.1*

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5. Logiciel (1 de 3)

Extraits de code – Simulation d'un balancier

```
void UpdateBalancier(/*float Courant,
     float &Theta, float &dTheta, float &ddTheta*/)
 {
  ddTheta=360/Lm*g*sin(Theta/180*pi)+300*Courant;
  dTheta=0.97*dTheta+ddTheta*dt;
  Theta=Theta+dTheta*dt;
  t=t+dt;
  return;
  }
```


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5. Logiciel (2 de 3)

Extraits de code – Régulateur PID avec composante a priori

```
float Controller1() // Calculer Courant
 {
  ConsigneTheta=StrToFloat(Form1->EConsigne->Text);
  Ecart1=ConsigneTheta-Theta;

  Integrale1=Integrale1+Ecart1*dt;
  Courant1=Kp1*Ecart1+Td1*(Ecart1-
              OldEcart1)/dt+Gi1*Integrale1+A1;

  OldEcart1=Ecart1;

  return Courant1;
}
```

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5. Logiciel (3 de 3)

Extraits de code – Moyenne pondérée des régulateurs

```
{W1=weight1(Theta);
 W2=weight2(Theta);
 W3=weight3(Theta);
 W4=weight4(Theta);
 W5=weight5(Theta);
 weightTemp = W1+W2+W3+W4+W5;

 if (weightTemp==0)
 Courant= 0;

 else
 Courant=
(W1*(Controller1())+
 W2*(Controller2())+
 W3*(Controller3())+
 W4*(Controller4())+
 W5*(Controller5()))/(weightTemp) ;
}
```


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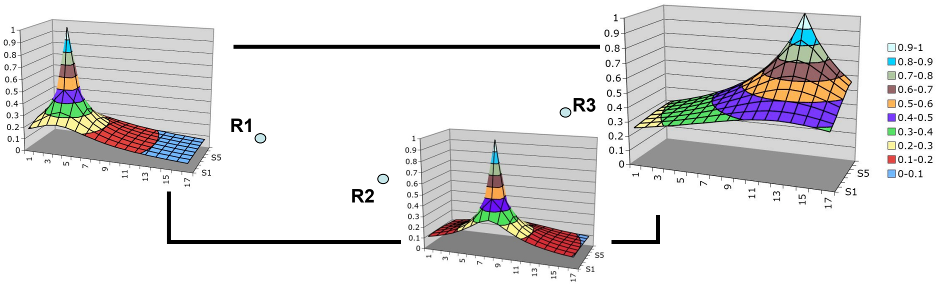
6. Exemple bidimensionnel

- **Amélioration de performances par régulateurs multiples**
- **Extrapolation de chaque régulateur Ri avec une surface de pondération en « cloche » (exemples: gaussiennes, ou ci-dessous fonctions de distances inverses Wi pour 3 régulateurs et un domaine 2-D, càd. à deux paramètres)**
- **Avec normalisation en tous points avec une division par la somme des poids des régulateurs en ces points**

$$w_i = \frac{1}{k_i \cdot (1 + d_i)}$$

$$d_i(x,y) = \sqrt{(x - R_{ix})^2 + (y - R_{iy})^2}$$

$$w_i' = \frac{w_i}{w_1 + w_2 + w_3}$$



7. Conclusion (1 of 2)

- Very well adapted for digital control
- Some light similarities with fuzzy controllers (weighting functions and membership functions, multiple components)
- Much more sophistication however in terms of working points (modes), elementary controller, feature space and weights (re. distances)

7. Conclusion (2 of 2)

- Fit to application specifications
- The test implementation proves that MMC can deliver much better performance figures than (single) classical controllers
- Addresses Swiss needs and opportunities: moderate increase of complexity (e.g. order of 10x computation load) for best possible results (leading quality)