Windsurfer, Fully Probabilistic Control Design and the Jobcontrol Package

Ladislav Jírů & Ludvík Tesar
Institute of Information Theory and Automation, Academy of Sciences of the Czech Republic.
E-mail: jiru@itino.cz

Fully probabilistic control design (FPD)

Fully probabilistic control design is a control design based on a description of a control closed loop behaviour using probabilistic models.

Control scheme

![Control scheme](image)

How is this approach reflected in theory?

The conservation construction of the ideal pdf is based on:
- given setpoints and input/output constraints,
- modelling of the observed closed loop behaviour by a “rough” model $f_y$, 
- gradual modifications of the rough model according to the closed loop behaviour in order to express better the control aims.

The windsurfer’s approach to elicitation of control aim (ideal)

The windsurfer’s approach suggests a conservative construction of the ideal pdf.

What the windsurfer-beginner is doing?

Windsurfer’s ideal: to sail across a lake

1. to climb on a sail and to keep there
2. to pull up the sail (and not to fall)
3. to learn manipulation with the sail
4. to move forward, do stop
5. etc.

He has realistic aims according to his knowledge and observations and modifies them.

How is this approach reflected in theory?

The conservative construction of the ideal pdf is based on:
- given setpoints and input/output constraints,
- modelling of the observed closed loop behaviour by a “rough” model $f_y$, 
- gradual modifications of the rough model according to the closed loop behaviour in order to express better the control aims.

Verbal description of the control aim

- keep interesting outputs $y$ as close as possible to the given setpoints $y^*$, 
- keep all inputs $u$ within the given intervals (constraints) with a high probability.

Main idea is an approximation of the ideal $f_y(\{T\})$ by a rough model $F_y(\{T\})$ and its gradual refinement. The rough model describes the closed loop behaviour in the neighbourhood of the actual one.

1. Choose a set of ideals $f_y(\{T\}) = \prod_{i=1}^{\mathit{f}_y(\text{system model})}$, where the factors $f_{i}\{\text{controller}\}$.
2. Using a chain rule, decompose the factor $f_{i}\{\text{controller}\}$ in time $t$:

The term $\frac{\partial}{\partial t} f_y(\text{system model})$ concerns non-interesting outputs, therefore is conservatively substituted by its rough model counterpart,

Put the maximum of the rough factor $f_{i}\{\text{controller}\}$ on the setpoints $y^*$ by finding the value of “optimal” input $\hat{u}_i$, i.e.

Such a factor is called optimistic $\frac{\partial}{\partial t} f_y(\text{system model}) = \hat{F}_y(\{T\}) = \hat{F}_y(\{T\})$.

5. Substitute the term $\frac{\partial}{\partial t} f_y(\text{system model})$ by the optimistic factor, i.e.

6. Minimize $\frac{\partial}{\partial t} f_y(\{T\})$ with respect to $\hat{u}_i$, $\hat{u}_i = \text{arg min}_{u_i} \frac{\partial}{\partial u_i} f_{i}\{\text{controller}\}$.

The optimistic ideal

The decomposition (27) can be expressed as

Verbally, optimistic ideal (K-L optimized approximation of unknown ideal) is obtained by replacing the rough factor $\frac{\partial}{\partial u} f_y(\{T\})$ by the optimistic factor $\frac{\partial}{\partial u} f_{i}\{\text{controller}\}$.

Algorithm

1. Initial mode
   - initialize the control loop, estimation of the system model, estimation of the rough closed loop model,
   - select the type of adaptive control strategy.
2. Iterative mode
   - evaluate the rough approximation to the ideal closed loop model
3. Recursive mode
   - collect data and update estimates of $f_{i}\{\text{controller}\}$ and $\hat{F}_y(\{T\})$,
   - construct PDF for the current $f_{i}\{\text{controller}\}$ and $\hat{F}_y(\{T\})$,
   - generate and apply the system input,
   - after some iterations, go to iterative mode.

Experiments

A system with transfer function

was mapped on $S(z)$.

and sampled with a period $0.1s$, added white noise with variance 0.001. Inputs are limited in the interval $[-5, 5]$ with probability 0.9. Outputs are controlled to zero. The second order AR rough model was used.

The optimistic ideal $F_y(\{T\}) = \hat{F}_y(\{T\})$.

Results for off-line FPD using Designer package:

<table>
<thead>
<tr>
<th>HS iterations</th>
<th>Initial mode</th>
<th>min</th>
<th>max</th>
<th>mean</th>
<th>variance</th>
<th>min</th>
<th>max</th>
</tr>
</thead>
<tbody>
<tr>
<td>1</td>
<td>0.0001</td>
<td>0.15</td>
<td>0.45</td>
<td>0.16</td>
<td>0.04</td>
<td>0.1</td>
<td>0.2</td>
</tr>
<tr>
<td>2</td>
<td>0.0124</td>
<td>0.19</td>
<td>0.47</td>
<td>0.21</td>
<td>0.06</td>
<td>0.12</td>
<td>0.3</td>
</tr>
<tr>
<td>3</td>
<td>0.0248</td>
<td>0.20</td>
<td>0.50</td>
<td>0.22</td>
<td>0.08</td>
<td>0.13</td>
<td>0.3</td>
</tr>
<tr>
<td>4</td>
<td>0.0497</td>
<td>0.24</td>
<td>0.50</td>
<td>0.25</td>
<td>0.10</td>
<td>0.14</td>
<td>0.3</td>
</tr>
<tr>
<td>5</td>
<td>0.0748</td>
<td>0.28</td>
<td>0.50</td>
<td>0.28</td>
<td>0.12</td>
<td>0.16</td>
<td>0.3</td>
</tr>
</tbody>
</table>

Jobcontrol package

The purpose of software package Jobcontrol is to integrate algorithms present in Mixtools and Designer Matlab packages to simplify its use for end-user.

Jobcontrol package splits the task of model identification and process control into logical steps. It starts by data filtration step. It is followed by four modelling steps, which are “prior information” step, model structure identification step, model parameters estimation step, and model validation step. After it, control design is performed in these steps: user ideal construction, design, and controller verification step.

Applications

The Jobcontrol system was applied in several real applications: caucine production line identification and control, control of the biotechnology process for biodegradable polymers production, diagnostics in lymphoscintigraphy and application for stock market futures trading.

Acknowledgements

The work on jobcontrol package was supported by DAR IM0572.