An indicator for powered wheelchair driving analysis

Hicham Zatla1,2, Yann Morère2, Amine Hadj-Abdelkader4 and Guy Bourhis2
1 LAT, université de Tlemcen, Algeria - 2 LCOMS, université de Lorraine, France

Introduction

- We want to define a new parameter for powered wheelchair (PW) driving analysis.
- The pilot-vehicle system is modelled with the Optimal Preview Control Model (OPCM).
- The key parameter is the visible distance $D_v$.
- Can the parameter $D_v$ be used as an indicator for learning task?

Methodology

- OPCM model
  - The OPCM represents the driver as data acquisition.

\[ P_{V}(z) = \frac{\alpha}{z^2 + \beta z + \gamma} \]

From $D_v$ and the vehicle speed we can deduce the preview time $T_p$. In practice $T_p$ is a multiple of the sampling time $T_s$, $T_p = q T_s$, with $q$ is the number of samples of the reference trajectory.

- Structure of the OPCM model

\[
\begin{align*}
\dot{x}(k+1) &= A_x x(k) + B_v u(k) + C_v y(k) + D_v w(k) \\
\dot{y}(k+1) &= A_y x(k) + B_T y_T(k) \\
\end{align*}
\]

For this model, a time invariant optimal control law that minimizes the following cost function:

\[ J = \sum_{k=0}^{n} Z^T(k) R_z Z(k) + u(k)^T R_z u(k) \]

where $Z = [x \ v \ y_T]^T$ is the state vector of the global system of order $(n + m + 2(q + 1) \times 1)$.

- The optimal control is given by: $u^*(k) = -K \cdot Z(k)$, where $K = (R_z + B^T PB)^{-1} B^T PA$. For more details on the model formulation and description, see [1].

- Visible distance estimation

- By combining the eye tracker system with the simulator 3D VIEW [2], we can estimate the user’s visible distance: $Z_v = \frac{E \cdot V}{E^2 - P^2}$.

\[ D_v \] can be used as indicator of learning.

Results and discussion

- From the figures below (trajectories of the left and right wheels) we see that the OPCM model tracks the experimental trajectory, which means that the user had a sufficient visible distance. In this case we can say that the user had a tracking behavior.

- The users were divided into two groups:
  - Group 1: users who were familiar with the simulator.
  - Group 2: users who used the simulator for the first time.

- The average visible distance for the two groups in each section of the path is given:

\[
\begin{array}{c|c|c|c}
\text{Portion} & \text{AB} & \text{BC} & \text{CD} \\
\hline
p(5\%) & 7.16 \times 10^{-7} & 1.85 \times 10^{-4} & 2.03 \times 10^{-4} \\
\end{array}
\]

- $D_v$ can be used as indicator of learning.

Conclusions

- The OPCM allows to get a precise reconstruction of the experimental trajectory for the powered wheelchair driving task since the visible distance is sufficient to guarantee a good control.

- The essential difficulty of the OPCM is the estimation of $D_v$. In our work, it was carried out using an eye-tracking system.

- The statistical analysis shows that $D_v$ for experienced driver is higher than for novice driver, then $D_v$ can be used as a driving performance indicator.

- The next work is to validate this result on people with disabilities at the Physical and Rehabilitation Medicine Center of Flavigny, France.

References


\[1 \{hicham.zatla,amine.hadj\}@gmail.com, \ 2\{yann.morere,guy.bourhis\}@univ-lorraine.fr\]