
EXQUISITUS

Centre for System Intelligence and Efficiency (*EXQUISITUS*)

EXQUISITUS is a Centre of Excellence which strives to advance research and development (R&D) in electrical systems for future cities. It develops key technologies in power electronic devices, intelligent control and optimization, and autonomy for applications in areas encompassing environmental monitoring, sustainability, renewable energy systems, transportation systems, aerospace engineering, maritime engineering, and defence.

Research activities can be broadly divided into areas of energy conversion devices, clean and renewable energy systems, energy storage, smart grids, energy efficient buildings, control system technologies, mobile robotics, intelligent transportations, and urban sensing. These activities are organized under the three research programmes: E Sustainability, E-Mobility and E-Sensing.

http://www.exquisitus.eee.ntu.edu.sg

Director

Professor Wang Danwei
Email: edwwang@ntu.edu.sg

Prof Wang is currently the Director for *EXQUISITUS* and a professor at NTU's School of Electrical and Electronic Engineering. He has taken up various positions in international conferences and is an associate editor of the International Journal of Humanoid Robotics, as well as a member of the editorial board of International Journal of Vehicle Autonomous Systems. A recipient of the Alexander von Humboldt Fellowship, Germany, Prof Wang's research interests include robotics, automation, intelligent transportation systems, control theory and applications. He has published widely in the areas of iterative learning control, repetitive control, robust control and adaptive control systems, as well as manipulator/mobile robot dynamics, path planning, and control.

Research Facilities and Capabilities

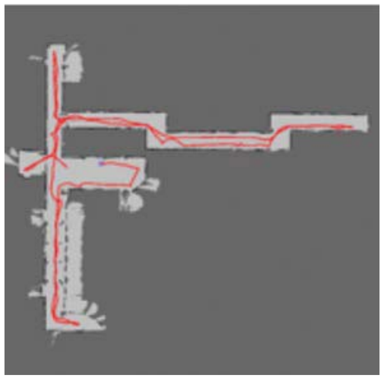
The Centre focuses its research on green cooling and air conditioning technologies, intelligent power and energy systems, unmanned systems and urban mobility, and urban sensing and data analytics. Our state-of-the-art laboratories offer support to the different types of expertise we have in each area. These include Autonomous Robotics Research, Control Engineering, Intelligent Robotics, Internet of Things, Laboratory for Clean Energy Research, Power Electronics Research, and Process Instrumentation and Water and Energy Research.

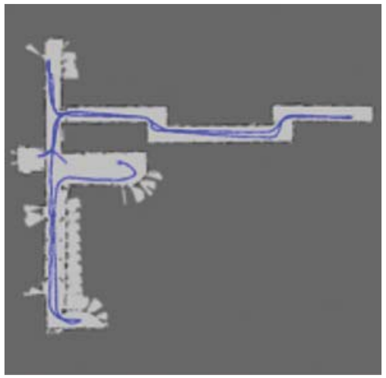
Highlight of Research

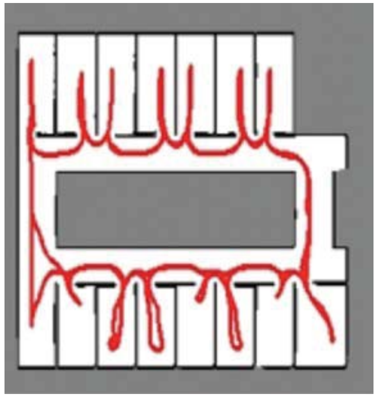
1 Autonomous Robot Navigation

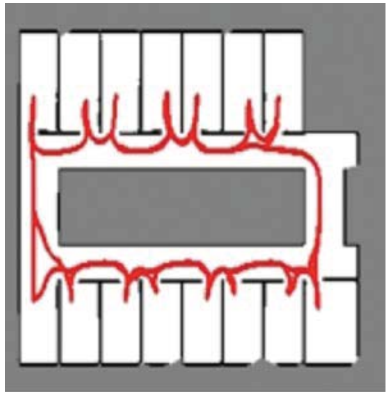
Led by Prof Wang Danwei, this project carries out research activities on autonomous robot navigation in challenging environments.

Exploring an unknown environment to generate a map is a fundamental requirement of autonomy for robots. We have developed an incremental algorithm (SRFD) that efficiently manages the underlying data structures used by robots for exploration. The SRFD method improves the efficiency of autonomous exploration missions by allowing faster decision frequencies for robots, especially for those with limited computing capabilities.

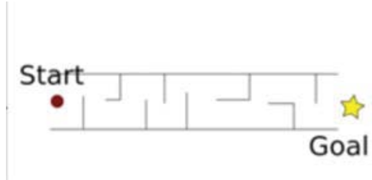






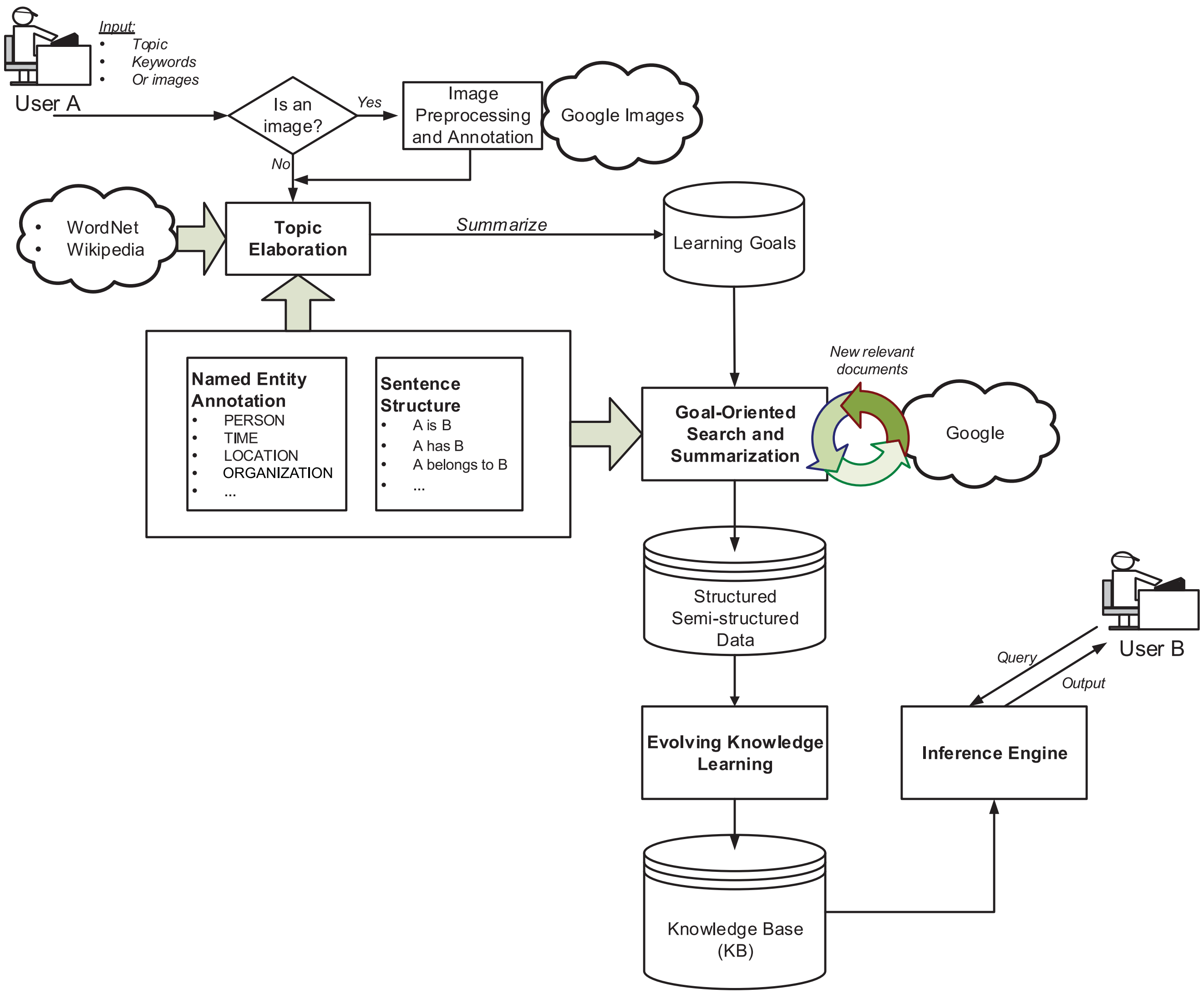


Goal oriented navigation in unknown environments must be able to adjust its existing plans based on the newly acquired environment data such as new obstacles and dead-ends. We have developed a new goal oriented navigation algorithm that is based on directing a robot's exploration towards the goal. It utilizes the SRFD approach's fast exploration data update rates to quickly detect and recover from dead-end situations and to send the robot in the correct direction towards the goal.

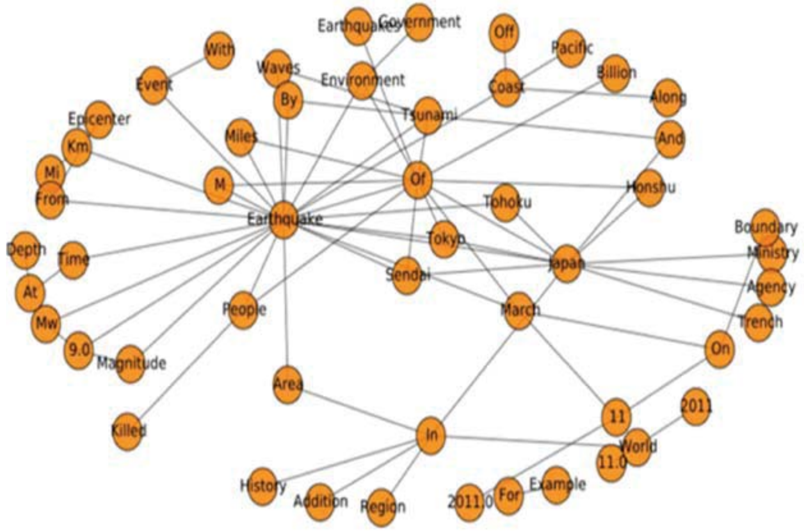


2 Automatic Knowledge Extraction from Unstructured Open Sources (AKEOS) for Autonomous System

This project is led by Assoc Prof Mao Kezhi, and is supported by the Ministry of Defence of Singapore. To build a human-like autonomous system that is capable of reasoning and decision making, it is imperative to encode knowledge into the system. Knowledge exists in various sources, but mostly in text and images, which are unstructured and are not machine understandable. This research aims to build an automatic knowledge extraction system that is able to extract knowledge from unstructured sources and then encode the knowledge extracted into machine understandable and usable form. The following diagram shows the architecture of the AKEOS system:



For a query, such as “Tohoku earthquake”, the system will first search the web to find relevant documents, identify informative sentences, and then extract knowledge and encode the extracted knowledge into a graph. Based on the knowledge graph, advanced query and reasoning can be performed. The system will automatically generate the following knowledge graph which was based on this particular query:



3 Energy Storage: 3-D CFD Thermal Modelling of Lithium-Ion Batteries

This research project is led by Assoc Prof Tseng King Jet, and is funded by the National Research Foundation Singapore under its Campus for Research Excellence and Technological Enterprise (CREATE) programme.

In this project, a transient three-dimensional computational fluid dynamics (CFD) thermal model of a single lithium-ion cell is proposed based on the actual structure of the cylindrical 18650 lithium-ion battery. Temperature distribution of the cell during its discharge process was simulated and verified by comparing simulation results with experimental data. Commercial CFD software was also applied in simulation studies which are accurate and reliable as the input parameters are obtained directly from experiments. Thermal behaviours of battery under adiabatic and normal conditions were studied in this research. Under other conditions, temperature behaviours can be simulated easily through our model by changing ambient conditions in the software. The proposed model offers potential in improving battery management systems (BMS) in terms of monitoring and control capabilities.

When considering thermal characteristics of the interior cell structure, it can be treated as uniform since the current collectors comprising coaxial rolls of copper and aluminum foil are good heat conductors as shown in Fig 1. The interior cell structure was regarded as a heat source in the model. It comprises a safety valve mechanism which will open in response to a sudden increase in cell pressure, thus allowing built-up gases to escape. If the pressure inside a cell builds up, a plastic laminate membrane will then be punctured by a spike incorporated in the valve usually located at the top surface of the cell. A safe release of internal pressure precludes any dangerous rupture of the cell casing.

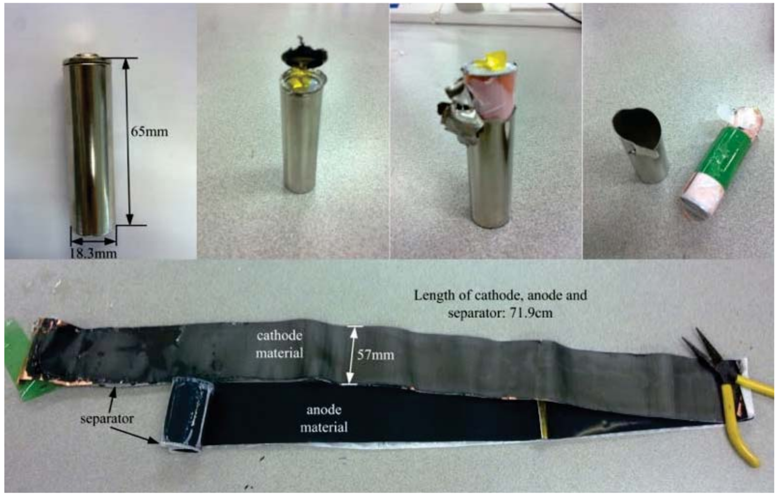


Fig. 1

The three-dimensional single cell CFD model is illustrated in Fig. 2. Simulated temperature distributions of the cell under adiabatic conditions at 2C and 3C discharge rates were found to be relatively uniform under adiabatic operation conditions, with a slight temperature difference occurring after a certain time period. Temperature is slightly lower at the top surface of the cell as the internal heat source within the cell is located at the base of the cell case shown in Fig. 2. At 2C discharge rate, the highest temperature reaches 45ºC at the end of discharge (1800s) whereas at 3C discharge rate, the temperature rises to 53ºC within 1200s. The simulation under the adiabatic condition is conducted for verification of the model. Comparisons of simulation and experiment results are shown in Fig. 3(a) and (b) for 2C and 3C discharge rates respectively.

We concluded that battery temperature distribution is generally uniform under adiabatic conditions. Under normal discharge conditions on the other hand, the disequilibrium between heat generation and dissipation causes a significant temperature difference on the cell surface during the transient discharge process. Current collectors also have minimal effect on the temperature distribution of the cell under normal conditions. As high current discharge leads to higher heat generation rate, a cell temperature exceeding 40ºC at 3C discharge is beyond the acceptable working temperature range of lithium-ion battery (0-40ºC).

Another possible application of the proposed model is to predict potential safety hazards of cells - in situations where temperature goes beyond the safe temperature range. Mitigating actions could then be taken to protect cells and keep the battery system well and healthy. This model is especially useful in the assessment of battery thermal behaviour under high current rate discharge processes.

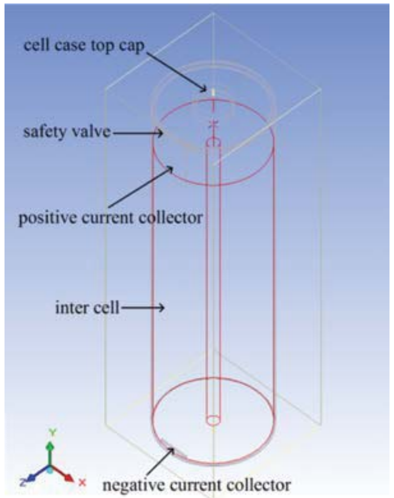


Fig. 2

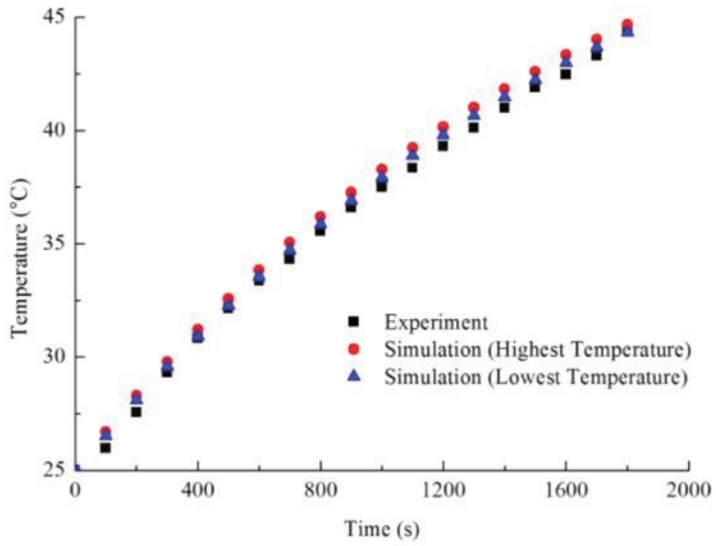


Fig. 3(a) under 2C discharge rate

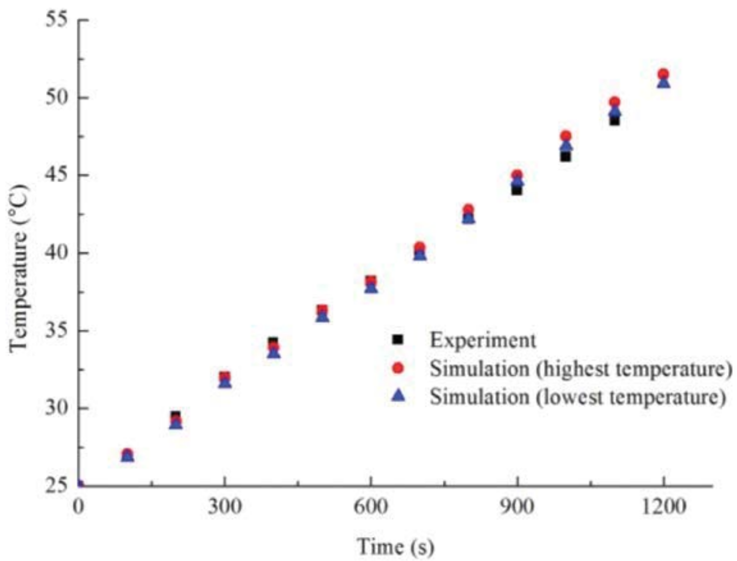


Fig. 3(b) under 3C discharge rate