INTELLIGENT CONTROL OF ELECTRIC SCOOTERS

D.T. Lee, S.J. Shiah, C.M. Lee, and C.H. Wu

Institute of Information Science
Academia Sinica
Taiwan

Outline

- Introduction
- System Implementation
- Experiments
- Conclusion

Introduction 3

- Scooters in Taiwan
  a) More than ten million gasoline powered scooters are used every day.
  b) These scooters are affecting the living environment seriously.
  c) In an effort to reduce air pollution, Taiwan government has implemented a subsidiary program to encourage research and development of battery powered electric scooters since 1997

Introduction 2

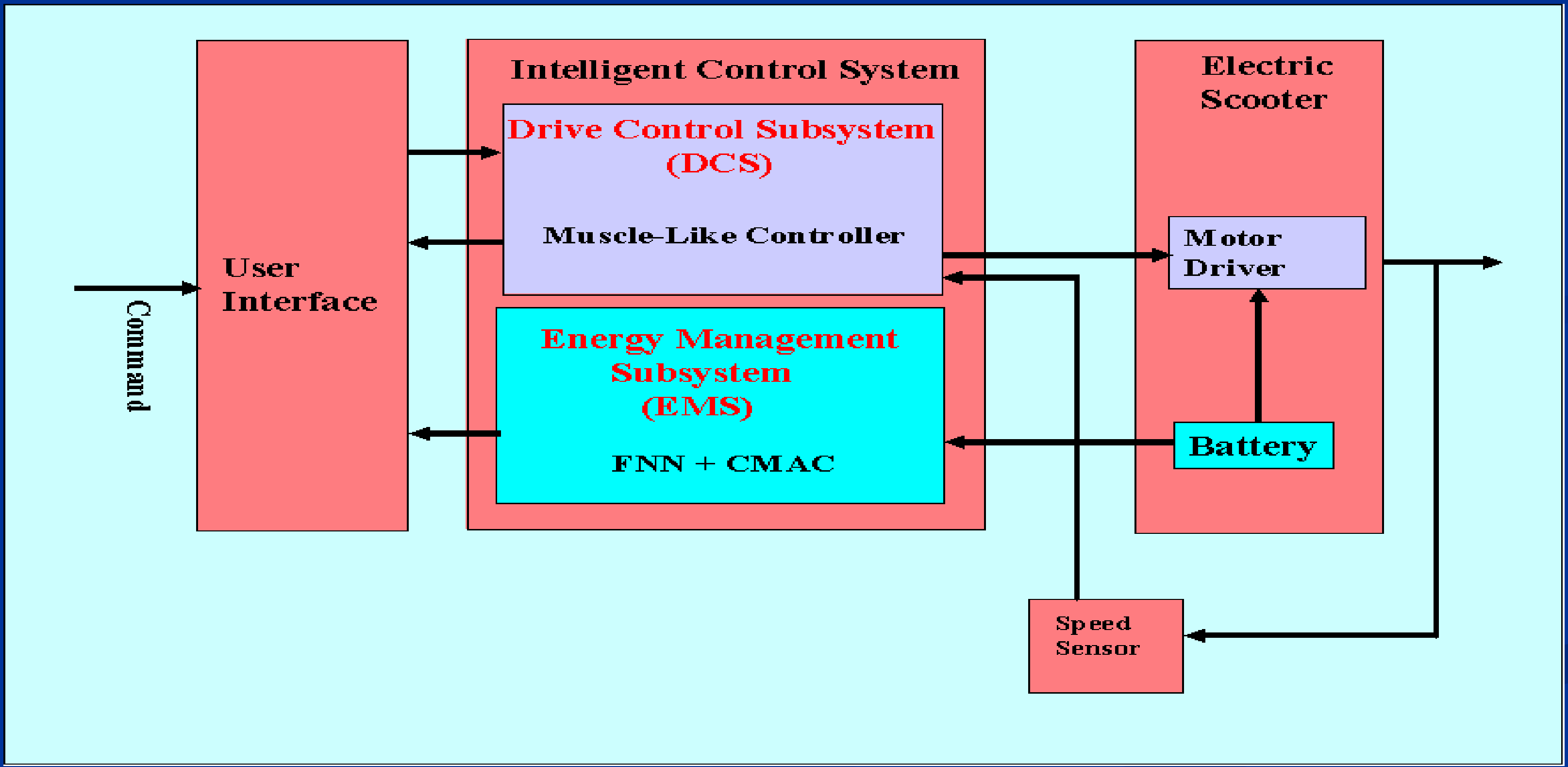
- Commercially available electric scooters to date produced by local companies :
  a) High cost
  b) Long battery recharging time
  c) Relatively short traveling distance for each re-charge
  d) Inadequate feedback information of the residual battery capacity

Introduction 1

- The lack of a more reliable power prediction and management mechanism could be troublesome and therefore hinders sales of electric scooters.
- To tackle the reliability problem, we propose an intelligent system which consists of
  a) Driver control subsystem (DCS)
  b) Energy management subsystem (EMS)

System Implementation 9

- A conceptual design of the proposed intelligent control system :



System Implementation 8

- Driver Control Subsystem : DCS
  a) Use a muscle-like control law
     - Fitted from the responses of voluntary and involuntary limb movements.
     - Unique nonlinear damping and excellent compliant property.
     - Allows an electric scooter to adapt to varying loads and sudden impacts under the desired speed.

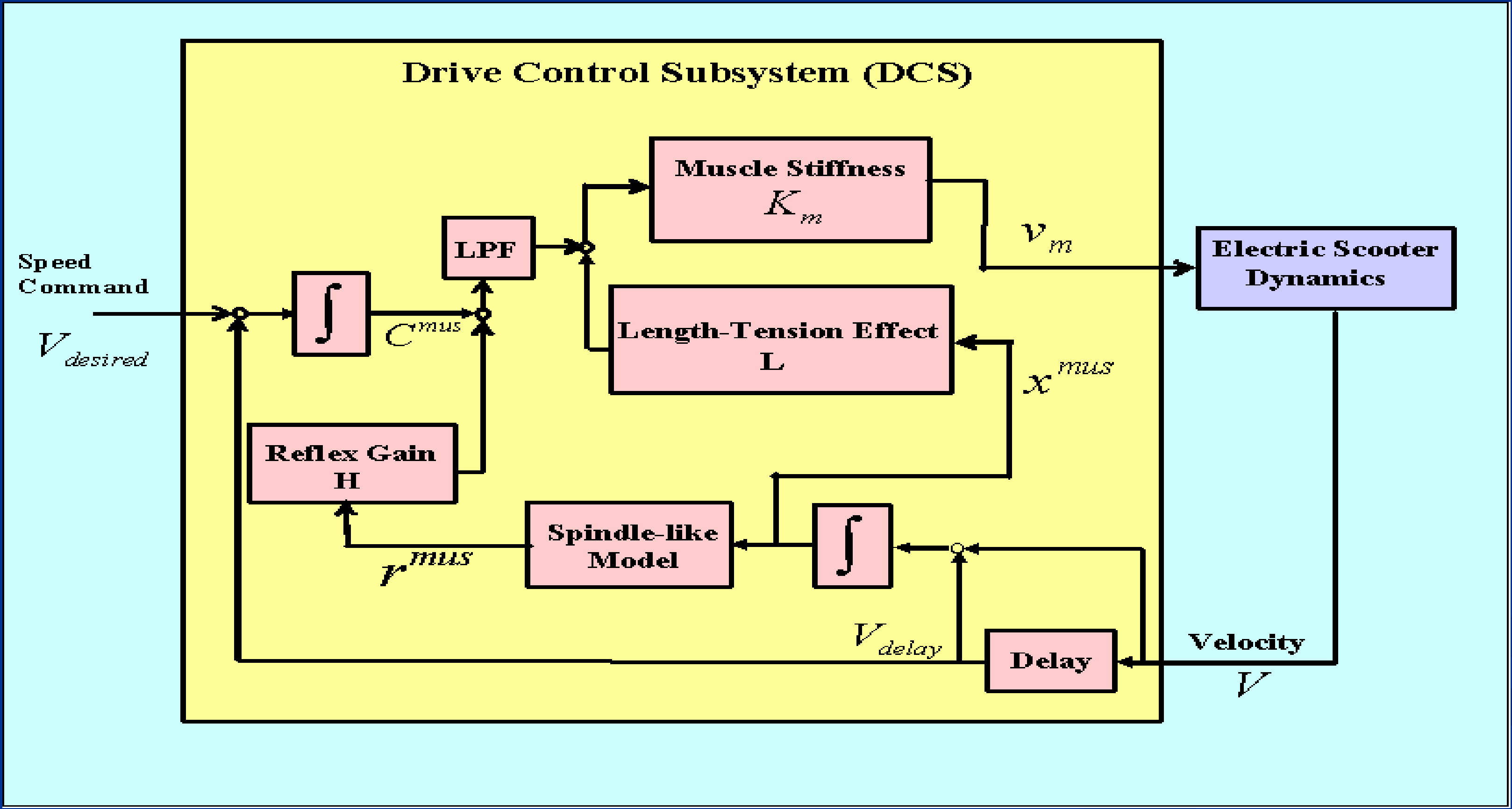
System Implementation 7

b) Provide a closed-loop speed control :

- Allowing riders to control the speed of the electric scooter quantitatively
- Controlling battery power consumption
- Reducing electric energy consumed by manual acceleration operations
- Fast response to give riders the needed feeling of acceleration and maneuverability
  - Let the rider feel as if it were an open-loop control.

System Implementation 6

- The control blocks of the DCS :



System Implementation 5

- The spindle-like model :

$$B_p \dot{x}_p^{1/n} \left(\left| x_p \right| - x_{p0} \right) = K_r \left(x^{mus} - x_p \right) = r^{mus}$$

System Implementation 4

- Energy Management Subsystem : EMS
  - a) Use fuzzy neural networks (FNN) and cerebellar model articulation controllers (CMAC) as the core
    - Estimate nonlinear dynamic characteristics of batteries
    - Provide on-line learning

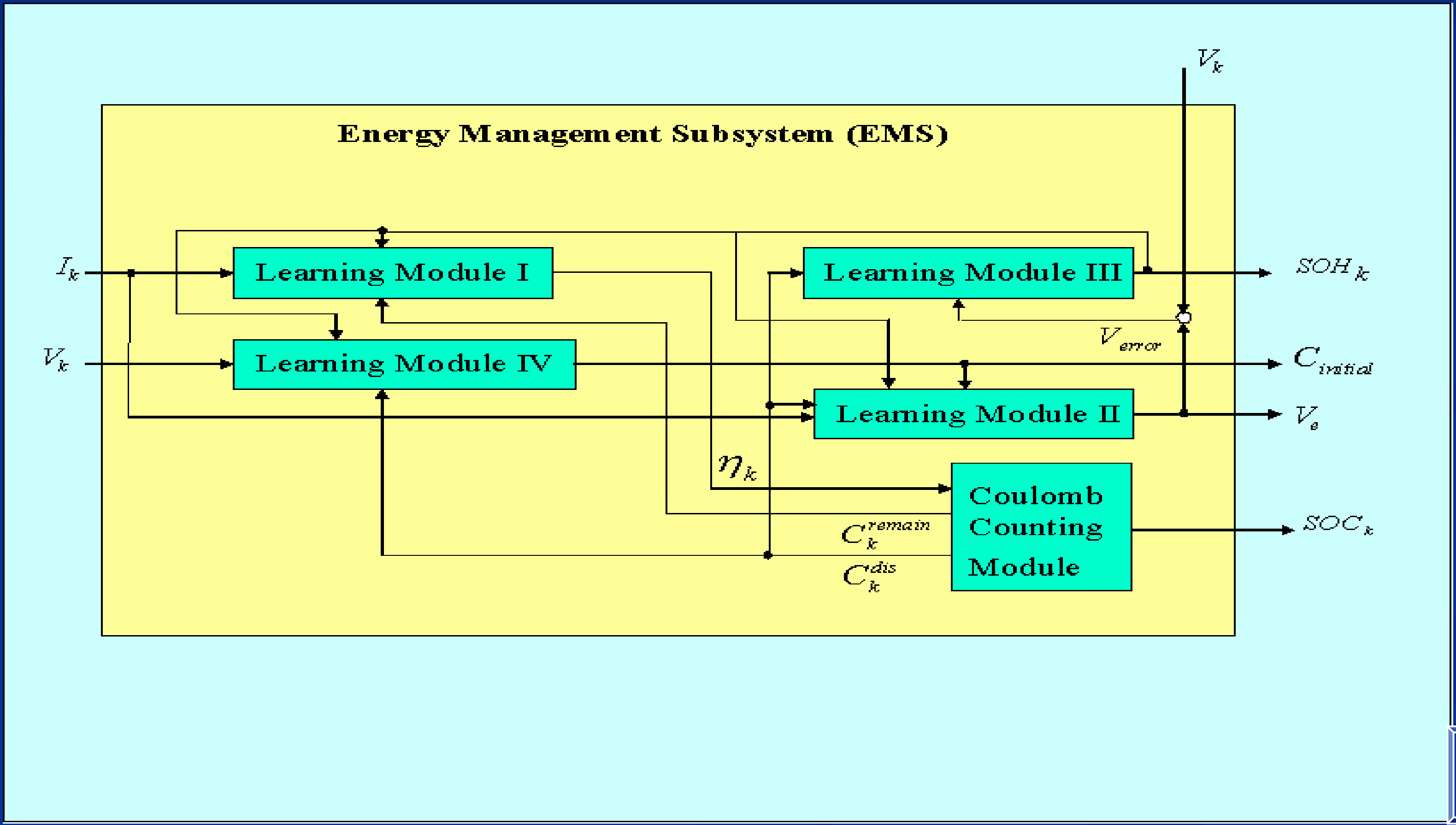
System Implementation 3

b) Provide riders with the critical information
   - Maximum traveling distance
   - Safe speed
   - Remaining battery capacity (SOC)
   - Battery state of health (SOH)

c) Ensure that the scooter can arrive at the destination safely

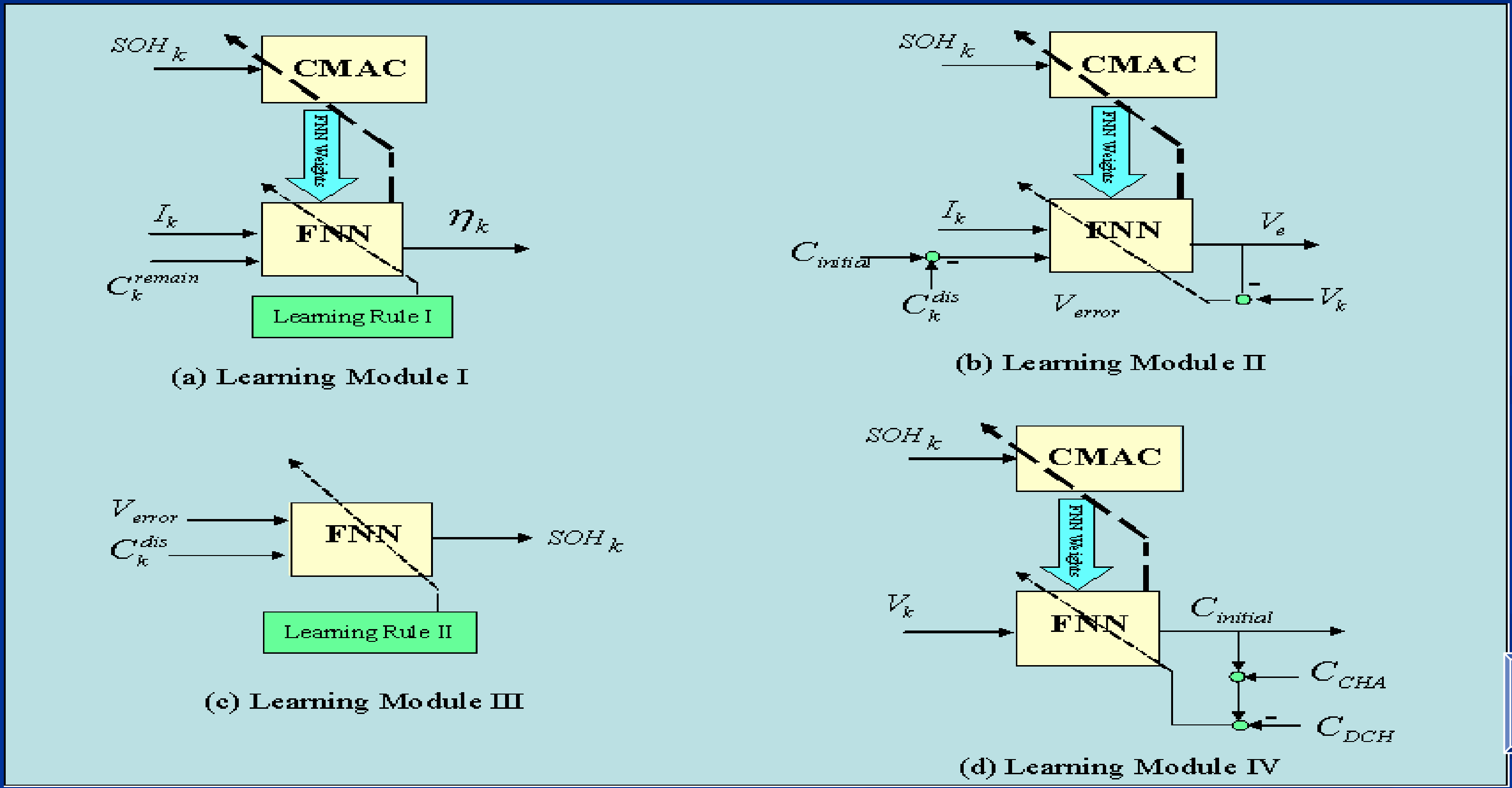
System Implementation 2

- An illustration of the EMS



System Implementation 1

- Learning modules in EMS



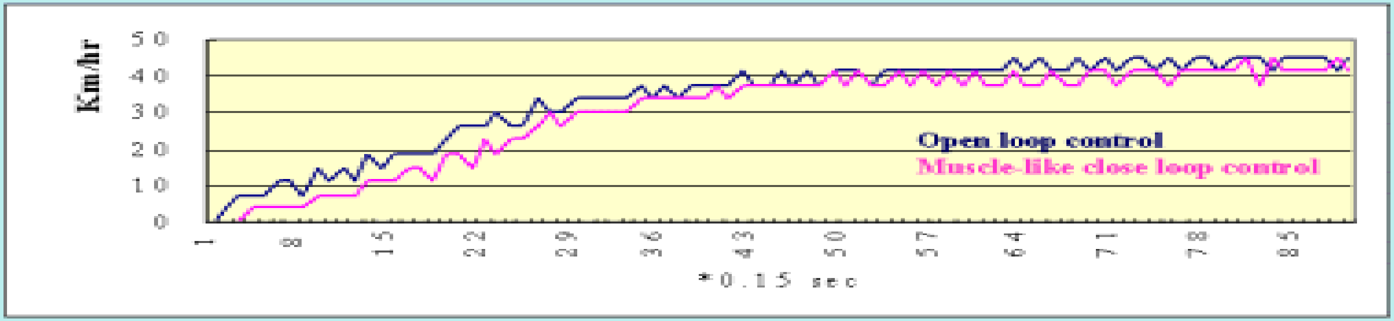
Experiment 8

- Scooter (EVT 4000) equipped with the proposed system :

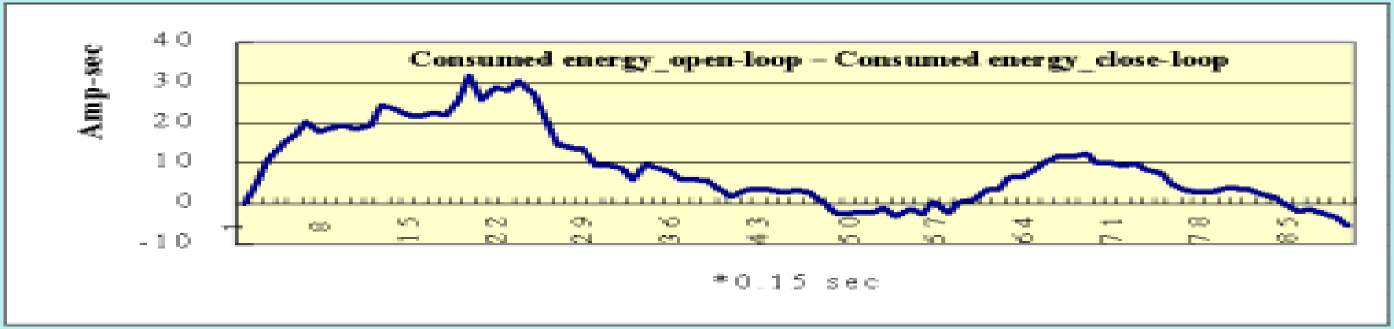
(a) (b)

Experiment 7

- Testing for DCS
  a) Acceleration test



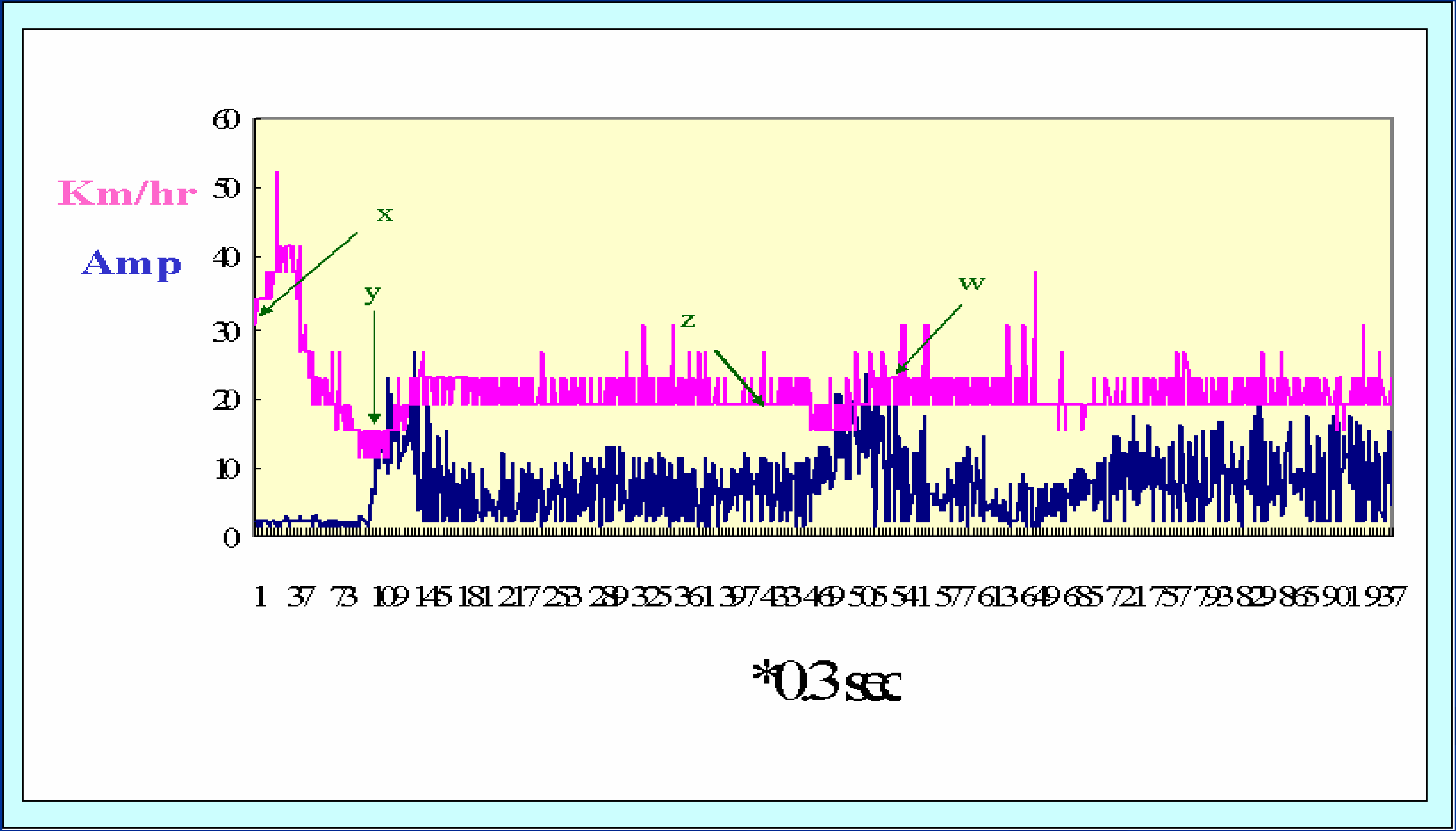
(a)



(b)

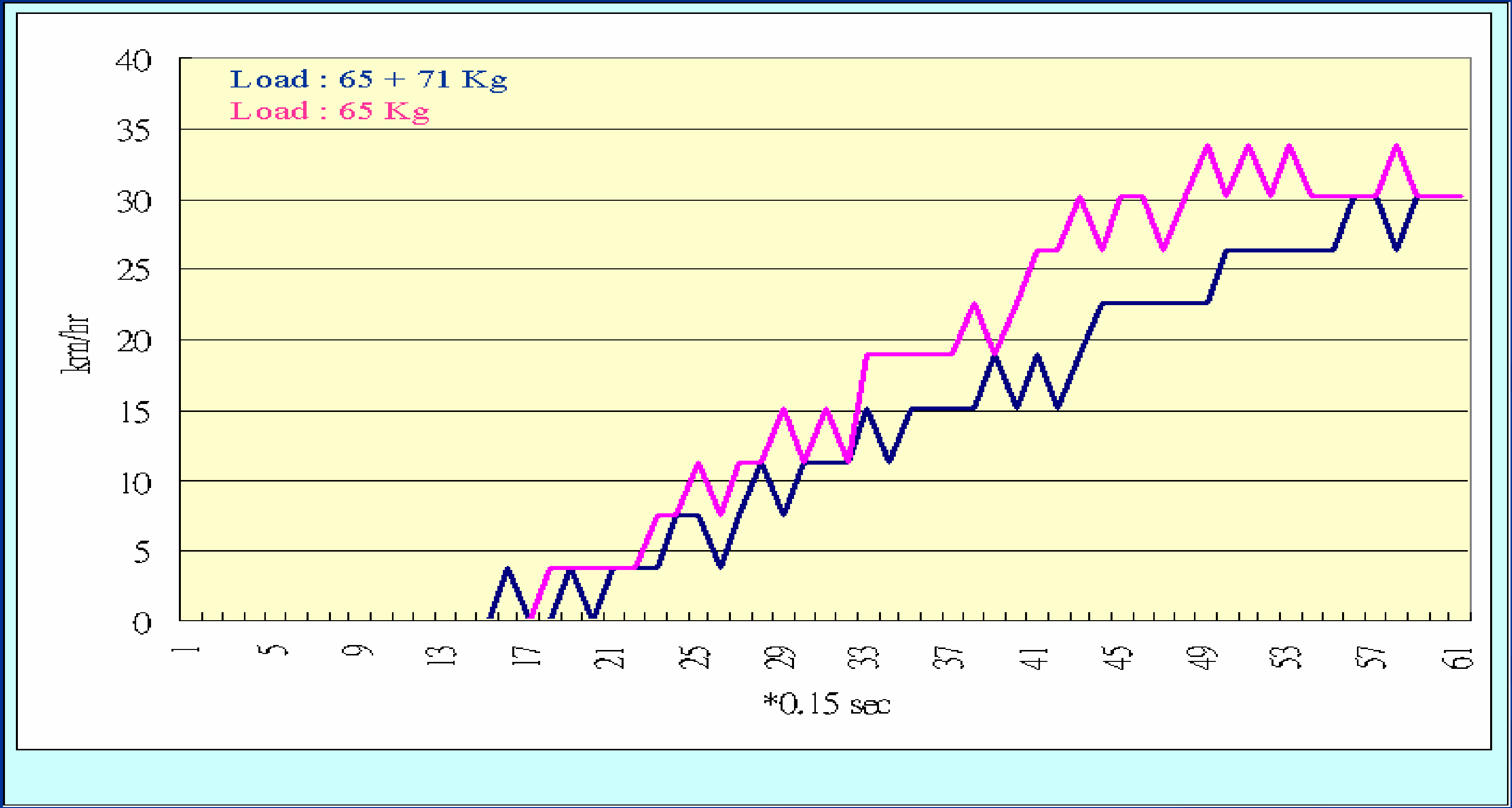
Experiment 6

b) Varying road conditions test



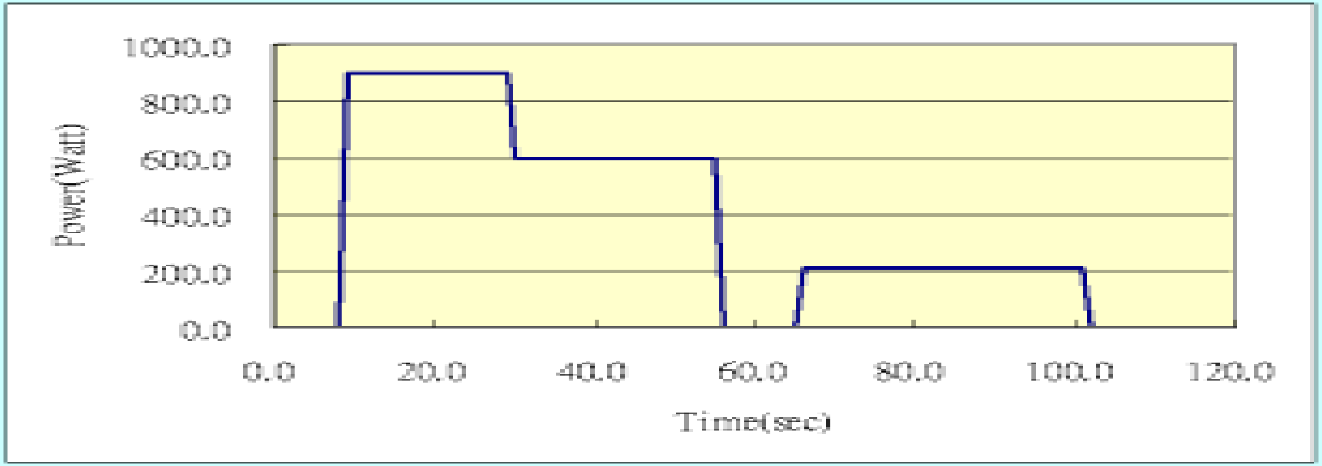
Experiment 5

c) Varying loads test



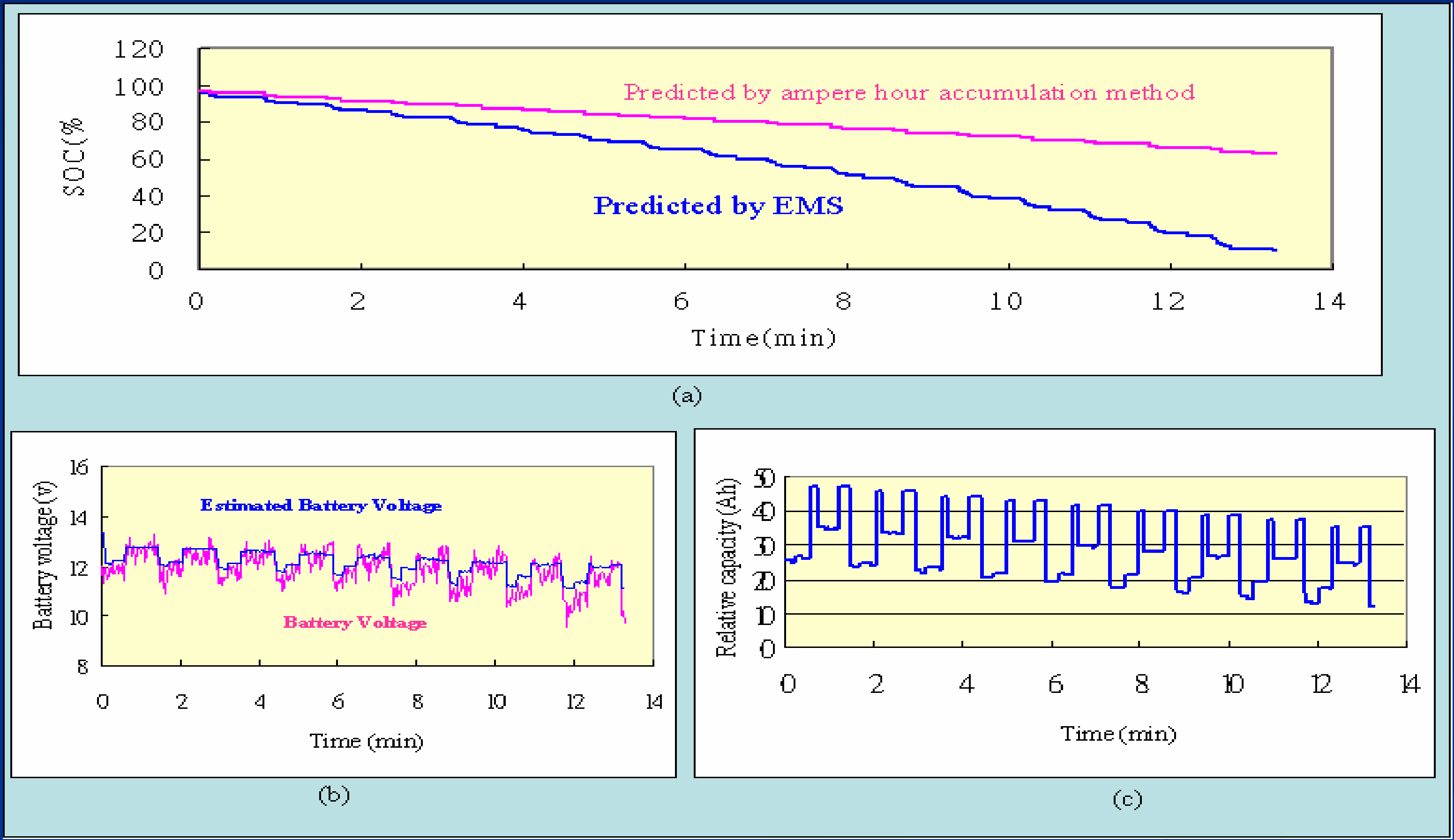
Experiment 4

- Testing for EMS
  a) Power consumption test
     - Power consumption pattern



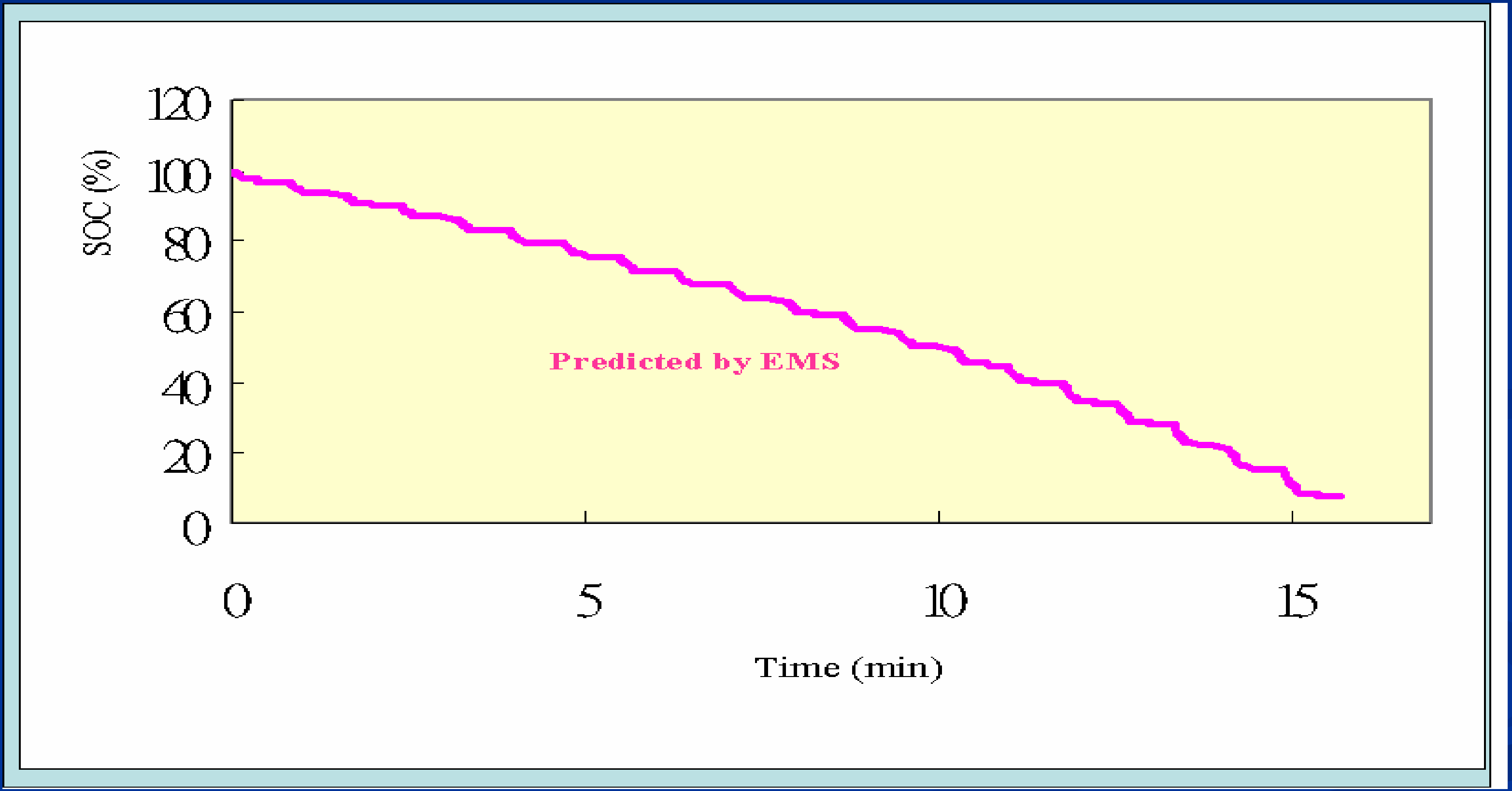
Experiment 3

- Testing result at the 1st training cycle : SOC error = 10%



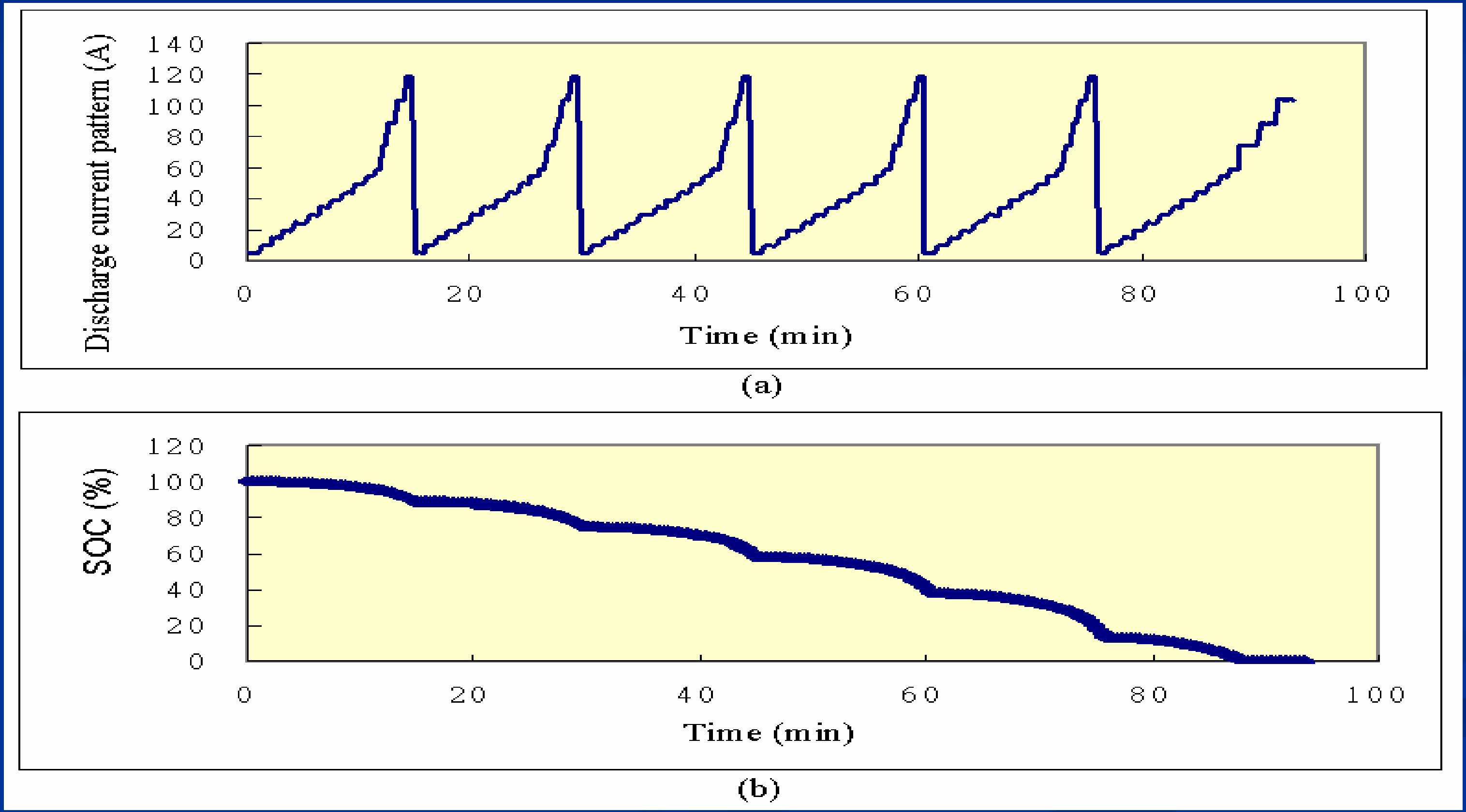
Experiment 2

- Testing result at the 20th training cycle : SOC error = 7%



Experiment 1

b) Varying discharge currents test



Conclusion

- The intelligent control system has greatly improved the performance of present electric scooters
- Working to cut down memory requirement in order to make the system more efficient and ready to have the technology transferred to private sector