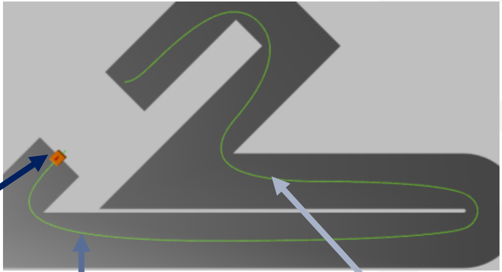
1. The dynamic optimisation of AGV (Automated Guided Vehicle)

(2022 ABB Smart Innovation Competition)

1.1 Project Structure

- 2022 ABB Smart Innovation Competition
- Incorporate and design both the control algorithm and racing line optimization of an Automated Guided Vehicle (AGV) controlled by PLC
- Analyze the friction range



Method Evolution

Control algorithm

Racing line optimization

Lap time

Energy use

Friction range

Tire's model (with ground)

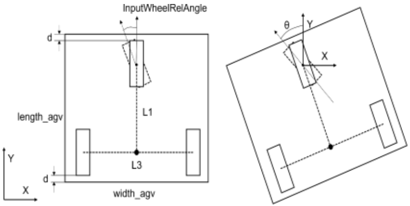
1.1 Method Evolution

First attempt: LQR + A
Valid: autonomous tuning;
Weak: implementing, slip at high curvature corner

Second attempt: Dual PID + B spline
Valid: high curvature corner;
Weak: AGV shake, Refresh not in time

Final version: Dual PID + ***Uniform B-spline*** + ***intelligent visual distance-refresh***
Valid: suppressing the inevitable jitter due to PID; compensate the non-uniform trajectory points

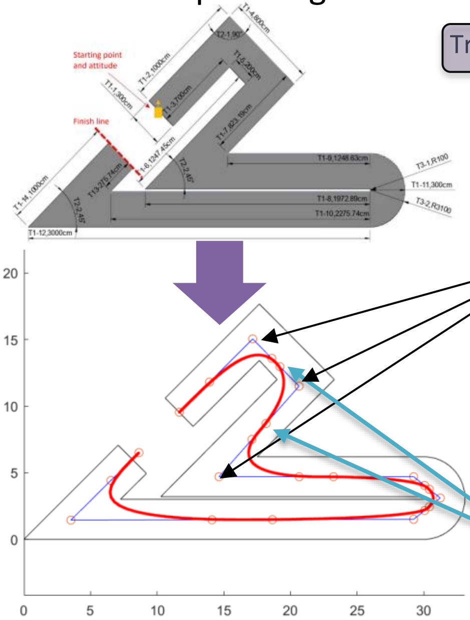
Uniform B-spline Algorithms



Forward-feedback
PID Controlling Algorithm

Self developed Intelligent
target refreshing method

1.2 Uniform B-spline Algorithms



Transform the calibration curve into a design curve:

Uniform B spline curve, i.e., the distribution of target points in this curve are all equidistant.:

$$P(u) = \sum_{i=0}^{n} P_i B_{i,k}(u) \quad \text{u in } [u_{k-1}, u_{k+1}]$$

Determine control points by trail and inspection until the optimal result

The position of the node vector in relation to the neighboring vectors is determined according to the De Boer-Cox recursive formula.

$$\begin{cases} N_{i,0}(u) = \begin{cases} 1 \text{ if } u_i \leq u \leq u_{i+1} \\ 0 \text{ otherwise} \end{cases} \\ N_{i,k}(u) = \frac{(u-u_i)N_{i,k-1}(u)}{u_{i+k}-u_i} + \frac{(u_{i+k+1}-u)N_{i+1,k-1}(u)}{u_{i+k+1}-u_{i+1}}, u_k \leq u \leq u_{n+1} \end{cases}$$

Nodes vector is defined as a set of points dividing a curve into equidistant segments.

1.2 Uniform B-spline Algorithms

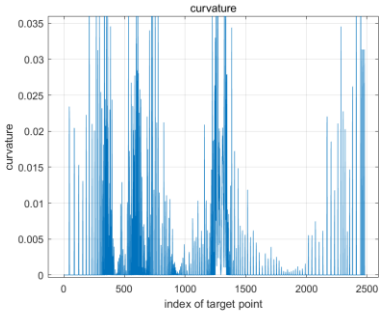


Fig.1.1 Curvature distribution of each target point

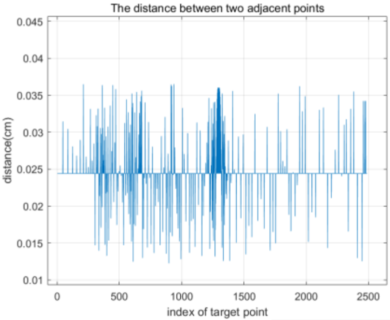


Fig.1.2 Adjacent distance distribution of each target point

- The distribution of curvature is generally smooth without sudden changes
- The adjacent distance validation between target points are restricted under 40%

1.3.1 Dual PID & self-developed refreshing method

Taking input as the distance between target point and attitude angle line, the control output θ (steering servo) is surprisingly satisfied.

$$d = \frac{at_A * x_0 + at_B * y_0 + at_C}{\sqrt{at_A^2 + at_B^2}}$$

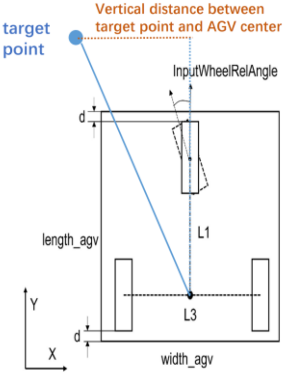


Fig.1.3 The imply of the designed control algorithm

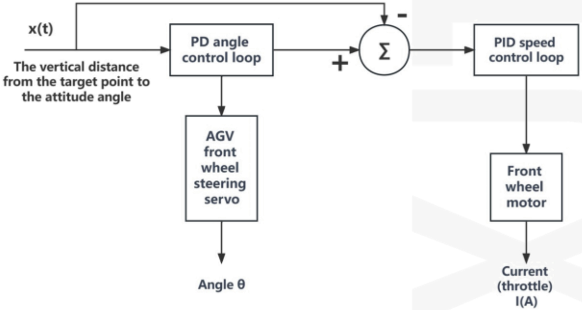
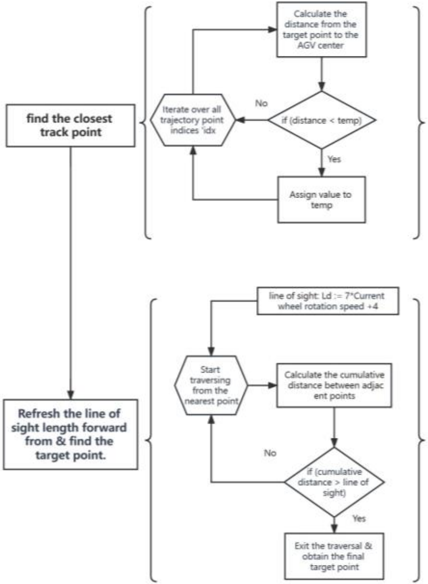


Fig.1.4 Dual PID control algorithm

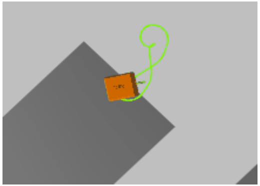
1.3.2 Dual PID & self-developed refreshing method



- Higher speeds result in a more forward-looking update, enhancing road anticipation.
- Excessively close line of sight can introduce errors, potentially causing deviations in the car's path.
- Conclude the process when the cumulative distance of points along the reference trajectory surpasses the line of sight.

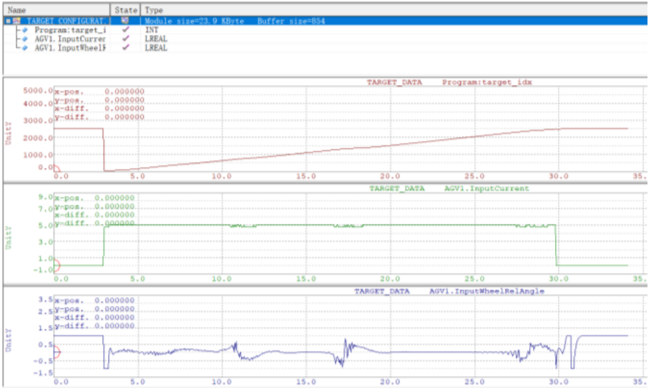
1. 4 Conclusion

Continuous tracking



Steer at corner

Refresh at U-shaped corner



- The uniform B-spline could suppress the inevitable jitter
- The intelligent line-of-sight could compensate the non-uniform trajectory points of B-spline
- The vibration of wheel is without sudden change

1. 5 Tire's model

Magic formular ✖

Industrial method approximation ✔

The industrial method is to approximate the sliding friction force coefficient as the adhesion coefficient using vehicle adhesion analysis. Then, compare the magnitude between traction and adhesion force.

coefficient of adhesion
≈
coefficient of maximum static friction
≈
coefficient of sliding friction

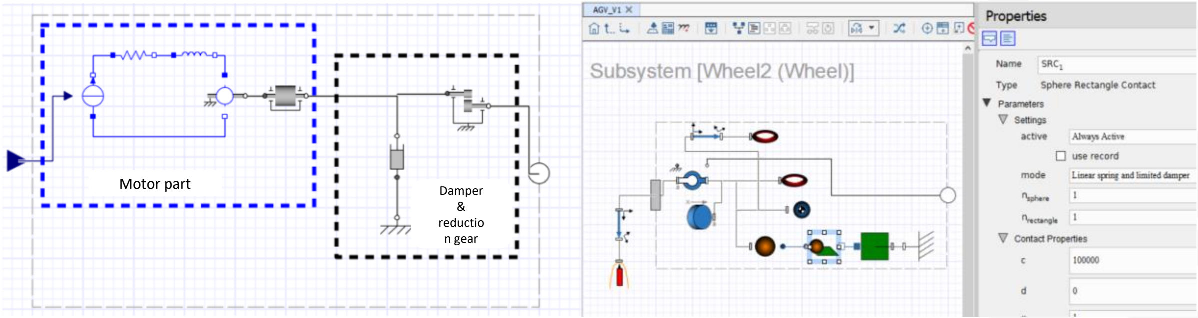


Fig.4 The motor and wheel modelling via MapleSim

1. 5 Tire's model

Approximate Conclusion
$u > 0.2175I$

Vehicle loading analysis

$$\mu = \frac{Kt * I * n1 * n2 * u}{r * P\mu}$$

$$c = 100000 \text{ N/m}$$
$$d = 0 \text{ N} * \text{ s/m}$$
$$L[0] = 0.04015 + T = 0.04015 \text{ m}$$
$$f_c = \begin{cases} -c(u - L_0) & u < L_0 \\ 0 & \text{otherwise} \end{cases}$$
$$f_d = \begin{cases} -dv & u < L_0 \\ 0 & \text{otherwise} \end{cases}$$
$$f_n = \begin{cases} f_c + \min(f_c, f_d) & f_c + f_d > 0 \\ 0 & \text{otherwise} \end{cases}$$
$$F(\text{ normal force }) = 15N$$
$$\text{P } \mu = 15N$$

Dynamic response of DC AGV motor

$$J * \frac{dw(t)}{dt} + B * w(t) = Tm = Kt * I$$

```
# appendix : angular speed figure by
    ODE45
function y = AGV_motor(t,w)
J = 9*10^-5;
c = 0.03167;
y = ( -c*w + 0.4) / J;
end
[t,w] = ode45('AGV_motor', [0,10],0)
    ;
plot (t,w)
[t,w] = ode45('AGV_motor', [0,10],0)
    ;
plot (t,w)
```

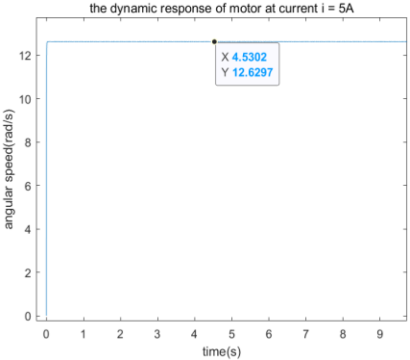
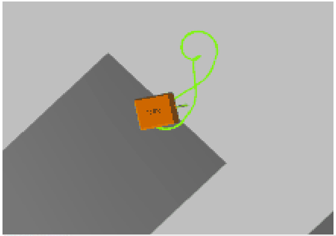


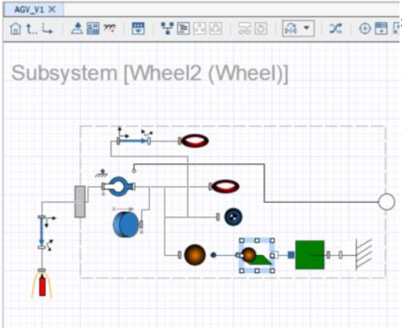
Fig.3 dynamic motor response when current i=5A

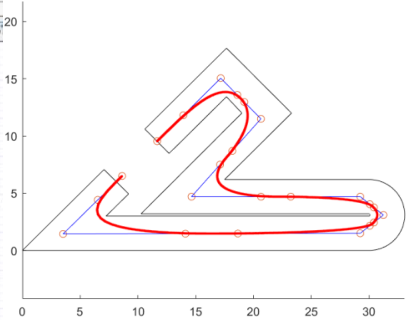
Continuous tracking

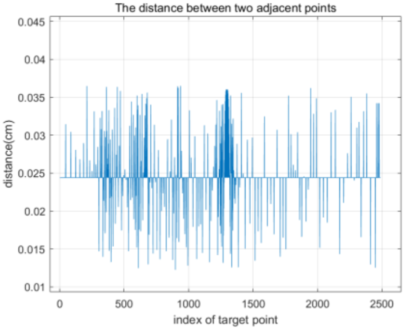
Steer at corner

Refresh at U-shaped corner









1. 6 Honor

2022 ABB杯智能技术创新大赛

ABB Cup Innovation Contest

相天翊

西交利物浦大学

荣获“贝加莱运动控制挑战未来比赛暨2022年度贝加莱学界联盟竞赛”一等奖

First Prize of B&R Future Challenging Championship of Motion Control / 2022 B&R Scholastic Union Competition

ABB（中国）有限公司
ABB (China) Ltd.

中国自动化学会
China Association of Automation

贝加莱工业自动化（中国）有限公司
B&R Industrial Automation (China) Co. Ltd.

此证书获得者拥有ABB应届生校园招聘及实习生职位优先录用权，仅限使用一次，有效期二年。制证时间：2022年10月