Table 2: Specifications of “UOT Electric March II”.

Motor	**4 PM Motors**
Max. Power(20 sec.)	36 [kW] (48.3[HP])*
Max. Torque	77 [Nm]
Gear Ratio	5.0
Battery	**Lead Acid**
Weight	14.0 [kg](for 1 unit)
Total Voltage	228 [V] (with 19 units)
Base Chassis	**Nissan March K11**
Wheel Base	2360 [m]
Wheel Tread F/R	1365/1325 [m]
Weight	1400 [kg]
Wheel Inertia**	8.2 [kg]***
Wheel Radius	0.28 [m]
Controller	
CPU	MMX Pentium 233[MHz]
Encoder	3600 [ppr]***
Gyro Sensor	Fiber Optical Type

* ... for only one motor.
** ... mass equivalent.
*** ... affected by gear ratio.

wheel started skidding, causing unstable growth of yaw rate γ.

On the contrary, if linear feedback of wheel velocity is applied such unstable growth of γ can be prevented. Fig. **??** and Fig. **??** shows this effect clearly. Note that controllers on rear-left and rear-right wheels are the same and independent ones. Each controller only requires the value of each wheel, thus it is not “connected” with each other, in any meaning. Consequently, each wheel was autonomously stabilized. These results indicate the validity of discussions in previous section.

One of the remaining problems is the high-frequency oscillation of rear-right wheel. We assuming that it will be depend on the design of contoller. The cut-off frequency τ in the proposed controller (Fig. 4) may have the important influence on this oscillation, however, such discusson must wait for the next experiments.

Note that chassis velocity in Fig. 12 or **??** is the mean values of trailing front wheels. The slip velocity in **??** is also calcurated with these values.

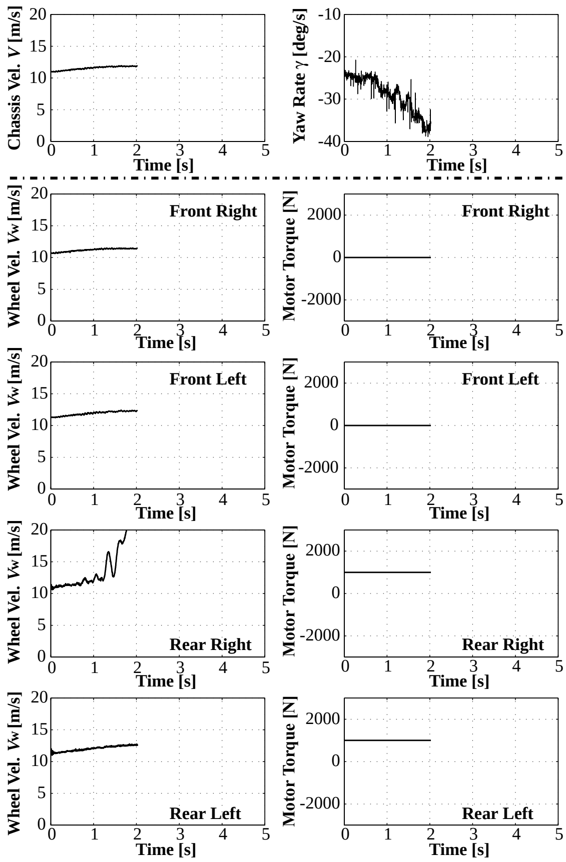

Figure 12: Unstable turning without feedback control. Sudden acceleration torque was applied on rear wheels of vehicle during steady-turning.

6 Conclusion

In this paper, we described the advantage of EVs in motion control issue. The goal is to enhance the vehicle stability with feedback control of motors. We proposed the wheel velocity controller for skid prevention, and confirmed with experiments using actual EV. This controller can change the wheel’s dynamics, or increase the equivalent inertia of wheel. Such feedback control is difficult with slow actuator like engine or hydraulic brake. The proposed feedback controller can enhance the vehicle lateral stability, as we showed with simulations. The motor control loop is a fast minor feedback loop in a total chassis control system, as depicted in Fig. **??**. This minor loop will enhance the stability of upper layer chassis control system, such as DYC. Note that DYC can be easily applied in EV with two or four motors. We have almost manufactured such EV for experimental studies (Fig. 1). Another example of our concept, fast minor-loop

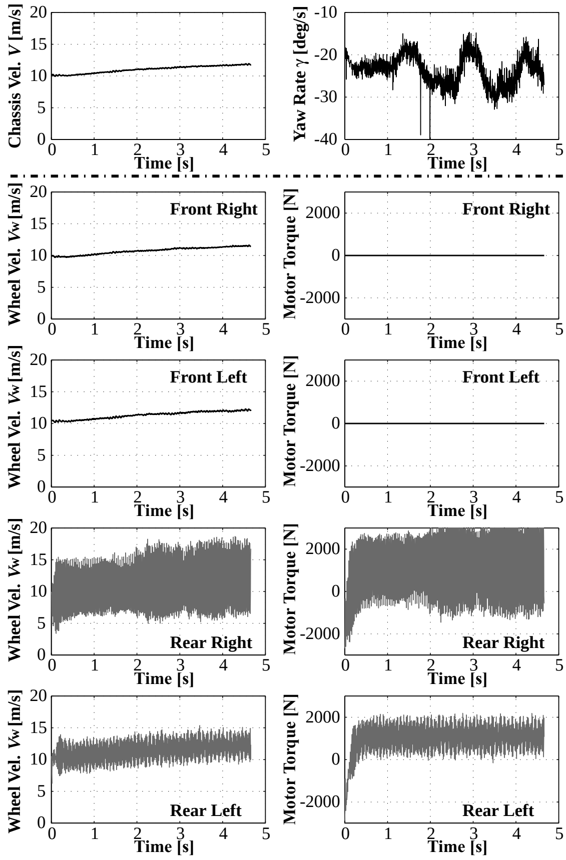

Figure 13: Stabilizing effect of wheel velocity feedback. Note that controller of rear-left and rear-right wheels are independent.

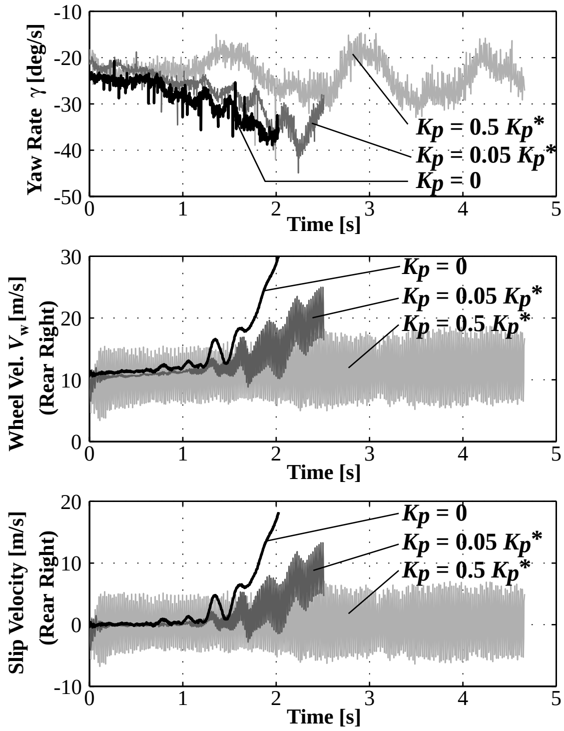

Figure 14: Comparison of vehicle motion: (a) without feedback controller, (b) with weak feedback controller, (c) and adequate feedback contoller(c).

with motor, was also shown. The novel regenerative braking controller was designed, and was confirmed to improve the performance of hydraulic ABS. The proper cooperation between slow ABS actuator and fast motor seems to be the interesting issue for further studies.

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