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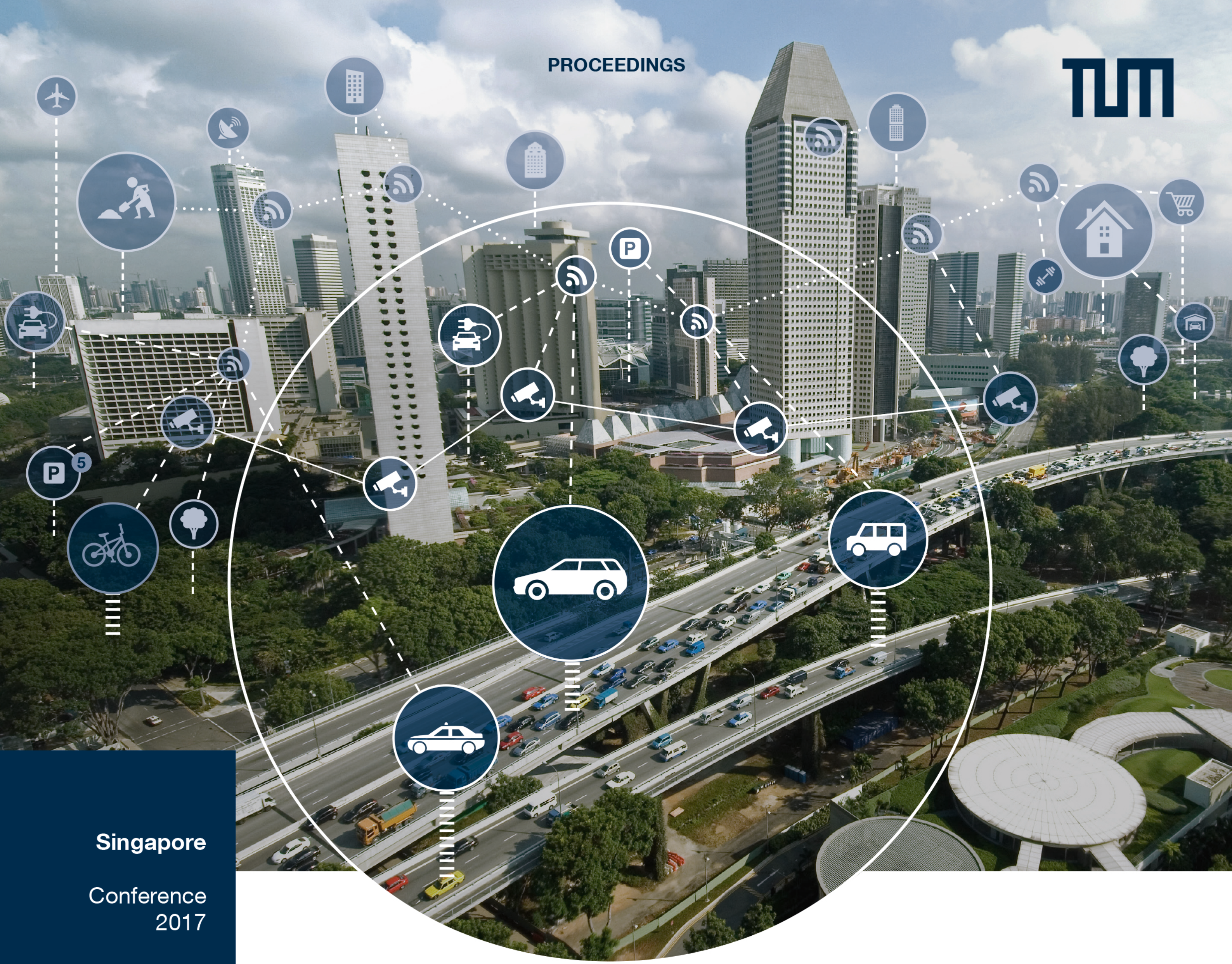

Singapore

Conference
2017

Technical University of Munich

1st TUM Research Alumni Conference

Living and Mobility in Smart Cities

TUM.University Press

1st TUM Research Alumni Conference

Living and Mobility in Smart Cities

Contributions by participants

Singapore August 28—29, 2017

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The Research Alumni Strategies competition is part of the International Research Marketing project that is being jointly conducted by the Alexander von Humboldt Foundation, the German Academic Exchange Service (DAAD), the Deutsche Forschungsgemeinschaft (German Research Foundation) and the Fraunhofer-Gesellschaft. The project is funded by the Federal Ministry of Education and Research and is part of the "Research in Germany" initiative. In 2012, 2014 and 2016 the Technical University of Munich was one of the award winners.

Research Alumni Strategies

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Every year, the Alexander von Humboldt Foundation enables more than 2,000 researchers from all over the world to spend time researching in Germany. The Foundation maintains a network of well over 27,000 Humboldtians from all disciplines in more than 140 countries worldwide — including 54 Nobel Prize winners.

Within the collaborative project "International Research Marketing" and building on decades of experience in alumni activities and networking, the Alexander von Humboldt Foundation has focused on promoting research alumni activities at universities and research institutions in Germany for several years.

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About the Conference

The 1st Research Alumni Conference, "Living and Mobility in Smart Cities", took place at the end of August 2017 in Singapore. It was organized by the Technical University of Munich (TUM) together with its wholly-owned subsidiary the German Institute for Science and Technology (GIST)-TUM Asia Pte. Ltd, and was funded by the Alexander von Humboldt Foundation.

The Conference took place at TUMCREATE, the research institute of TUM Asia. In this interdisciplinary center, new concepts for the mobility of tomorrow are developed using Singapore as an example. Singapore has made it its aim to be a Smart Nation pioneer for the whole of Asia.

The conference participants were research alumni (former guest researchers) of TUM who live and work in Asia, scientists from TUM and TUMCREATE as well as experts from Singapore. Thanks to their diverse cultural, professional and research backgrounds, they were able to inspire each other, and exchange and discuss ideas across disciplines.

The conference covered three main topics in three sessions: Mobile Applications and Technology as Innovative Solutions, Innovations for a Seamless Public Transport Experience, and Smart Living. Each session was opened by an expert in the appropriate field, with participating research alumni then giving presentations.

The presentations are published in these conference proceedings.

Foreword

At TUM we believe in individuals who have the passion to develop their talents, and we invest in them. We measure our scientific, structural and organizational performance by the best international standards, and therefore we build international networks and draw on international alliances with leading teaching and research institutions. For us it is essential to attract outstanding scientists from abroad for research visits to our university and to make TUM a second “home” or “alma mater” for them.

Thanks to the internationalization strategy of the last decade, TUM today is dynamic and tightly networked and attracts many top-level scientists. But beyond this, TUM has consistently worked to create a strong alumni culture. For us, as an entrepreneurial university, alumni are essential “transmission channels” between the intellectual advances achieved within our walls and their practical implementation in the outside world. Research alumni are the visiting professors and guest researchers who have spent long or short periods at TUM and have enriched the university with their scientific experience and international practice. We encourage our research alumni to share their knowledge and experience, to maintain contact with us and to actively take part in our network.

This network not only brings together renowned scientists from all over the world at events like this conference. TUM’s goal is also to cultivate long-lasting relationships with our research alumni. We want to be part of their research biography, not just during their stay but also after it, and to keep them in an active, vital network. To make this as easy as possible, TUM provides alumni activities, meetings, and an online community with access to other alumni around the world.

In August 2017, for the first time, TUM organized an alumni conference abroad for TUM research alumni. This was the 1st TUM Research Alumni Conference: Living and Mobility in Smart Cities, which took place in Singapore at the TUM CREATE facility and was one of the networking highlights of 2017. We are proud of our research alumni who made it such a successful and rewarding event.

Our sincere thanks go to the Alexander von Humboldt Foundation for its staunch promotion of research alumni activities in Germany and for supporting our 1st TUM Research Alumni Conference.

Prof. Juliane Winkelmann
Senior Vice President, International Alliances & Alumni

Foreword

As the then acting Senior Vice President for International Alliances and Alumni, it was an honor for me to open the 1st TUM Research Alumni Conference in August 2017.

Theory meets practice — that is how I experienced this alumni networking event. There is no better place for a “Smart Cities” conference than Singapore — a city with plans to become the world’s first “Smart Nation”, and a site where research and smart technical developments can be tested quickly and applied in real life.

In this smart city the TUM CREATE building became a hub for brilliant scientists from around the world. It was a pleasure to meet them and take part in exchanges at professional, personal and intercultural levels. Researchers at different stages in their careers and from very diverse professional backgrounds got together to present their ideas for a smart future and to discuss solutions for smart living at many levels.

On the theoretical side, the conference saw presentations on Mobile Applications, Seamless Public Transport Experience, and Smart Living. On the practical side, there was the TUM CREATE Lab that brought smart driving alive, and a visit to Singapore’s Land Transport Authority that gave insights into the practical application of smart transport surveillance.

The special feature of the 1st TUM Research Alumni Conference was its group of attendees: top scientists from different disciplines and of different ages from around Asia who have all once been guest researchers at TUM — in short: our TUM research alumni. It was a pleasure to take part in this conference and have the chance to interact with these brilliant scientists. It proved — once more — how engaged our TUM research alumni are. They are open-minded people who want to share knowledge and exchange ideas with like minds, and they are strong supporters of the TUM network.

The conference showed once more that relationships do not end with the stay at a university.

Let’s keep in contact!

Dr. Hannemor Keidel
Senior Vice President for International Alliances and Alumni (2016 to September 2017)

Contents

1. Remote Monitoring of Power Equipment

Sivaji Chakravorti and Riddhi Ghosh

Electrical Engineering Department
Jadavpur University, India

Stay at Technical University of Munich: 1995–96, 1999, 2007
TUM Department of Electrical and Computer Engineering

The article presents the application of advanced techniques for signal conditioning and data acquisition to remote monitoring of high voltage power equipment. The primary focus is on the monitoring of leakage current in transmission line insulators, which have a particularly pronounced need for remote monitoring due to the large number of insulators that are currently in service. Remote monitoring of overhead insulators is met with significant challenges, which tend to limit the large-scale deployment of remote monitoring units, and also the interpretation of the obtained results. The specific challenges limiting the large-scale deployment of monitoring units are power consumption in the processing module deployed in the field, the problem of identification and elimination of field noise from leakage current measurements, and the presence of voltage distortions, which can render most traditional monitoring indices ineffective. This article will present the key challenges and the state-of-the-art techniques that are being investigated to overcome these challenges, while keeping in mind the requirement of low-complexity algorithms for deployment in on-field measurements, so that large-scale deployment of remote monitoring units becomes economically feasible. The last aspect is particularly relevant for smart cities, as the proposed methodology is not limited to remote monitoring of insulators, but can be extended to other units, which are distributed across a large area.

1.1. Introduction

Smart cities have become an important focus area for researchers, scientists and governments across the world. Smart cities refer to a place where services and networks are made more efficient, flexible and sustainable through the use of digitization, information and communication technology [1]. The smart cities are characterized by features, such as smart transportation, communication, technology, infrastructure and energy. Of these, smart energy has been an important research area for power utilities. Over the past decade, with the advent of the smart grid, the system for energy generation, transmission and distribution has become more and more efficient and resilient to disruptions.

1.1.1. Remote Monitoring Systems for Smart Grids

The concept of smart grids necessitates continuous online monitoring and intelligent control of power system components from a central location. Smart grids combine advanced measurement and sensing technologies with modern communication techniques to efficiently monitor and control the power grid [2]–[4]. Amongst the various requirements and benefits of a smart grid, enabling preventive maintenance of the grid and improving resilience to disruptions are decisive factors for building an intelligent power grid [5]–[6]. Preventive maintenance can be carried out through real-time online monitoring of power system components. When such components are operational in the field, remote monitoring of any grid component becomes a much desired requirement for the smart grid. Remote monitoring of the transmission system is critical to the smooth operation of the power network, as it is able to make the transmission network more flexible and reliable by predicting impending failure, enabling condition-based maintenance and reducing outages and downtime.

A typical remote monitoring system will consist of different stages such as the data acquisition stage, signal conditioning and pre-processing stage, data storage and transmission followed by data analysis, report generation and corrective action. Among these, the data acquisition, signal conditioning and storage are generally deployed at the processing module on site, and are faced with significant challenges since the bulk of the power consumption takes place in the processing module. Hence there is a need for low-complexity algorithms to be deployed in the processing module of remote monitoring systems.

1.1.2. Need for Remote Monitoring of Line Insulators

Breakdown of the electrical insulation is perhaps the biggest threat to the sustainability of power transmission systems. The vast transmission network carries electric power over several hundred kilometres and is exposed to environmental stresses. The line insulators, which provide electrical insulation between the high voltage line and earthed tower, are therefore among the most critical grid components for a smart grid. Since insulators are deployed in large numbers, and each insulator can fail independent of the service condition of other insulators in its vicinity, a very large number of insulators must be monitored to ensure the reliability of the network.

The monitoring of in-service insulators is most commonly done using the surface leakage current pattern. Environmental pollutants and moisture deposition on insulators result in an increase in the magnitude of leakage current causing surface heating and formation of dry-bands. This results in an increase in the leakage current harmonic content due to an increase of non-linearity in the leakage current pattern. Therefore, the harmonic content of leakage current is one of the most widely used monitoring parameters for line insulators.

1.2. Challenges in Remote Monitoring of Insulators

Remote monitoring of insulators is met with significant challenges that limit the large-scale deployment of remote monitoring units.

1.2.1. Field Noise

Remote monitoring of insulators requires continuous monitoring of leakage current, so that the electrical activity may be recorded as and when the electrical activity becomes significant. Since the sensors are continuously acquiring the data, a significant problem in remote acquisition is associated with field generated noise and waveforms that do not reflect actual electrical activity on the insulator surface. Continuous monitoring of insulator leakage current data often results in the collection of unwanted information in the form of field generated noise and waveforms that do not signify true surface activity.

1.2.2. Energy Consumption

The processing module of the monitoring system will require a low voltage power source. In field monitoring, it is difficult to obtain such a low voltage source on a high voltage transmission tower. The common practice is the use of a solar power module to cater to the energy requirements of the processing module. The higher the computational burden of the computational methods adopted in the monitoring system, the higher the power requirement; consequently, larger solar panels will be required. Therefore, application of any mathematical technique to field devices for insulator monitoring will be a costly affair for power utilities, unless the employed mathematical technique deploys a low computational load on the processors.

1.2.3. Voltage Harmonics

The condition assessment techniques for insulators are based on the assumption that detailed voltage information is available at the instant of monitoring and the applied voltage is sinusoidal and does not vary over time. In reality, however, the system voltage during online monitoring of insulators will be prone to harmonic distortions. Due to the non-linear nature of the degraded and contaminated insulator surface, the voltage harmonics can have considerable impact on the nature of the insulator leakage current, even when the distortions are within the recommended level. In the presence of voltage harmonics, the traditional monitoring indices such as the magnitude of lower order harmonics and third/fifth harmonic ratio, will lose their significance. Hence, there is a need to identify an index that will exhibit low sensitivity to harmonics in system voltage.

1.3. Identification of Field Noise

Continuous long term measurement of insulator leakage current results in the accumulation of huge amount of data, most of which consist of waveforms signifying low-activity in insulators and field generated noise that has low significance in terms of insulator condition monitoring. Accumulation of data and noisy waveforms will result in unnecessary energy consumption in processing the data, consumption of storage space and bandwidth in transmitting the data.

Different types of noise are encountered in field monitoring of insulators: typical noise, dysfunction noise and spikes [7]. Each of the noise types have a different characteristic and hence a combination of different mathematical techniques, such as fundamental frequency estimation, maximum and minimum point smoothing, multi-resolution analysis and thresholding, is required to identify the noisy waveforms [7]. The method is slow since different mathematical techniques must be applied to each recorded data window and it is also computationally intensive.

Instead of using a number of different mathematical techniques to discard the various kinds of noise, a better solution would be to use a mathematical technique, having a strong correlation to the local characteristics of the waveforms to differentiate between field noise and waveforms portraying electrical activity. The instantaneous slope of a signal is one such characteristic that can help in discriminating noise from waveforms representing surface activity. Hence, a mathematical technique that has a strong correlation with the instantaneous slope of a waveform has been proposed in this work for identifying noisy waveforms.

1.3.1. Short-Time Modified Hilbert Transform

The instantaneous slope of the recorded leakage current waveforms can give significant information regarding the nature of the waveforms. Leakage current waveforms exhibit a gradual variation of slope in a fairly regular manner, starting from zero at a negative peak to a maximum at the next negative-to-positive zero crossing. Sudden large changes in slope are generally absent. On the other hand, presence of noise is generally characterized by sudden significant changes in the instantaneous slope of the waveform around the noisy peak. The sudden rise in magnitude of the waveform as a result of a noisy peak will result in a sudden large positive value of slope at that instant, whereas the falling edge will result in a sudden large negative slope. Thus, noisy waveforms may be discriminated from waveforms portraying significant electrical activity using the local slope.

It has been previously reported by the authors in [8] that the short-time modified Hilbert transform has a strong correlation with the instantaneous slope of the waveform. Figure 1 shows the schematic representation of the technique and how it helps in enhancing the local slope of the waveform. The method consists of applying a shifting window to the waveform, finding the Hilbert transform of the windowed section followed by extracting the centre value of the windowed Hilbert transform.

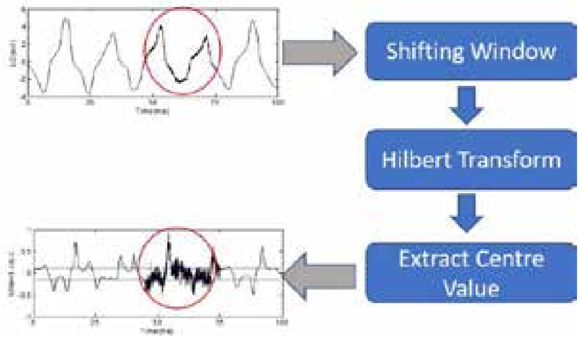


Figure 1 Use of Short-Time Modified Hilbert Transform to enhance the instantaneous slope of a waveform

Figure 2 shows how the noise in different leakage current signals is enhanced in the corresponding Short-Time Modified Hilbert Transform. Different parameters may be extracted from the transformed waveforms, which can help to discriminate between noisy waveforms and leakage current waveforms portraying electrical activity on insulator surfaces. A more detailed description of the mathematical technique and results may be found in [8].

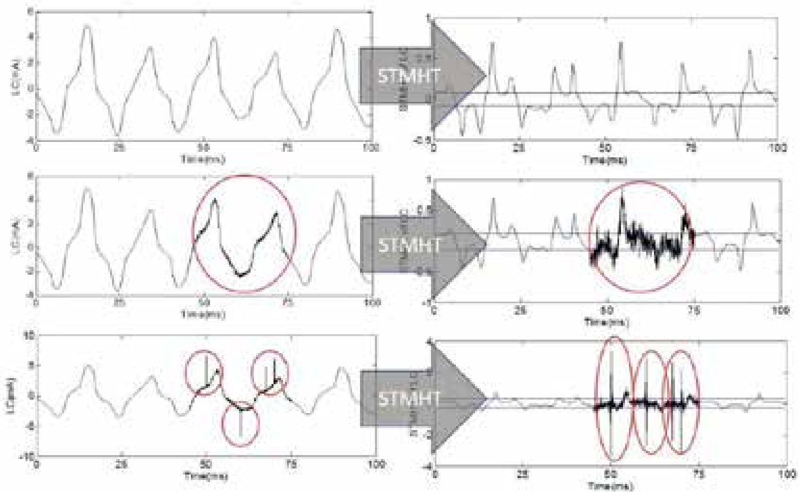
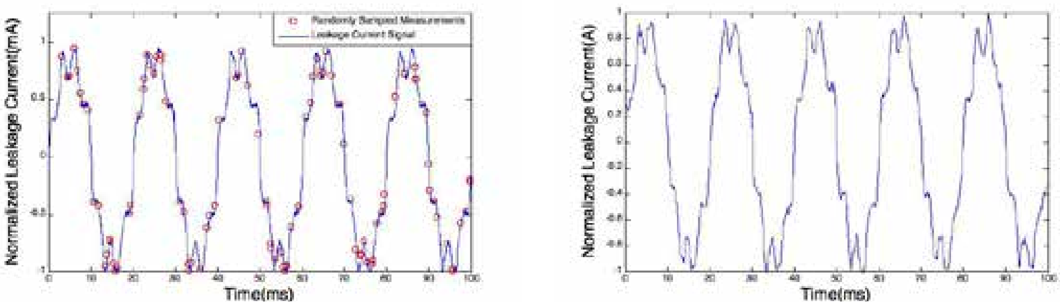


Figure 2 Effect of Short-Time Modified Hilbert Transform on superimposed noise in leakage current waveforms

1.4. Energy Consumption

Energy consumption in data acquisition and compression in remote monitoring units is a major factor, which limits the large-scale deployment of the units. Most data acquisition techniques acquire data at a high sampling rate and then employ some compression or data modelling technique to reduce the data size. As a result, energy is expended in acquiring data and then compressing it. There is scope for further reduction of energy consumption at the processing module through the implementation of state-of-the-art signal acquisition techniques that involve minimal mathematical algorithms at the field device. It is possible to reduce the computational burden at the processing module by shifting the computational load from the processing module of the remote monitoring unit deployed on-site to the central monitoring station by utilizing a recent development in information theory, known as Compressed Sensing. This method highlights the recovery of leakage current waveform at the central monitoring station from a small number of random measurements of the leakage current signal taken at the insulator site. The low-complexity method shifts the entire computational burden from the monitoring unit to the central monitoring station. This technique has the potential of making large scale deployment of monitoring systems possible by reducing the energy consumption at the field monitoring device through minimization of the computational load, as well as processor costs.

Compressed Sensing is a signal acquisition methodology that consists of simultaneous acquisition and compression of acquired data that may be applied to any real-valued, discrete time signal, provided the signal has a sparse representation in some transform domain. The compressed sensing process consists of taking linear non-adaptive measurements of the leakage current waveform. The decoder uses a l1 minimization approach to recover the waveform from the random non-adaptive measurements. A typical leakage current signal and the waveform reconstructed from the random measurements have been shown in Figure 3. A more detailed analysis of the proposed method has been reported in [9].



(a) (b)

Figure 3 Typical leakage current waveform and its randomly sampled measurements and recovered signal from random measurements

The practical implementation of an insulator monitoring system based on compressed sensing is convenient and easy to install. As has been mentioned earlier, conventional leakage current monitoring systems reported in literature consist of a processing module and leakage current sensor. The processing module samples the signal from the sensor at a uniform sampling rate, and either extracts features from the waveform or compresses the waveform, which is then communicated via a communication module to the central monitoring station. A monitoring system based on the proposed method will consist of similar sensors and communication modules. However, there will be a significant reduction in the computational load on the processing module. The function of the processing module will be to sample the signal randomly in a non-uniform manner according to the nature of the measurement matrix, and pass the sampled values to the communication module for transmission.

1.5. Problem of Voltage Harmonics

It has been previously reported by researchers that some of the most widely studied parameters of insulator leakage current are the waveshape and harmonic content of the signal. It has been shown that harmonic changes in leakage current are a good indicator of surface condition of insulators. However, the presence of harmonic distortions in the system voltage can alter the leakage current pattern, which may lead to incorrect interpretations regarding the surface condition of insulators. For a remote monitoring system, it is necessary to correctly identify the leakage current changes arising from changes in voltage distortion and to differentiate them from leakage current changes arising as a result of changes in the degree of contamination.

For understanding the behaviour of insulators under non-sinusoidal voltage, experimental setup was developed and leakage current waveforms under varying voltage waveforms have been recorded. Figure 4 shows some of the applied voltage waveforms and the corresponding leakage current signals.

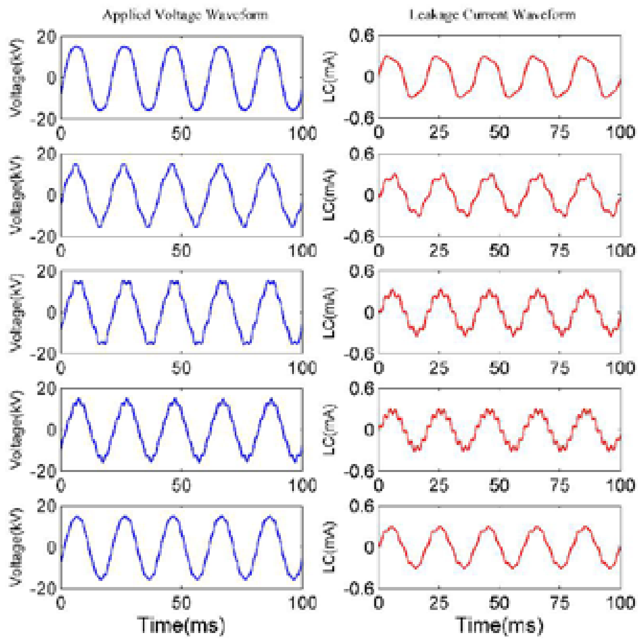


Figure 4 Applied voltage waveform with different harmonic content and the corresponding leakage current waveform

In the present work, a monitoring index extracted from the insulator leakage current has been proposed, which exhibits low-sensitivity to changes in AC harmonic voltages. The proposed index is based on the time-integral of the leakage current, which shows the area under the leakage current waveform. It has been demonstrated that the time-integral can be highly stable if the harmonic components are varying with time. It has been shown that for any harmonic, the time-integral of the harmonic component is inversely proportional to the order of harmonics. Hence, the maximum contribution of any harmonic component towards the time integral of the overall leakage current is limited to a maximum of one cycle of that particular harmonic. The contribution of the time-integral of the harmonic component towards the overall time-integral is inversely proportional to the order of the harmonics. Since the time-integral is inversely proportional to the order of harmonics, the contribution of the higher order harmonics becomes progressively smaller with an increase in the order of harmonics. This has been demonstrated in Figure 5, in which the leakage current has been decomposed into its constituent harmonics — the fundamental and third harmonic. As may be seen, within the half cycle of the fundamental component, each shaded area under the third harmonic represents areas of equal magnitude and opposite polarity. Therefore, the area under the two shaded areas will not contribute towards the total time-integral. The maximum contribution will be limited to one half cycle. A more detailed analysis has been reported by the author in [10].

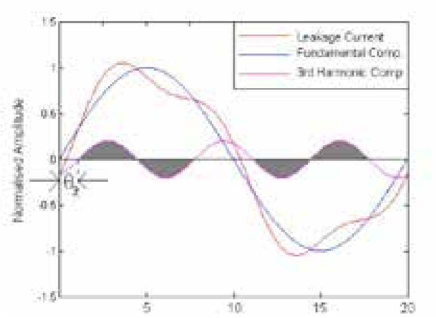


Figure 5 Applied voltage waveform with different harmonic content and the corresponding leakage current waveform

1.6. Conclusions

This paper presents an overview of remote monitoring of power equipment in a smart energy transmission system, with focus on transmission line insulators. A smart energy transmission system needs to be reliable, sustainable and resilient to disruptions. Remote monitoring enables the transmission system to be reliable by enabling condition-based maintenance through real-time monitoring. However, some of the common challenges in building an efficient remote monitoring system for the transmission network are power consumption, field noise and presence of voltage harmonics. The approach taken by the authors to overcome the challenges, involve focusing on the underlying physics of insulator behaviour in the field, and identifying fundamental signal characteristics such as instantaneous slope, signal sparsity and time-integral, which may be correlated with the physical characteristics of the insulator. The employed mathematical techniques take the need for a low computational burden for large-scale deployment of monitoring units into consideration.

Although the present work focuses exclusively on insulators, the methods proposed represent a generic approach towards monitoring remotely located components distributed over a large area. The paper highlights the need for low-complexity techniques for on-site monitoring of components. The paper also presents the advantages of using the fundamental signal properties as important parameters for monitoring instead of complex signal processing approaches. Thus it will be economically feasible, as well efficient to implement such approaches to the monitoring of any remote power system component in the transmission network.

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2. Made-in-China-2025 Meets Industry-4.0

Houde Dai

Quanzhou Institute of Equipment Manufacturing
Haixi Institutes, Chinese Academy of Sciences, China

Stay at Technical University of Munich: 2009–2013,
TUM Department of Mechanical Engineering

2.1. TUM Alumni at a CAS Sub-Institute

Germany‘s 4th industrial revolution (Industry 4.0) is a hot topic nowadays. It inspired “Made in China 2025 (MIC 2025)”, a 10-year blueprint, announced to transform China from a manufacturing giant into a global manufacturing power based on its creative and high-tech driven economy. In fact, TUM alumni perform a great role in bridging these two strategic initiatives. A very special model, the new sub-institute of the Chinese Academy of Sciences (CAS) will be introduced in the first part of the paper. Four of its nine core principal investigators (PIs) hold Ph.D. degrees from TUM. The location of this CAS sub-institute is one of the pilot cities of the MIC 2025 programme and is also the starting point of the Maritime Silk Road. In the second part, motion tracking and its applications in smart logistics will be presented, which is one of the four dominant research directions of the CAS sub-institute.

2.2. “Made in China 2025”: China‘s Answer to Industry 4.0

“Made in China 2025 (MIC 2025)” is a 10-year blueprint for the comprehensive upgrading of China‘s industry and draws direct inspiration from Germany‘s “Industry 4.0” plan, which was first discussed in 2011 and later adopted in 2013. The core of the “Industry 4.0” idea is intelligent manufacturing, i.e., applying information technology tools to

[1] https://www.csis.org/analysis/made-china-2025

production. In the German context, this idea primarily means that the Internet-of-Things (IoT) can connect small and medium-sized enterprises more efficiently in global production and innovation networks, so that they could not only more efficiently engage in mass production, but easily and efficiently customize products[1].

MIC 2025 is unveiled by the Chinese State Council in 2015 to transform China from a manufacturing giant into a global manufacturing power based on the creative and high-tech driven economy.

In 2016, Quanzhou City in the Fujian Province was listed as one of the pilot cities of the MIC 2025 program, which is the first national plan of action (2016-2019) designed to achieve that purpose. At the same time, Quanzhou launched the Made-in-Quanzhou-2025-initiative, to upgrade its traditional industries to technology-based ones.

2.1.2. From FJIRSM, CAS to Haixi Institutes, CAS

2.1.2.1. Fujian

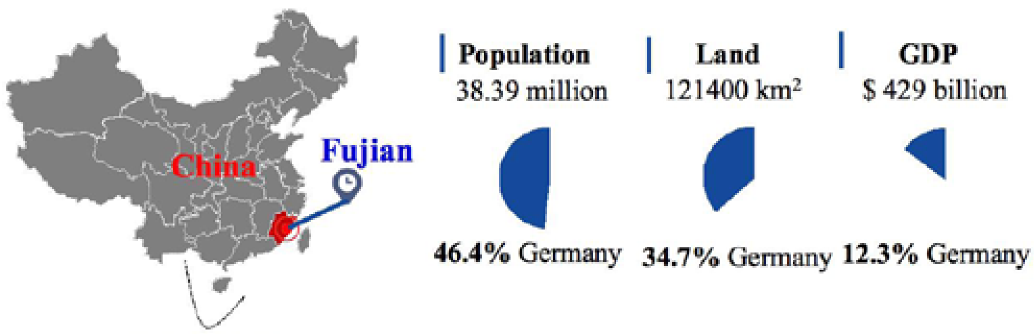

Figure 1 General information of Fujian Province, Houde Dai

Fujian is the core area of the Western Taiwan Straits Economic Zone, whose leading industries are electronics, petrifaction, and machinery. Figure 1 shows the general information of the Fujian Province[2]. Quanzhou, which is the starting-point of the Maritime Silk Road, is also the biggest city in Fujian, both in terms of economy and population.

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[2] https://www.fujian.gov.cn/english/FujianInfo/AboutFujian/
[3] http://english.cas.cn/

Equipment manufacturing industry is the strategic industry of the Fujian Province, which has the following goals for 2020: both intelligent equipment and industrial software >14 billion €; 70% industrial processes are of intelligent automation.

For the Fujian Province, however, there are two development bottlenecks, i.e., lack of a high-level engineering university and no national industrial technology institute.

2.1.2.2. Chinese Academy of Sciences (CAS)

Based on 104 institutions, 3 universities and 22 CAS-invested holds, CAS is the highest national academic institutions of natural science, high technology and consulting[3]. Fujian Institute of Research on the Structure of Matter (FJIRSM) is the institution of CAS located in Fujian, and its structural chemistry ranks 1st in the world.

2.1.2.3. Haixi Institutes (HI), CAS

To cope with the MIC 2025 program, Fujian and Quanzhou agreed to create a national industrial technology institute, and FJIRSM intends to extend its research field.

Thus, HI, which was jointly built by the Fujian Province and CAS, was announced in 2011. Five sub-institutes were established consequently, of which the Quanzhou Institute of Equipment Manufacturing (QIEM) was signed in Dec. 2013.

2.1.2.4. Quanzhou Institutes of Equipment Manufacturing (QIEM)

Currently, QIEM is the only national all-round research organization specializing in intelligent manufacturing in the Fujian Province. Its goal is to integrate resources, as well as services in the industry and to develop pioneering research, and engineering industrialization.

There are four major research directions: high-performance motor drive system, mobile robot and intelligent logistics, smart pension and healthcare and industrial robot application technology.

At present, QIEM occupies 60 km^2 office space and has more than $10 million equipment.

There are 150 staff members with the mean age of 32 years, including more than 30 doctors and 8 visiting professors (from Germany, Japan, Chile, UK). A postdoctoral program, master degree program, and an exchange program with other countries are provided.

Since 2015, QIEM had published more than 80 SCI/EI indexed academic papers including 18 papers whose Impact Factors are bigger than 5, together with 2 books and 122 patents (authorized 51).

2.1.3. Relationship Between TUM and QIEM-HI-CAS

9 PIs are the core staff of QIEM, of which 4 are TUM alumni. Figure 2 shows 4 PIs who have obtained a Ph.D. degree from TUM.

QIEM provides a master‘s degree program in Control Engineering affiliated with the University of Chinese Academy of Science and other universities, and the responsible person is Prof. Fengxiang Wang.

Prof. Wang is the visiting professor of QIEM, and since 2016, he is also the visiting professor of TUM. His team has the exchange activity of Ph.D. candidates with the Institute for Electrical Drive Systems and Power Electronics at TUM (Prof. R. Kennel).

In addition, two successive deputy directors of QIEM are from TUM:
June 2013–Oct. 2015: Prof. Peng He (Ph.D. in Mechanical Engineering, TUM). He moved to Kangde Group in Oct. 2015. Now he is the vice president of Kangdexin Composites Material Group and president of KDX Europe Composites R&D Center[4], which cooperates with the LCC (Institute for Carbon Composites at TUM, Prof. Klaus Drechsler).
Oct. 2015–present: Prof. Fengxiang Wang (Ph.D. in Electronic Engineering, TUM).

[4] http://en.kangdecomposites.com/Industrial/Center/; http://kdx-erd.com/en/

2.2. Motion Tracking and Its Applications in Smart Logistics

2.2.1. Background: High-Accuracy Positioning and Navigation

2.2.1.1. Intelligent logistics and warehousing equipment

"Intelligent logistics and warehousing equipment" is defined as one of the five pending key technical equipments of the "Guidelines for the Engineering Implementation of Intelligent Manufacturing of China (2016–2020)"[5].

For flexible manufacturing, the key of intelligent logistics and warehousing equipment is high-accuracy positioning and navigation, while the traditional automatic guided vehicles (AGVs) are of strict environmental requirements and less flexibility.

2.2.1.2. Research experience of Prof. Houde Dai

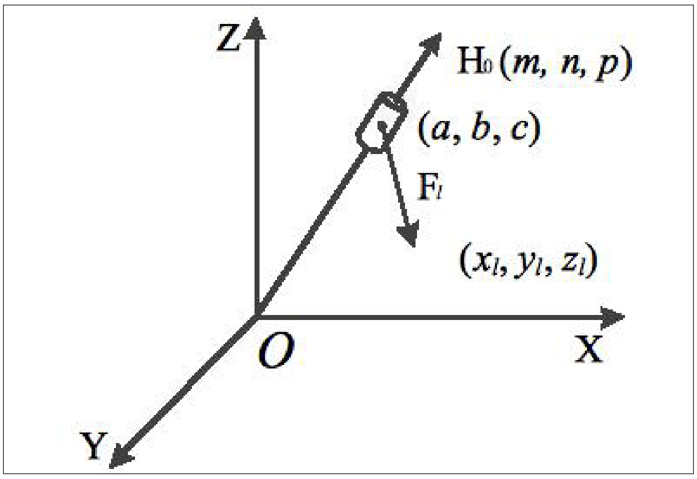
Since 2004, Prof. Dai has investigated the 6-dimensional (6D) orientation and position tracking based on the optical, electromagnetic and inertial sensors. Furthermore, Prof. Dai has done systematic research on the positioning and navigation of mobile robots since 2007. Since 2014, Prof. Dai has expanded research on core techniques of smart logistics.

2.2.2. Core Techniques of AGV Navigation

Based on the optical, electromagnetic and inertial sensors, the tracking can be applied in the high-precision navigation of AGVs. Following are the core techniques we achieved.

[5] http://www.chinesemicronews.cc/a/105846.html

2.2.2.1. Electromagnetic positioning navigation



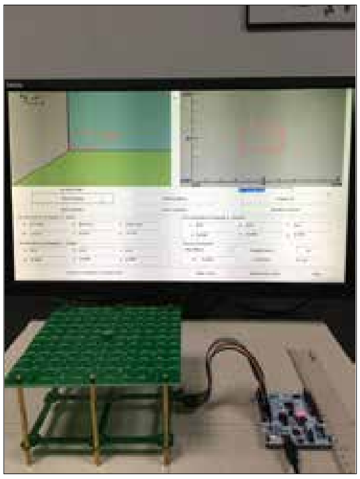


Figure 2 Magnetic dipole model for the tracking system and its prototype, Houde Dai

Electromagnetic navigation is the most widely applied navigation method for AGVs. Prof. Hu firstly presented the hybrid strategy of linear and nonlinear optimization algorithms for the magnetic tracking[6] in which the accuracy, speed and stability are greatly improved. After further improving both the hardware and software, we achieved the best tracking accuracy compared with other researches[7]. Figure 2 shows the system diagram and prototype of the magnetic tracking system. Table 1 depicts the comparison of this magnetic tracking system with two other typical systems.

Researcher	**Accuracy**	**Power Consumption**
V. Schlageter[1]	3mm, 1.2°	>10W
Chao Hu	1.8mm, 2.3°	>3W
Houde Dai	0.7mm, 1.22°	0.5W

Table 1 Comparison of Magnetic Tracking Systems

[5] http://www.chinesemicronews.cc/a/105846.html

[6] C. Hu, M. Meng, S. Song, H. Dai,"A six-dimensional magnetic localization algorithm for a rectangular magnet objective based on a particle swarm optimizer," IEEE Transactions on Magnetics, 2009, 45(8): 3092–3099

[7] S. Su, W. Yang, H. Dai* et al., "Investigation of the relationship between tracking accuracy and tracking distance of a novel magnetic tracking system," IEEE Sensors Journal, 2017, 17(15):4928–4937

2.2.2.2. Inertial positioning navigation

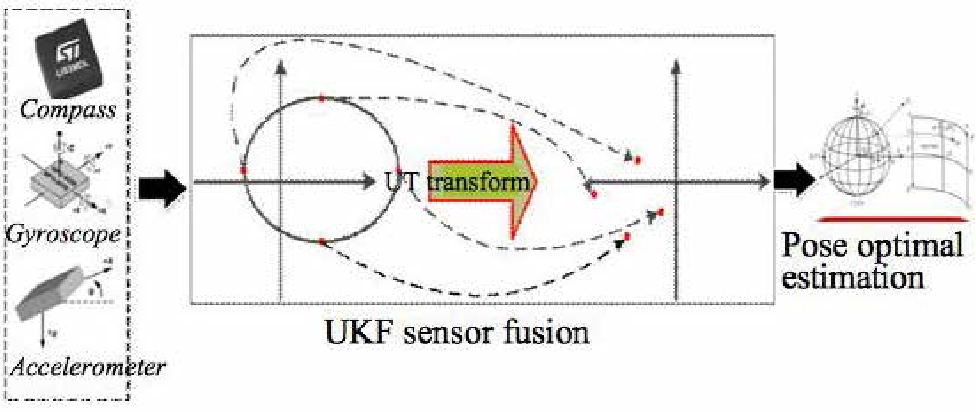


Figure 3 Optimization and sensor fusion algorithms, Houde Dai

Inertial sensing has great potential for the AGV navigation. However, the trouble issue is that the consumer-grade inertial sensors have big drift (consumer-grade accuracy is 3~5° and industrial-grade accuracy is 0.3~0.5°)[9], while the industrial-grade and the aerospace-grade inertial sensors are of big dimensions and power consumption. Based on consumer-grade MEMS inertial modules, the orientation accuracy is achieved at 0.8° after performing optimization and sensor fusion algorithms[10], which can be seen from Figure 3.

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[9] http://www.analog.com

[10] Z. Lin, Y. Xiong, H. Dai*, and X. Xia,"An experimental performance evaluation of the orientation accuracy of four nine-axis MEMS motion sensors,"5th International Conference on Enterprise Systems (ES), 2017.

2.2.2.3. Optical positioning navigation

We presented an optical tracking system based on a stereo camera with 4 infrared cameras. The signal processes includes calibration, feature matching, 3D reconstruction, and object tracking[11]. This optical tracking system presents 0.2mm accuracy in $1m^3$ space, while the accuracies of commercial systems are: NDI (0.1mm)[12], Vicon (0.1mm)[13].

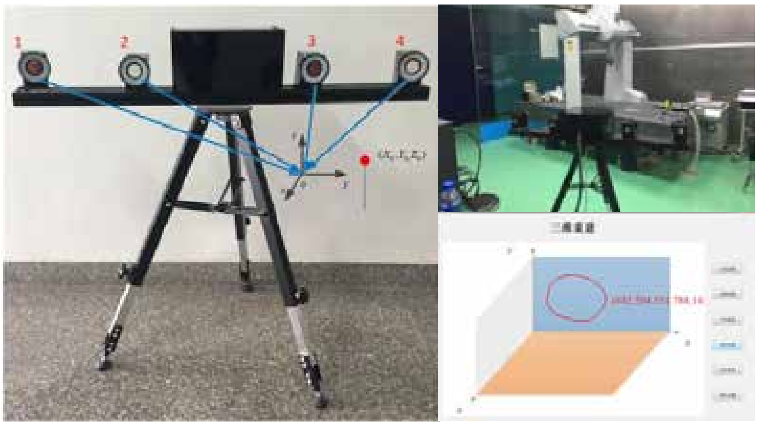

Figure 4 Optical positioning tracking system, Houde Dai

2.2.2.4. Laser Radar-based SLAM for AGV Navigation

A novel global descriptor (spherical entropy image, SEI) and the SEI-based scan registration method for 3D point clouds processing promote the registration rate to 100% and reduce the processing time to 0.5s in an unknown environment[14], while the registration rate of other algorithms is smaller than 100% and their processing time is bigger than 1s.

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[11] Y. Zeng, H. Dai*, et al., „A 3D passive optical localization system based on binocular infrared cameras," IEEE International Conference on Information and Automation (ICIA), 2016: 368-373.

[12] https://www.ndigital.com/msci/products/certus-hd/#certus-hd-specifications

[13] http://www.vicon.com/

2.2.3. High precision navigation and Its Applications in AGVs

We developed several intelligent AGVs based on the high-precision 6D orientation and position tracking. Based on the magnetic, inertial, and optical sensors, the integrated navigation approach was adopted. The navigation accuracy and the positioning accuracy were improved from ±10mm to ±5mm and from ±5mm to ±1mm, respectively. Thus, we met the requirement for material assembly in the plant logistics.

Figure 5 Self-developed intelligent AGVs, Houde Dai

2.2.4. Future Works

Machine learning and integrated optimization methods for sensor fusion will be utilized to improve the positioning accuracy and navigation performance.

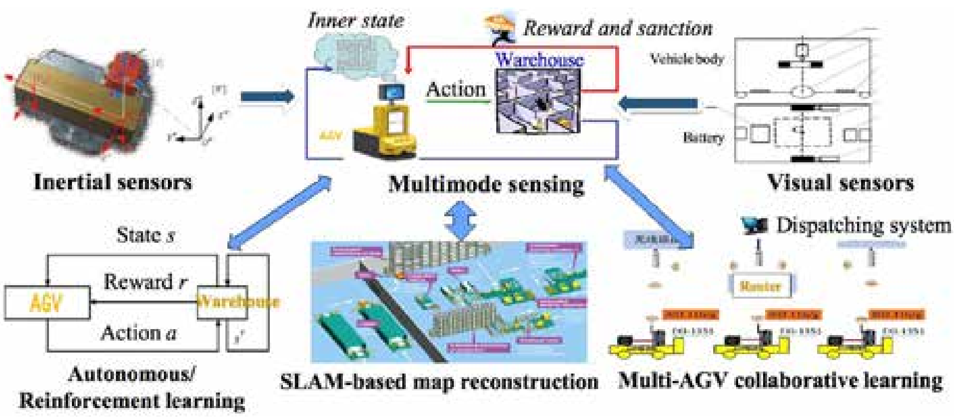

Figure 6 Future works for intelligent AGVs, Houde Dai and Xian Wei

3. Visual Mobility Analysis of Trajectory Data

Linfang Ding

Chair of Cartography, Technical University of Munich, Germany
and KRDB Research Centre for Knowledge and Data, Faculty of Computer Science
Free University of Bozen-Bolzano, Italy

Stay at Technical University of Munich: 2010–2016,
TUM Department of Civil, Geo and Environmental Engineering

In the digital society, spatial trajectories representing the mobility of a variety of moving objects are collected in enormous quantities using advanced location positioning and wireless communication technologies. These complex and large trajectory data contain rich information and bring new opportunities to understand urban dynamics, and are crucial for decision-making in environmental and transportation planning. This work introduces the research on visual analytical approaches for the exploration of large trajectory data. Based on big real-world floating car data (FCD) gathered in Shanghai, China, three cases studies on traffic congestion patterns, transport-hub traffic flows, and taxi driving behaviours will be presented.

3.1. Introduction

Mobility is one of the most important aspects in urban areas and has great socioeconomic and environmental impacts on peoples lives. In large cities, mobility-related problems like traffic congestion and energy consumption propose great challenges in building future smart cities. Understanding mobility patterns is a necessity to tackle these problems. With the advances in location positioning and wireless communication technologies, spatial trajectory data from various moving objects, such as cars equipped with GPS devices and people using mobile phones, is increasingly being collected. These big data contain rich movement information and provide opportunities for understanding human mobility patterns and tackling the above-mentioned social economic and environmental problems. Extensive studies on mobility analysis have been conducted in a variety of fields and applications. Gonzalez et al. (2008) investigated large amounts of mobile phone data to model individual human mobility patterns. Andrienko et al. (2013) analysed the temporal patterns of visits and extracted semantics of individual places from movement data. Liu (2015) inferred the urban land uses and city structures from large taxi trips. In the context of navigation and location based services, Zhang (2016) proposed several knowledge discovery approaches for the classification of multimode travel modes and the identification of different types of behaviour, such as anomalous driving patterns based on massive amounts of GPS-trajectory data. Since trajectory data involves geographical space, time, and multidimensional attributes, it still poses significant challenges for the analysis. Most of existing researches rely on computational approaches and usually lack the involvement of human interaction and the effective communication of the results. Visual analytics (Thomas and Cook 2005) of trajectories can enhance the analytical reasoning facilitated by interactive visual interfaces.

This work introduces the researches on visual analysis and exploration of large amounts of floating car data (FCD), from which different aspects of mobility patterns can be uncovered. We present three cases studies to illustrate mobility analysis results based on innovative visual analytical techniques for FCD, including interactive visual data mining techniques, information visualization and cartographic representations. For investigation and illustration, big real-world FCD data gathered from 2000 taxis in May and June 2010 in Shanghai, China, with a temporal resolution of 10 seconds have been used as test data.

3.2. Floating Car Dataset

FCD have been used as the essential source for traffic information and for most intelligent transportation systems (ITS). The test FCD dataset consists of temporally ordered position records collected from about 2000 taxis within 52 days between May 10^{th} and June 30^{th}, 2010 in Shanghai with a temporal resolution of 10 seconds. Each GPS entry is associated with fields of date, time, car identifier, location, instantaneous velocity, and car status. Table 1 lists the fields for each GPS record along with sample values and descriptions. Fig. 1 shows the raw GPS points of a taxi with the identifier 10003 on May 12^{th}, 2010.

Field	Example value	Field description
Date	20100517	8-digit number, yyyymmdd
Time	235903	6-digit number, HHMMSS
Car identifier	10003	5-digit number
Longitude	121.472038	Accurate to 6 decimal places, in degrees
Latitude	31.236135	Accurate to 6 decimal places, in degrees
Velocity	16.1	In km/h
Car status	1/0	1-occupied; 0-unoccupied

Table 1 Floating taxi data properties

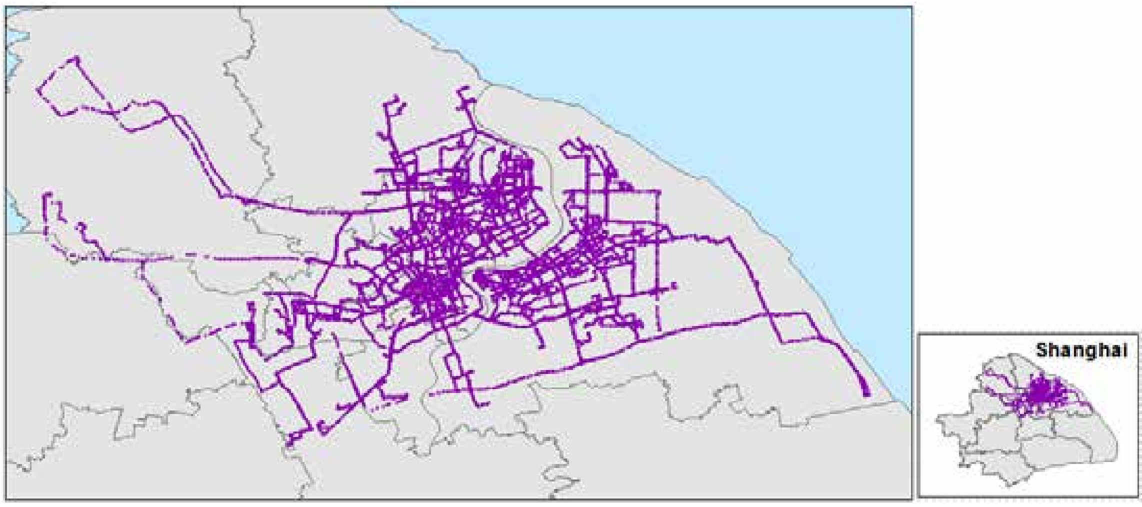

Figure 1 GPS points of one taxi on May 12th, 2010.

3.3. Case Studies

This section presents three case studies on the visual mobility analysis of the trajectory data. To demonstrate the effectiveness of the visual analytical approaches, these case studies focus on the exploration of mobility patterns of three different aspects: traffic congestion, transport-hub related traffic flows and taxi driving behaviours.

Traffic Congestion

After matching FCD points to the street network acquired from OpenStreetMap1, Keler et al. (2016) aggregated the points based on street segments and for each segment calculated its point density and average velocity. Furthermore, based on the density and average velocity, traffic congestion of each street segment was inferred. Basically, congestion is positively correlated to density and negatively correlated to average velocity. The derived traffic congestion was classified into three levels - high, middle, and low. Fig. 2 (a) shows a 2-D traffic congestion visualization with red, yellow, and green indicating decreasing congestion levels. The light blue area in the middle of the map is a selection circle that allows the user to inspect information for certain areas in detail. Fig. 2(b) shows the 3-D extrusion view after the selection of the circle. The extrusion height represents the vehicle density and the colour of the extruded street represents the averaged velocity. With the linked 2-D visualization and 3-D extrusion view, users can have an overview of the traffic congestions and also explore interesting areas in detail.

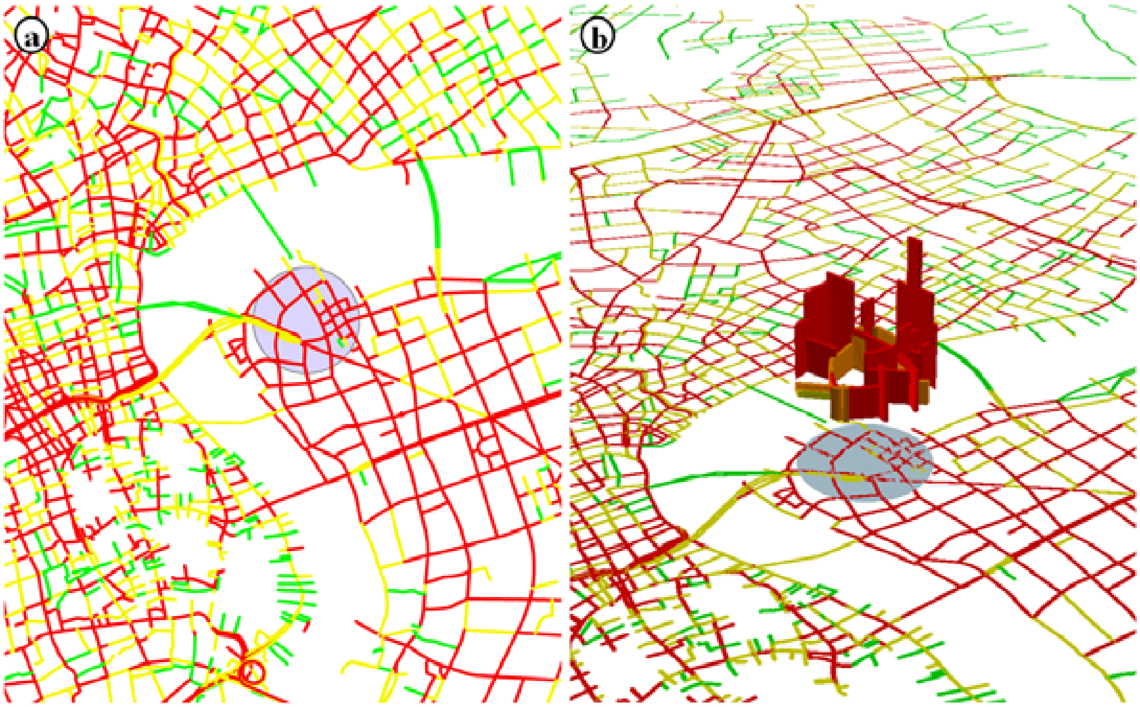

Figure 2 Traffic congestion visualization using 2- and 3-D representation methods. (a) A 2-D view of congestion with a selection circle in light blue, (b) a 3-D extrusion view of density and velocity in the selection circle. (Keler et al. 2016)

[1] https://www.openstreetmap.org

Transport-hub Related Traffic Flows and Interesting Places

Transport hubs are important components in the urban transportation system. Ding et al. (2015b) investigated the traffic flows related to transport hubs. Pick-up and drop-off events related to the transport hubs are extracted and clustered around significant places. In addition, by using a straightforward maximum frequency method, those significant places are classified and assigned the label with the dominating function of surrounding buildings collected as POIs in OSM, such as public building, commercial building, residential building or industrial building. The visual analytical system with its interface is shown in Fig. 3.

Figure 3 The screenshot of the visual analytical user interface with three linked graphic components — a map field, a circular histogram (lower right) and a clock diagram (upper right). (Ding et al. 2015)

Taxi Driving Behaviour

To explore taxi driving behaviours, Ding et al. (2015a) classified taxi states into three groups 1) moving with passengers; 2) moving without passengers; and 3) stationary. The taxi driving behaviour of each state could be visually investigated. Fig. 4 shows the temporal patterns of stationary taxis using a time matrix graph. The time matrix is based on the aggregation of FCD from all the 2000 taxis with a 15-minute average stationary duration. The darker the individual block is, the longer the taxis remain static. White colour indicated missing data. Users can immediately perceive significant daily patterns e.g. sleeping, lunch and dinner periods, and also weekly patterns, such as that on weekends the stationary spots are about 1-2 hours later than on weekdays.

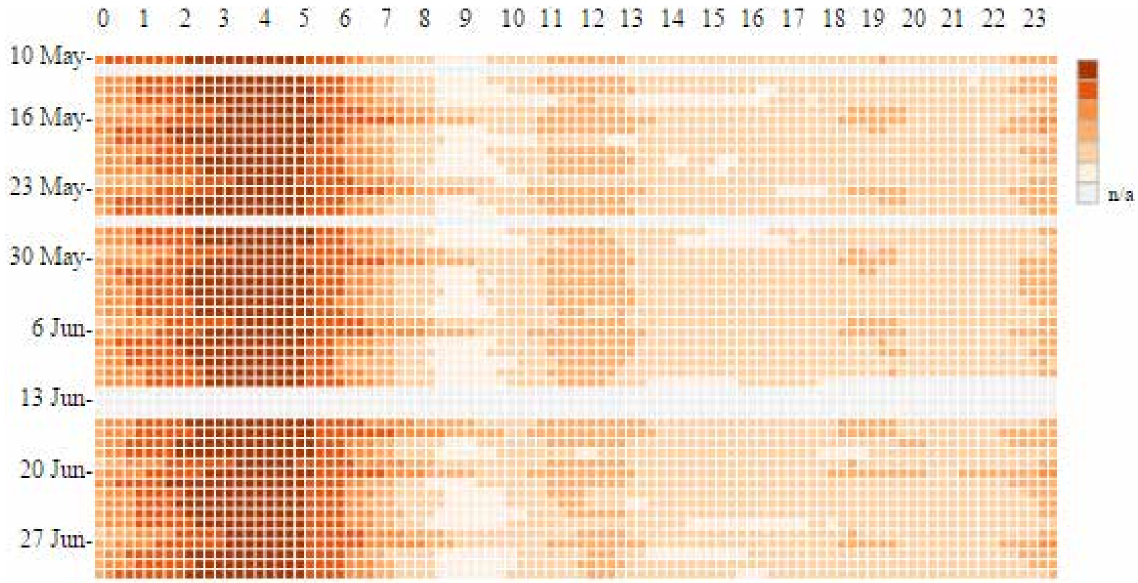

Figure 4 Temporal patterns. The time graph of the stationary durations aggregated into 15-minute intervals (the stand-by duration is proportional to the darkness of colour). (Ding et al. 2015)

Furthermore, to observe the dynamic driving behaviour when taxis are driving without passengers, Ding (2016) visualized trajectories in a space-time-cube. Fig. 5 shows the taxi driving trajectories from and to Pudong airport on 31 May 2010. Regarding the number of trajectories, obviously there are far more non-occupied trips from the airport (Fig. 5 left) than to the airport (Fig. 5 right), which means that more taxi drivers directly cruise back to the city centre after dropping off passengers at the airport, rather than waiting there for the next passengers, while less drivers travel from the city centre to the airport to pick up passengers.

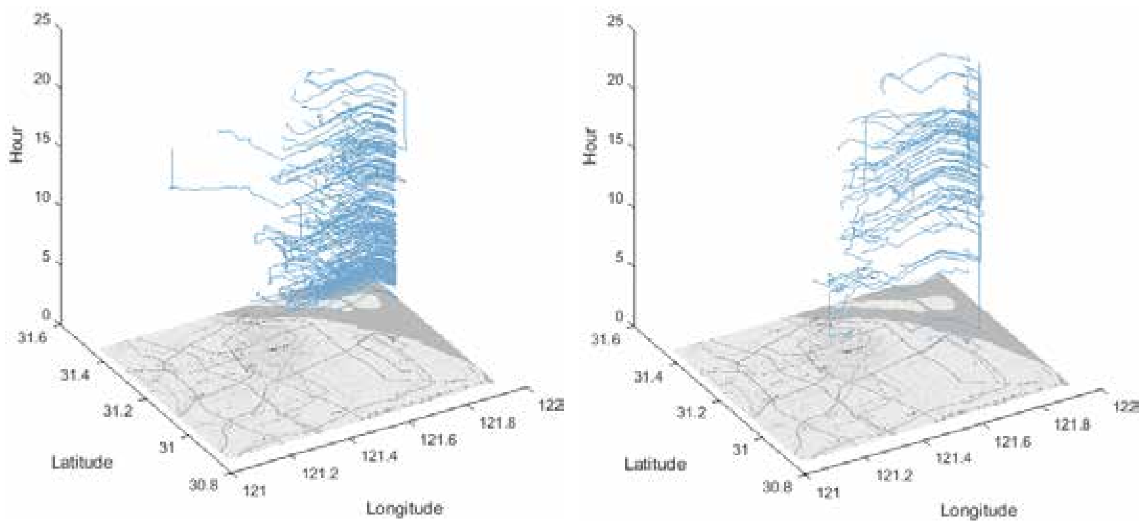

Figure 5 Travels without passengers from (left) and to (right) Pudong airport on 31 May, 2010. (Ding, 2016)

3.4. Conclusion

This work introduced visual analytical approaches for understanding mobility patterns from large amounts of trajectories. Our methodology is explained by three cases studies in which we demonstrate how a visual exploration approach can help to gain insights into traffic congestion patterns, transport-hub traffic flows and taxi driving behaviours respectively. Future work will be focused on the development of visual analytical tools to facilitate mobility analysis and decision making in real-world scenarios. In addition, other data sources will be integrated for deep mobility analysis, for instance, to analyse negative traffic events from FCD together with geotagged social media data (Zuo et al. 2018).

Acknowledgment

I sincerely thank Prof. Chun LIU from Tongji University, Shanghai for sharing with us the floating taxi data.

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4. Polymer-made Planar and Spatial Mechanisms for One-Room-Factories in Smart Cities

Mikio Horie

Laboratory for Materials and Structures (MSL) & Laboratory for Future Interdisciplinary Research of Science and Technology (FIRST), Tokyo Institute of Technology, Japan

Stay at Technical University of Munich: 1996,
TUM Department of Mechanical Engineering

In this research, in order to realize the functions equivalent to the functions of the spherical bearing, which is frequently used in conventional spatial mechanisms, a polymeric manufactured hinge with Hytrel® (DU PONT-TORAY), which has excellent flexural fatigue resistance, has been proposed. Next, the shape and dimensions of the polymeric manufactured hinge, having low stress values at bending deformation, have been found by FEM analysis. In addition, a polymer-made three-degrees-of-freedom (3DOF) spatial parallel manipulator, which consists of this polymer-made hinge is being designed and developed, and the output displacement characteristics of the manipulator will be revealed.

4.1. Introduction

Maintenance of the bearing, including lubrication, is time-consuming. In order to dispel this negative side, in the Horie laboratory the rotation bearing was replaced with a polymer material, and a polymer-made revolute hinge (R hinge) was proposed. Next, the design and development of a polymer-made two-degrees-of-freedom pantograph mech. and a polymer-made three-degrees-of-freedom planar parallel manipulator, which consists of R hinges, was carried out, and their characteristics were revealed (Horie et al. 2006, Horie et al. 2002). In this paper, polymer-made spherical hinges, which can represent three degrees-of-freedom (3DOF), as spherical bearings are proposed. In order to design and manufacture polymer-made spatial mech. consisting of polymer-made spherical hinges, the shape and dimension of the polymer-made spherical hinges are discussed, and characteristics of 3DOF spatial parallel manipulators consisting of S hinges are presented.to achieve that purpose. At the same time, Quanzhou launched the Made-in-Quanzhou-2025-initiative, to upgrade its traditional industries to technology-based ones.

4.2. Polymer-made Revolute Hinges

This paper is a study on the spatial mechanism containing a polymer-made S hinge having a function of the spherical pair. However, as the previous studies show, the author studied with respect to the two DOF planar pantograph mechanism and the three DOF planar mechanism made of R hinges functioning as the revolute pair. This study is the study of its extension. Therefore, first, characteristics of polymer-made R hinges are described. Next, research contents regarding 2DOF pantograph mechanisms and a 3DOF mechanism made of R hinges are presented.

4.2.1. Fatigue Test — Under a Static Tensile Load And Repeated Bending

Figure 1 shows a polymer-made revolute hinge. A fatigue test was conducted under a static tensile load W and bending repeated angle ±45°. Bending is carried out by use of the polymer-made revolute hinge specimen.

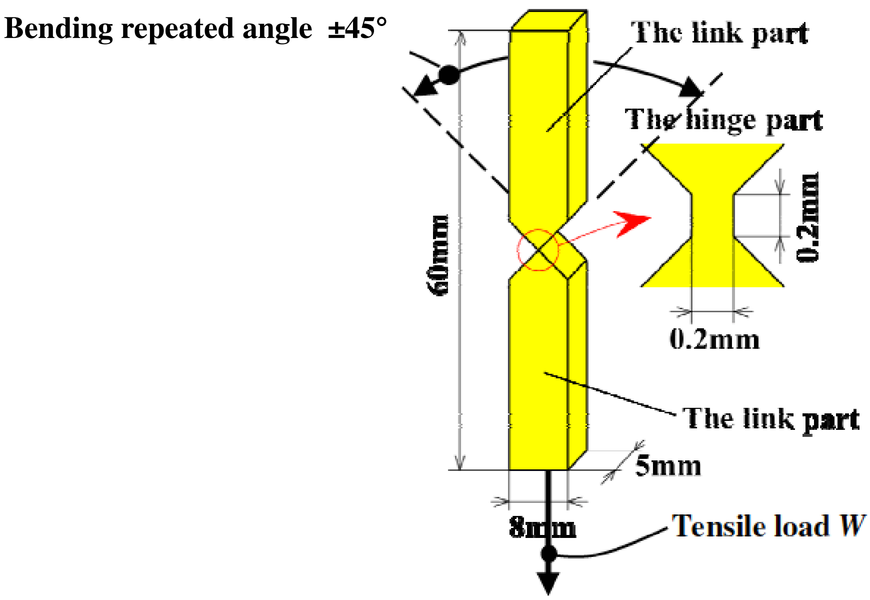


Fig. 1 Revolute hinge specimen

Figure 2 shows the fatigue test results of the R hinge. PP (Polypropylene) has displayed that repeated bending motion of ± 45° can be conducted more than one million times. From Fig. 2, we discovered that PP (Polypropylene) is a good material for long life materials.

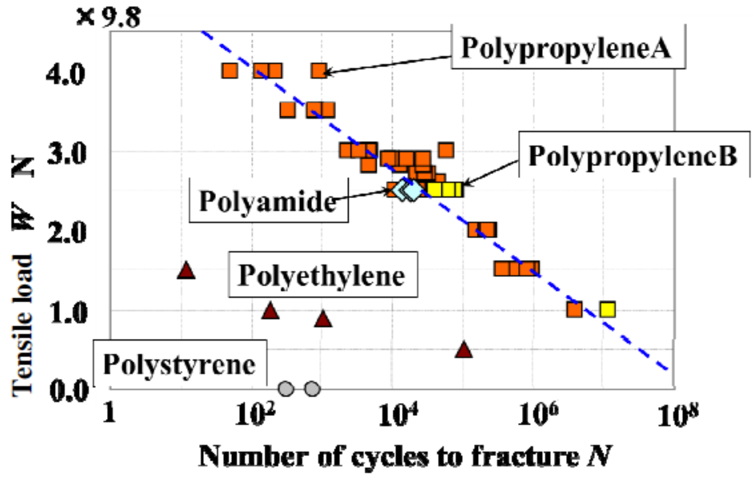
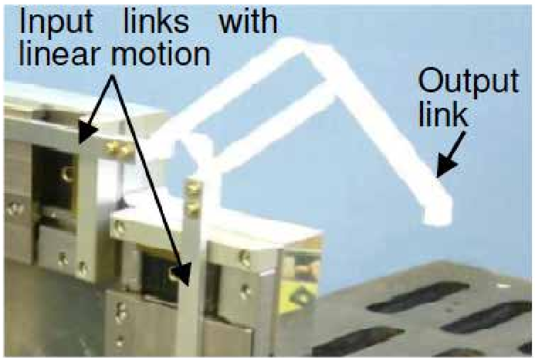


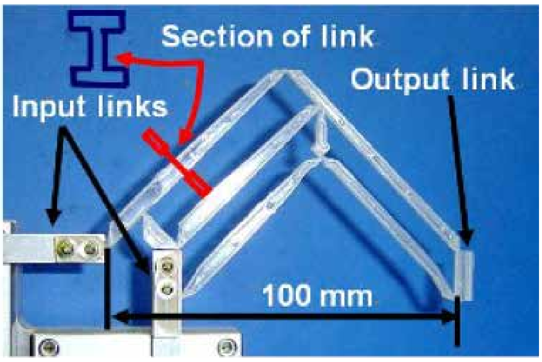
Fig. 2 Results of the fatigue test of the R hinge with static pull load and repeated angulardisplacement ±45° bending (Horie et al. 2006)

4.2.2. Polymer-made 2DOF PlanarPpantograph Mechanisms and Polymer-made 3DOF Planar mechanisms

On the basis of the fatigue test PP (Polypropylene) was discovered to be a good material with a long life. Therefore, first, the 2DOF planar pantograph mechanism shown in Fig. 3 was proposed and developed (Horie et al. 2006). Figure 1(a) is Version 1 of the pantograph mechanism. Unfortunately, the direction of the output link changes when two liner actuaters move. Consequently, we thought of Version 2, shown in Fig. 3(b). This pantograph mechanism has three parallelograms. Therefore, the direction of the output link with a short length does not change the direction when two linear inputs move, three short length links are the same length and parallel; the motion is always parallel, since the leftmost vertical input link moves vertically as usual.



(a) A pantograph mechanism having a parallelogram (Version 1)



(b) A pantograph mechanism having three parallelograms(Version 2)

Fig. 3 Polymer-made 2DOFpantograph mechanisms (Material: Polypropylene)

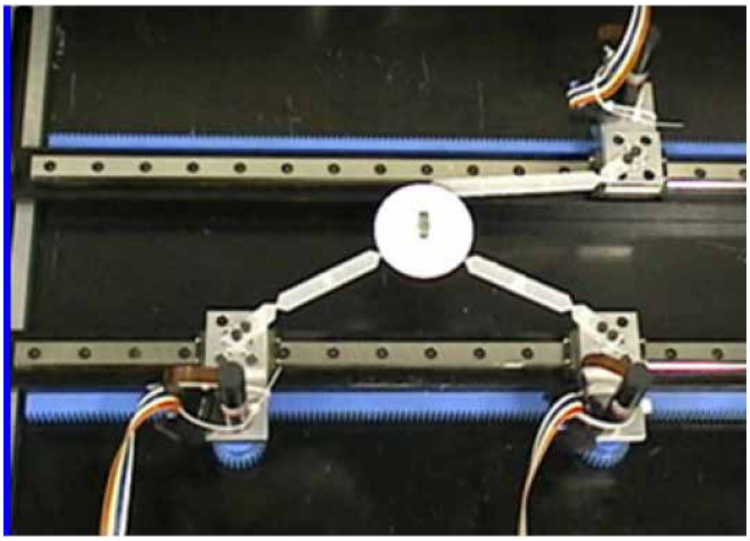


Fig. 4 A polymer-made 3 DOF planar parallel manipulator (Material: Polypropylene)

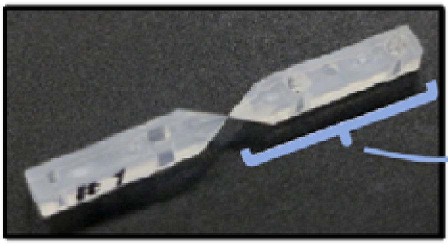
In the case of Fig. 3(a), there is one parallelogram in the mechanism. Hence the output link orientation changes when the two input links have linear motion, vertical and horizontal. In Fig. 3(b), there are three parallelograms in the mechanism. Accordingly, when two input links move, the short output link oriented in the vertical direction does not change the orientation. Moreover, as the forces acting at the hinge part are minimized, each link, whose cross-section is I-shaped and is lightweight, has an optimum mass distribution.
In Fig. 4, there are three actuators on two rails and a 3DOF planar parallel manipulator with hinge joints made of polypropylene (Horie et al. 2002).

In the above mechanisms, polymer-made planar mechanisms are shown. However, typically, in the case of realizing polymer-made spatial mechanisms, it is necessary to propose and make a compact polymer-made hinge, which has the function of the ball bearing. We call this polymer-made hinge “polymer-made spherical hinge” or “S hinge”. In the next chapter the polymer-made spherical hinge will be discussed.

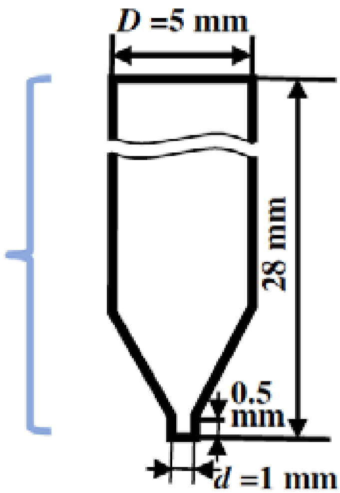
4.3. Polymer-made Spherical Hinges

In this chapter, a polymer-made spherical hinge (S Hinge) is proposed and its bending characteristics are discussed.

Figure 5(a) is one example of a hinge specimen, and Fig. 5(b) shows the shape and dimension of the hinge. In Fig. 5(a), the shape of the centre part of the hinge is a cylinder shape. Half of the spherical hinge specimen is shown in Fig. 5(b), including its dimensions.



(a) Spherical hinge specimen (an example)



(b) Shape and dimensions of the half of the S-hinge

Fig. 5 Spherical hinge (Center part is cylindrical)

Next, three types of central parts of the S hinge between two links, as shown in Fig. 6, are considered. Figures 6(a) through (c) respectively show a cylindrical type, an hour-glass type, and a mountain type.

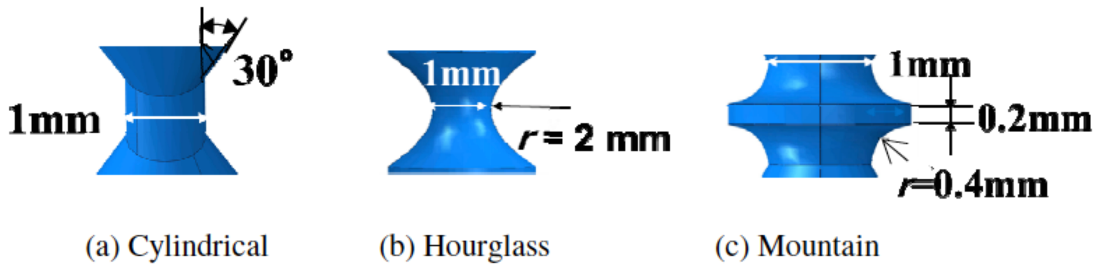


Fig. 6 Three types of central parts of the S hinge

Regarding S hinges shown in Fig. 6, the stress analysis by use of FEM is tested in the next session.

4.3.1. FEM Analysis of Polymer-made S Hinges

In order to stress analysis of the central part of the S hinge, the FEM called Abaqus/CAE was used. The analysis conditions consist of the following: The material is polypropylene (PP), material density is 0.9gw/cm3, Poisson's ratio is 0.4, and the tensile modulus of elasticity is 750 MPa. Moreover, the boundary condition of the analysis is shown in Fig. 7. In Fig. 7, the centre of the test piece is fixed. And, as one of the links bends 30 degrees, the displacement vector (16.1658 mm) is added to the end of the left link.

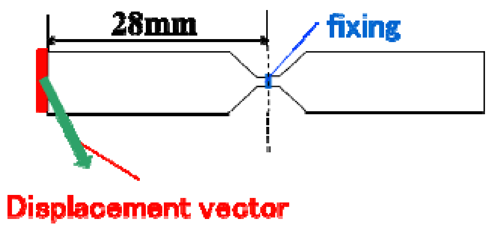


Fig.7 The boundary condition of FEM analysis for S hinge

The results of FEM analysis are shown in Fig. 8.

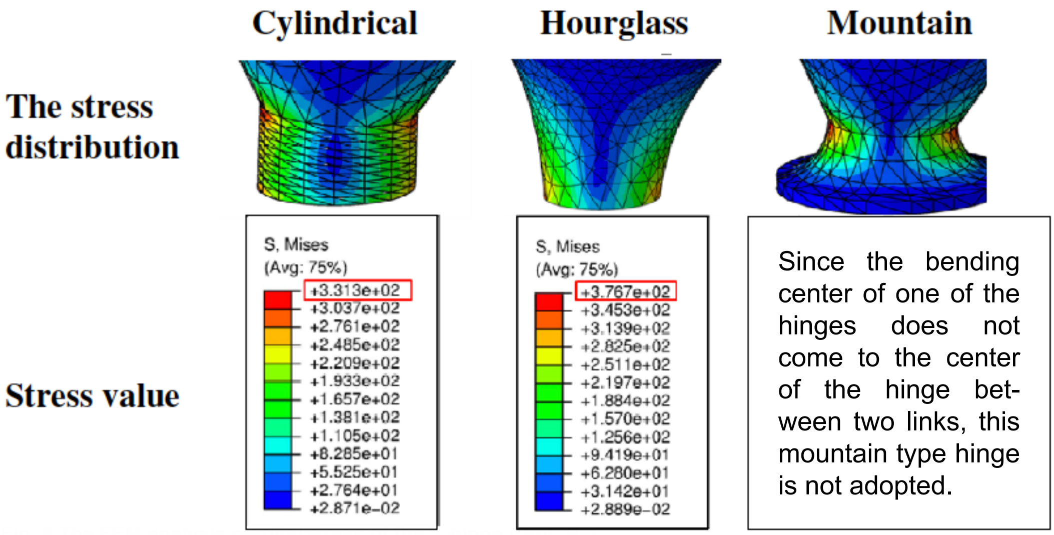
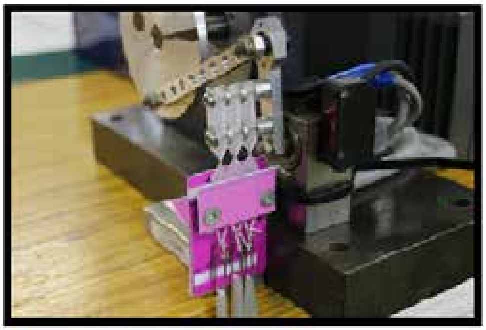


Fig. 8 The FEM analysis results/Stress of the S-hinge (Unit; Pa)

In Fig. 8, since the bending centre of one of the hinges does not come to the centre of the hinge between two links, the mountain type hinge is not adopted. Moreover, in Fig. 8, maximum stress of the cylindrical hinge and the hourglass hinge has similar values. Therefore, for reasons of simple manufacturing the cylindrical hinge is adopted as the S hinge.

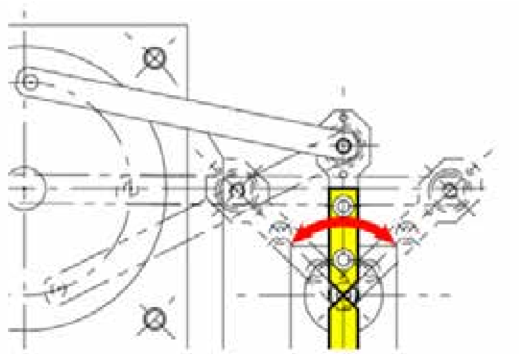
4.3.2. Fatigue Test of the S Hinge

Based on the results of the previous section, a cylindrical hinge was fabricated using an injection moulding machine. Polypropylene was used as the fatigue test piece material. Using this test piece, the fatigue bending test by tensile load and repeated bending operation was performed. The test piece dimension is already shown in Fig. 5. For the fatigue test, the experimental apparatus shown in Fig. 9 was used.



(a) A four-bar linkage and specimens

(b) Specimens



(c) Detailed movement of the four-linkage

Fig. 9 A four-bar linkage, S hinge specimens and detailed movement of the linkage

In Fig. 9(c), the rocker of the four-bar linkage has a ±45° and 5 Hz movement. The lower part of the hinge, the dead weight 90 gw, is acting in a downward direction, and the upper part of the hinge is coupled to the rocker of the four-bar linkage. As shown in Fig. 10(a), after the fatigue test was repeated 340,000 times, the hinge extends by plastic deformation, having a diameter of d=0.5 mm. If there is a diameter of d=1.0 mm or more after 9,000 times of movement, cracking occurs in the hinge centre, which is shown in Figs.10(b) and (c). After that, in the subsequent repeated bending movement, cracking does not easily proceed.

To improve the strength of the central portion of the polypropylene hinge, in the case where the lengths of the hinges were the same, it was found to improve by increasing the diameter d.

(a) d= 0.5 mm
(After 340000 times)

(b) d=1.0 mm
(After 9000 times)

(c) d=1.5 mm
(After 9000 times)

Fig. 10 Central part view of the S hinge after repeated bending movement

From the above results it can be concluded that in order to obtain a long life S hinge, a material with strong-repeated fatigue bending properties, such as rubber, is needed.

Searching for a material having such properties, elastomer Hytrel, which is heat resistant, oil resistant, chemical resistant, impact resistant, and displays rebound resilience, and excellent flexural fatigue resistance, was found. Accordingly, this Hytrel/Thermoplastic-polyester-elastomer was used as the S hinge material. In the next section, the 3DOF spatial mechanism, using polymer-made S hinges is presented.

4.4. Polymer-made 3DOF Spatial Parallel Manipulators

In the present chapter, there is a description of the design and development of a polymer-made three-degrees-of-freedom (3DOF) spatial parallel manipulator with Hytrel-made S hinges, as described in Chapter 3.

The polymer-made 3DOF parallel manipulator and its mechanism parameters are shown in Fig. 11.

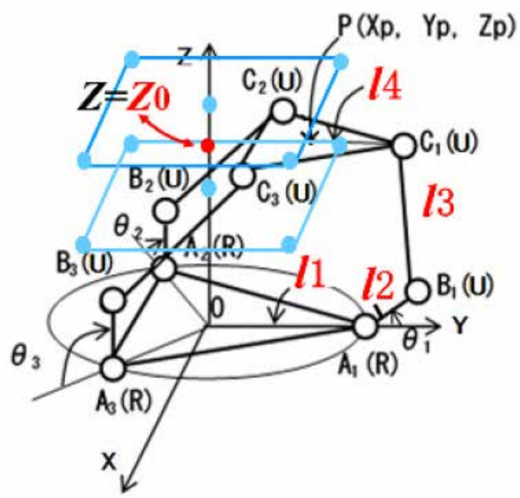


Fig. 11 Mechanism parameters and working space

In Fig. 11, on the fixed link L1 of the mechanism, there is an equilateral triangle. The centre of the equilateral triangle is the origin O of the orthogonal coordinate system O-XYZ. The distance from its centre of gravity (centre) to the three rotary actuators position Aj (j = 1 ~ 3) is l1. The length of the input links L2j (j = 1 ~ 3) is l2, the length of the intermediate link/coupler L3j (j = 1 ~ 3) is l3, the distance between the centre of gravity of the equilateral triangle on the output link L4 and the joint position Cj on L3 is l4, and the initial position of the centre point P of the output link L4 in the Z-axis is Z = Z0.

The squares in Fig. 11 show the loci of the centre point P of the equilateral triangle, which is the output link of the manipulator, and represents the limits of the working space of the mechanism when Z= ±25 mm. The length of one side of the square is 100 mm. The square centre, which is the initial position of the output point P, is on the Z-axis.

4.4.1. Mechanism Synthesis

In order to synthesize the mechanism at the position Z = Z0 mm and Z = Z0±25 mm, the mechanism parameters l1, l2, l3, l4, and the value of the Z0, each varied by 1mm, were determined by considering the following conditions.

(1) As the point P passes through the square of the four corners point and the square centre point, i.e., 10 points on the square in Fig. 11, mechanism parameters were determined by using inverse kinematics (Laribi1 et al. 2008; Lo´pez et al. 2006). Among the results obtained, only the mechanism parameters with three input angles determined by

the equation of inverse kinematics have been the correct solution.

(2) Reduce the size for miniaturization.

(3) The relative angular displacement of the two links across the hinge portion is in the range of ±45°.

(4) In order to reduce the driving torque of the motor, the ratio of the length of the links L2 and L3, that is, L2/L3 to 0.6 (Arai et al. 2012).

4.4.2. Mechanism Parameters and Discussion

From the results of the mechanisms synthesis described in the previous session, mechanism parameters have been obtained, as shown in Table 1. By using these parameters, the 3DOF spatial parallel manipulator has been manufactured. Next, in order to consider the relative displacement angles between L2 and L3, L3, and L4 at the S hinge positions, the displacement analysis was carried out. Table 2 shows the analytical results about pitch angles and yaw angles at joints Bj and Cj (j = 1 ~ 3).

Table 2 reveals that the relative displacement angles are within ±45°.

	l_1	l_2	l_4	l_5	*Z0*
mm	35	60	100	27,5	97

Table 1 The decided mechanism-parameter

pitch angles 21	pitch angles 22	pitch angles 23	pitch angles 31	pitch angle 32	pitch angles 33	yaw angles s1	yaw angles s2	yaw angles s3
79.84	72.94	81.90	83.75	81.72	83.75	60.00	86.16	86.16

Table 2 Difference angle between Max and Min relative angles between AB and BC(Pitch 2j), BC and CP (Pitch 3j), / sj: j-Chain number (j=1~3), Yaw angles from Bi to Ci / Unit; Degree

4.4.3. Displacement Analysis and Joint Force Analysis of the 3DOF Parallel Manipulator

By use of the method of inverse kinematics, the input displacements are obtained when the output displacements are given. Moreover, by using the angular velocity and the angular acceleration obtained by differentiating the expression for the angular displacement, each kinematic pair acting force was obtained.

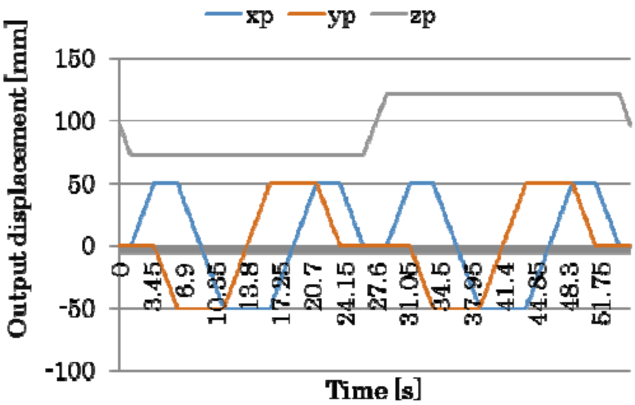


Fig. 12 Output displacements given in the inverse kinematics

As a result, as the forces acting on the S hinge per one hinge are small, SS links are assumed to be numerous. In this case, it was decided to use four of the SS-hinge links per one link chain as shown in Fig. 13.

Links with SS-hinge/Coupler links

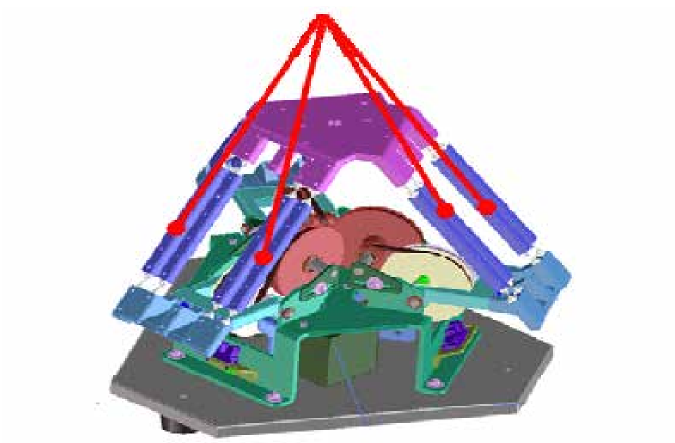


Fig. 13 Polymer-made 3DOF parallel manipulator including four SS-hinge links per one link chain

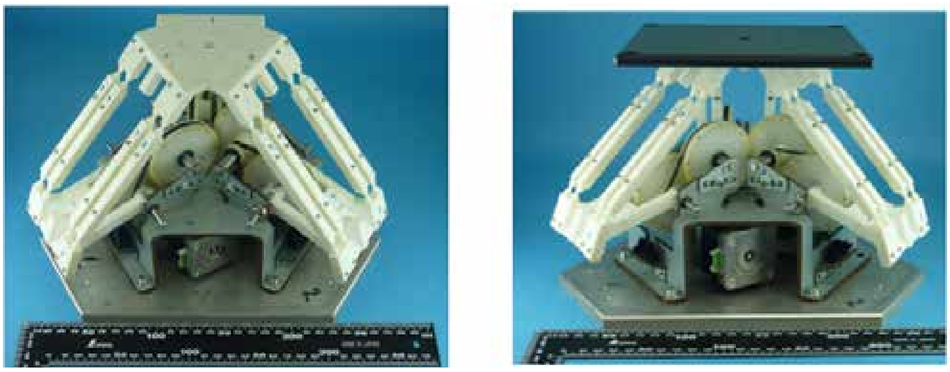


Fig. 14 Polymer-made 3DOF spatial parallel manipulator (Right : With output table)

4.4. The Polymer-made 3DOF Parallel Manipulator

Fig. 14 shows the polymer-made 3DOF parallel manipulator with stepping motors. The left one is the manipulator without an output link. The right one is the manipulator with an output link. The locus of the output point for measuring is shown in Fig. 15. The output link for measuring is shown in Fig. 16.

As shown in Fig. 15, in order to measure the positioning accuracy and repeatability, four measurement points represented by a hemisphere concave diameter of 1cm were created on the output link.

When the central point P on the output link moves along the circle in Fig. 16, the output link will move while maintaining a horizontal position. And the direction of the output link/square-plate does not change. The coordinates of four points are measured by use of the three-dimensional measuring machine/Crysta-Apex C7106 made by Mitutoyo Corporation.

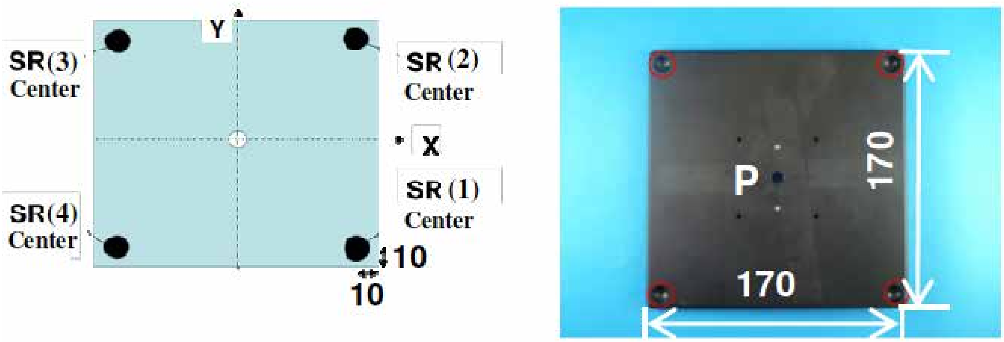


Fig. 15 Output link/table and measuring points(1)~(4); mm

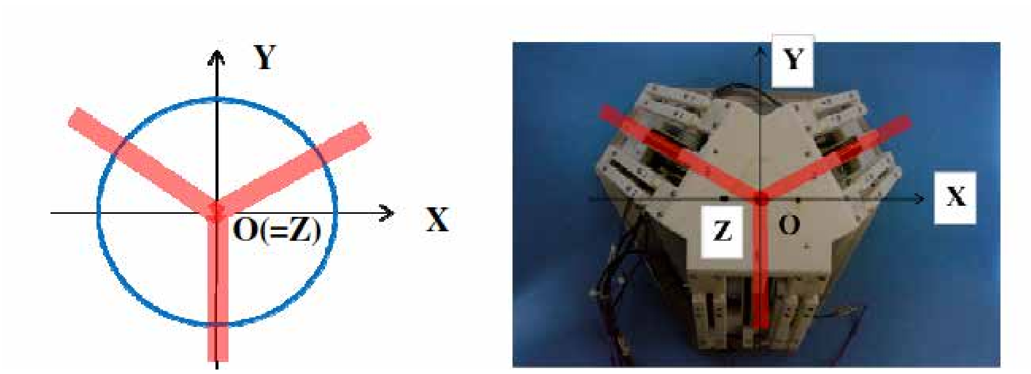


Fig. 16 O-XYZ coordinate system (Circle: Locus of the output point for measuring, Three thick lines: Input-link motion planes)

In the results, the positioning accuracy, that is, the coordinates at the measurement point SR (1) ~ (4), is obtained as shown in Table 3. The order of movement of the output link centre (Xp, Yp, Zp) is given as shown in Table 4.

	Xp	Yp	Zp	Xp	Ym	Zm	ΔXm	ΔYm	ΔZm	Xd	Yd	Zd
SR (1) [Start data]	0	0	0	-17.4663	-179.059	195.1906	–	–	–	–	–	–
X=0, Y=0	0	0	-25	-17.7775	-179.042	170.3303	-0.3112	0.0171	-24.8603	-0.3112	0.0171	0.1397
X=0, Y=36	0	36	-25	-17.6413	-143.041	171.4225	-0.175	36.0177	-23.7681	-0.175	0.0177	1.2319
X=-36, Y=0	-36	0	-25	-53.6359	-178.855	171.7004	-36.1696	0.2036	-23.4902	-0.1696	0.2036	1.5098
X=0, Y=-36	0	-36	-25	-17.8601	-214.666	169.8161	-0.3938	-35.6074	-25.3745	-0.3938	0.3926	-0.3745
X=36, Y=0	36	0	-25	18.3609	-179.417	170.3696	35.8272	-0.3582	-24.821	-0.1728	-0.3582	0.179
SR (2) [Start data]	0	0	0	-18.1046	-29.0309	194.3438	–	–	–	–	–	–
X=0, Y=0	0	0	-25	-18.2771	-29.0139	169.2848	-0.1725	0.017	-25.059	-0.1725	0.017	-0.059
X=0, Y=36	0	36	-25	-18.0185	6.9823	169.587	0.0861	36.0132	-24.7568	0.0861	0.0132	0.2432
X=-36, Y=0	-36	0	-25	-54.0549	-28.8418	170.4662	-35.9503	0.1891	-23.8776	0.0497	0.1891	1.1224
X=0, Y=-36	0	-36	-25	-18.4996	-64.6461	170.7002	-0.395	-35.6152	-23.6436	-0.395	0.3848	1.3564
X=36, Y=0	36	0	-25	17.6559	-29.394	168.9737	35.7605	-0.3631	-25.3701	-0.2395	-0.3631	-0.3701
SR (3) [Start data]	0	0	0	-168.022	-29.6793	194.5826	–	–	–	–	–	–
X=0, Y=0	0	0	-25	-168.18	-29.522	169.9056	-0.1585	0.1573	-24.677	-0.1585	0.1573	0.323
X=0, Y=36	0	36	-25	-167.921	6.6214	170.4642	0.1003	36.3007	-24.1184	0.1003	0.3007	0.8816
X=-36, Y=0	-36	0	-25	-203.975	-29.2853	169.5892	-35.9532	0.394	-24.9934	0.0468	0.394	0.0066
X=0, Y=-36	0	-36	-25	-168.406	-65.299	170.7742	-0.3843	-35.6197	-23.8084	-0.3843	0.3803	1.1916
X=36, Y=0	36	0	-25	-132.229	-30.0724	171.1818	35.7925	-0.3931	-23.4008	-0.2075	-0.3931	1.5992
SR (4) [Start data]	0	0	0	-167.379	-179.691	195.4131	–	–	–	–	–	–
X=0, Y=0	0	0	-25	-167.69	-179.537	170.9313	-0.3116	0.1542	-24.4818	-0.3116	0.1542	0.5182
X=0, Y=36	0	36	-25	-167.56	-143.388	172.2647	-0.1807	36.3031	-23.1484	-0.1807	0.3031	1.8516
X=-36, Y=0	-36	0	-25	-203.565	-179.292	170.8998	-36.1861	0.3991	-24.5133	-0.1861	0.3991	0.4867
X=0, Y=-36	0	-36	-25	-167.769	-215.316	169.8815	-0.3904	-35.6249	-25.5316	-0.3904	0.3751	-0.5316
X=36, Y=0	36	0	-25	-131.561	-180.047	172.374	35.8182	-0.3555	-23.0391	-0.1818	-0.3555	1.9609

Unit; mm

Table 3 Positioning accuracy (Suffix m, measured; d, displace. error Δ, measured data — start data)

Measuring order	Xp	Yp	Zp
1	0	0	-25
2	0	36	-25
3	-36	0	-25
4	0	-36	-25
5	36	0	-25
6	0	0	25
7	0	36	25
8	-36	0	25
9	0	-36	25
10	36	0	25

Table 4 The order of movement of the output link center (Xp, Yp, Zp); mm

Moreover, the repeatability is obtained, as shown in Table 5.

From Table 3, the positioning accuracy in the Z-axis direction is 2 mm at maximum in the working space 100*100 mm. This value may be possible to improve by local possibilities of further reducing the diameter of the hinge. And, from δz in Table 5, the reproducibility is found to be 0.082 mm at maximum.

	(0,0, 0)		
	δ_X	δ_Y	δ_Z
SR (1)	±0.0729	±0.0294	±0.0624
SR (2)	±0.0695	±0.0107	±0.0578
SR (3)	±0.0627	±0.0098	±0.0236
SR (4)	±0.0279	±0.0363	±0.0481

	(36,0, -25)		
	δ_X	δ_Y	δ_Z
SR (1)	±0.0290	±0.0061	±0.0107
SR (2)	±0.0121	±0.0041	±0.0239
SR (3)	±0.0191	±0.0055	±0.0097
SR (4)	±0.0158	±0.0084	±0.0210

	(36,0, 25)		
	δ_X	δ_Y	δ_Z
SR (1)	±0.05325	±0.02805	±0.0078
SR (2)	±0.0641	±0.0081	±0.025
SR (3)	±0.0498	±0.0019	±0.03555
SR (4)	±0.04605	±0.00825	±0.08195

Table 5 Repeatability; mm

4.5. Conclusion

In the present study, polymer-made planar hinge and polymer-made spherical/S hinge are discussed. Especially, shape and dimensions of polymer-made S hinges made by a „Thermoplastic polyester elastomer" called Hytrel were discussed. The Hytrel was found to be a good material for the S hinge. Then, polymer-made three degrees-of-freedom (3DOF) spatial parallel manipulator, which obtained a mechanism synthesis were designed and manufactured by use of the Hytrel. The positioning accuracy and repeatability positioning accuracy of this parallel manipulator was revealed.

Acknowledgments

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5. Innovative and Friendly Temperature Conditioning in Smart Cities

Vijay Jindal

Guru Jambheshwar University, India

Stay at Technical University of Munich: 2009, TUM Department of Physics

Smart city concepts are becoming very popular and the important factors, which are usually attributed to smart cities pertain to quick mobility, handling traffic congestion, controlling pollution, energy efficiency, waste treatment, cleanliness, upkeep and facilities of health care, education etc., including looks and social environment. Tackling these issues may be interconnected and one common factor for all of them is clean energy and energy conservation.

Most smart cities have to withstand extremes of temperature and thus require heating and cooling. Heating and cooling large volumes costs huge energy and destroys natural living environment and adds to all kinds of pollutions, from air to noise including adding heat to the environment. It is proposed that one should invoke innovative ideas to take care of temperature conditioning in smart cities. It has been proposed that this issue can be profitably and adequately addressed by resorting to individual heated or cooled conditioned garments and clothing with provision of conditioned intake of air to minimize wastage of energy and save smart cities from added pollution, too. One may plug in these enclosures for heating or cooling and thus lead to great savings on both energy and pollution. Passive heating and cooling is also avoided, as the heating and cooling need not be forced on co-occupants of a room. These advanced materials need to be designed based on nanotechnology, which has been tailored to enhanced Peltier coefficient by decreasing thermal conductivity and increasing electrical conductivity.

5.1. Introduction

There is growing concern for power not only because of shortfalls in many developing countries, but also because of increasing concerns of right power sources. High production costs and dirty sources are primary questions, which need a proper analysis. It is true that the dependence on electricity has increased manyfold and exposure to automation has resulted in button era for all solutions — be it in the field of transport, cooking, congenial temperature conditioning in houses, workplaces or in any temporary transit, which invisibly adds to huge drains and energy costs. The convenience of using power through electricity — thanks to Michael Faraday (1831), who showed us how to push all energy through a pair of wires and deliver it to a distant point by just a simple connection is one of the most wonderful achievements of technology, which has gone unnoticed. Subsequent advances in usage of electric power to drive any practical utility application for heat, light, motion, devices and control systems based on modern electronics — all have made life too dependent on this energy and automation so that we simply have forgotten to care, how it becomes possible in the first place. Modern life is unthinkable without power — from the time you get up and return to sleep — the entire 24 hours you have, require power or electricity at any or everyplace.

A unit of energy, which has been used to quantify power is measured in Kilo Watt Hour (Kwh) — a typical standard window air conditioner (AC) would consume around one unit like this in about half an hour. But the amount of energy required for this half an hour of cooling will mean burning about 1Kg of coal or about 200ml of petrol. These are relatively high energy density fuels but if you agree to do manual work equivalent to one unit, it would mean a heavy man weighing 100 Kg going up a 10 stories building 10 times in an hour. If this man does not agree to generate it this hard way, we have to realize that energy is arduous to produce and it will cost. However, if we have Uranium 235 and use it to generate energy you will only require one mg of Uranium. So the energy density of nuclear fuel is million times larger. On the other hand, you may need a full roof area of a standard apartment to produce 1 unit in one hour of full sunshine using efficient, expensive photovoltaic solar cells. Thus, energy density is extremely high for nuclear fuel and very small energy/area for solar sources.

We want everything to be power driven and all this is costing huge energy. Our effort to use all the water heads, all the coal, all the gas, which got accumulated with nature's effort over centuries, is becoming exhausted because our rate of using it is far more than the rate of production and thus can't be sustained, and we will be forced to go back to primitive living.

Indeed, the world's requirements of energy are in tens of Terra Watts. Using nuclear fission to meet this, despite hazards, is also a tremendous effort — it requires the building of 15000 nuclear power stations supplying 1 Giga Watt each. Also, at this rate of consumption, we only have economically recoverable uranium reserves to last five years, and thus global-scale investment is not justified. Even extension of fuel lifetimes with breeder cycles does not justify this level of investment, given the costs and risks.

Nuclear fusion is a technology that does not exist yet, though solar energy results from fusion reactions. We have no guarantee that fusion will be both safe and economically viable. Claims are far too premature. Even if we hypothetically consider fusion, it irreversibly transmutes lithium. Lithium is a scarce resource that has a host of industrial uses and is used in batteries in every laptop computer and mobile phone.
This leaves us with renewables such as wave, wind, hydroelectric, biomass, geothermal, and solar power. Wind, wave, biomass, and hydroelectric power are all indirect forms of solar energy with enormous conversion efficiency losses. So this leads us to ask: why not go directly to solar? The fact is there is about 350 times more solar power available than all other renewables put together. In fact it has been calculated that a 500x500 sq. km area is adequate if utilized for solar conversion and this area can be made available from a desert or on the surface of sea.

These sources have been supplemented by newer research on methods of production of green energy either from hydrogen, combination of solar and chemical processes, which act like absorption of solar energy and its reemission through excitation and de-excitation processes, artificial photosynthesis or other newer, cleaner methods, which do not cost oxygen and are non nuclear but are like solid state fuels delivering energy transiting from excited to de-excited states.

The most sensible alternate option even for vehicles appears to be hydrogen, as it can be obtained from splitting water and turns back to water on combustion. Thus, it is infinitely sustainable and mimics the Earth's natural water cycle. However, the production by splitting of water is usualy costly unless it is done as a by-product. But then density of hydrogen is low, and its storage and transportation is problematic. Hydrogen fuel cells are simple clean and green silent generators, which convert hydrogen into electricity but these do not scale for a global solution due to the use of expensive membrane technology coupled with exotic chemicals.

As a result, energy requirements are not easily met, whatever the source. Before we say that we must be conservative in our use of energy — energy saved is energy produced, we must rethink strategic production and usage. We can't throw any of the methods in the dustbin, we have to keep exploiting easily manageable water heads, fossil fuels, wind, etc. depending on the locations. We must use a combination of methods to generate electricity depending upon the location. The usage of solar energy has been much in focus in recent times. Sun gives us light and heat. Both are exploitable. The light is used by exploiting photovoltaic (PV) effect and some special materials like silicon and dopants such as arsenic have provided us with direct conversion of sunlight into electricity through PV cells. This low voltage DC is inverted to get AC domestic supplies. This is a high-tech area, additionally requiring constant cleaning of the exposed surface from dust etc. However, when we calculate the PV silicon solar cell area required to supply the world's power consumption, the PV technology does not seem like a winning game. Apart from meeting silicon requirements, toxicity is also an issue, and the dopant e.g. arsenic alone would exceed world reserves. One may think of supplementing PV technology using solar concentrators to reduce effective cell area but the rate of chemical usage is still not tenable because the cells will not withstand high temperatures due to concentrating solar light as heat also gets concentrated.

In fact it turns out that high-tech solutions are not cost effective. Low-tech solar collecting dishes, and concentrators can survive higher temperatures and provide easier technology and large scale solutions. This concentrated solar power (CSP) is using solar heat rather than solar light and the conversion directly to the AC supply through steam turbines and generators is another option of using solar energy. CSP is being adopted more and more and we have seen about 740 MW of generating capacity added between 2007 and the end of 2010. As of January 2014, Spain had a total capacity of 2,204 MW, making this country the world leader in CSP. It is expected to meet 25% of the world requirement in some decades, using low tech CSP like parabolic-trough plants, which superheat water and run steam based turbines from free solar fuel giving us green power at nearly the price of fossil fuel.

Whether effort on new sources of energy will go on, nothing is going to match the hunger for power. We have to live a life closer to nature. If you try to take up the whole of solar energy, even though it is not apparent yet, but it will surely be at the cost of other vegetative and animal life. We should leave electricity for industry, education, hospitals, public transport etc. but not for too much luxury and wastage. Design houses which are not air conditioned but have natural cooling architecture. Use the cold temperature in basements to pump up cold air for cooling.

Therefore new innovative methods of energy saving will be a great help. One such idea is to cool or heat only your jackets to cut down on the volume of cooling. Use Peltier chips for cooling processors and not all of the machine. Hence choose innovative ways of introducing comfort for men and machines, which require a fraction of the power. For vehicles, use hybrids of fuels like hydrogen and fossil fuels. For hydrogen, use water splitting at sources where abundant solar or wind energy is being used. Also the overcharging battery current while a vehicle is run on alternate fuels can be used to split water and hydrogen thus produced can be fed back into the fuel cycle and save some percent of fuel. Indeed intelligent use of this convenient commodity coupled with a combination of production methods is the only answer. In the following we discuss how such innovative methods can help saving the environment, energy and neighbourhoods.

5.2. Conventional Heating and Cooling — drawbacks

Climate conditioning costs huge energy. For cold climates most places of living, working, shopping and travelling are invariably heated and for hot climates, cooled. The huge volumes, which are thus cooled and heated also include extra-body volumes, which may be much above 90%. We must focus on reducing these 90%.
Conventional heating and cooling is based on extra comfort of heating and cooling buildings, corridors, shopping centers, offices and homes using huge heating plants and cooling systems or AC units. While cooling you distribute inside heat to outside in addition to a factor of efficiency of AC units which add to tremendous heat to the environment.
As a result, it is like passive smoking — people who want a normal and natural environment are forced to bear extra heat thrown out by others. This also changes the natural environment in a big way. Additionally, cooling systems are usually based on evaporator through a refrigerant gas exchanging heat. Common refrigerant gases used in air con-

ditioning systems include hydrofluorocarbons or HFCs (like R-410A), hydrochlorofluorocarbons or HCFCs (like R-22), and hydrocarbons (like R-290 and R-600A). Although this gas is recycled during the process of heat exchange, a lot is leaked into the atmosphere during various stages and causes destruction of the ozone layer. Nice cool air is available but all unwanted objects and humans are also forcibly cooled in that space. Huge consumption of energy and all is in closed atmosphere.

Furthermore, air conditioning is unhygienic because usually the air in the closed room is being recycled — not usually being refreshed and thus becomes contaminated with concentrated “sick air”.

5.3. Some Innovative and Simple Solutions

It is suggested that the space or volume of the artificially heated and cooled air be contained limited to the body volume of individuals as far as possible. This can be done through the use of devices woven into personal garments worn on the body using a different technology based on thermoelectric effect. This is not a new technology but up til now its use is limited to low power devices. The materials which are responsible for this simple device based on the Peltier effect have very low efficiency for conversion of electric power to distribute heat so that one side becomes hot and the other cold in a silent way. Assuming that the materials can be designed with highly increased Peltier coefficients coupled with enhanced figures of merit, they provide us with a very handy and noiseless solution. The energy requirements of individual garments can be met by batteries while in transit and by individual plug in supplies in offices and homes.

It leads to huge energy conservation and cost cutting primarily due to a huge reduction in volume of space needed to be cooled or heated while leaving the rest of the environment relatively unaffected, which includes living and non-living entities.

The Peltier effect, also known by the more general name thermoelectric effect, has been exploited to make chips so that and when a DC electric current flows through the device, it brings heat from one side to the other resulting in one side getting cooler while the other getting hotter. The „hot“ side is attached to a heat sink so that it remains at ambient temperature, while the cool side goes below room temperature. In some applications, multiple coolers can be cascaded together for lower temperatures.

5.4. Thermoelectric Effects

Energy is carried by anything that propagates in a material. It could be electrons, holes or phonons or any other massive particle. The point of interest is that when you pass an electric current you force mobility of charge carriers — electrons or holes which also carry energy. This possibility of heat flow is caused by electric current and vice versa, and leads to the origin of Thermoelectric effect.

In the presence of electric fields and temperature gradients, the carrier concentration is reaching an equilibrium because of collisions, so that for any given velocity and position, the total time derivative of fluctuations vanishes.

Electric or heat (energy) current **J** or **U** are defined through charge or energy flow per unit area per sec.

If a material has **n** as the number density of the carriers moving in a direction with velocity **v**, at a given instant of time **t**, the electrical current and heat current will be caused by all possible distributions in velocity, and **J** which is defined by nev and **U** by nƐv where Ɛ is the energy of a carrier. Since there is a distribution of n spread over velocities in general, these will be summed up over the distributions to get total electrical **J** and heat currents **U**.

Because the carriers collide and fluctuate in density under application of a electrical field and temperature gradient, in equilibrium all these processes have to give us a time independent value of **n** which is say n0 and is dictated by its total time derivative vanishing through three processes of (i) diffusion due to varying velocities through temperature gradients, (ii) imposed forces through applied electrical fields which brings about changes in momentum (k) and (iii) an inter-carrier collision process dictated through a collision time . All this is a part of a well established theory through the Boltzmann Transport equation. The end result appears in the form of the following equations if linearized equation is applied:

$$\boldsymbol{J} = e^2\kappa_0\boldsymbol{E} + \frac{e}{T}\,\kappa_1(-\boldsymbol{\nabla}T) \quad (1)$$

$$\boldsymbol{U} = e\kappa_1\boldsymbol{E} + \frac{1}{T}\,\kappa_2(-\boldsymbol{\nabla}T) \quad (2)$$

Where matrices κ_i are given as

$$\kappa_i = -\frac{1}{(2\pi)^3}\int d^3\boldsymbol{k}(\epsilon-\mu)^i\tau\boldsymbol{v}\boldsymbol{v}\frac{\partial n_0}{\partial \epsilon} \qquad (3)$$

These κ_i coefficients determine electrical conductivity, thermal conductivity and the thermoelectric effects. However, it is easily noticed that temperature gradients alone can give rise to electrical currents and vice versa. The point to be noted is that you need two different materials to get a net temperature difference which is sustainable — otherwise in a series connection where electric current is uniform, the thermal current will also show no net effect. In case of different materials with differing then the net heat can be deposited at one end because of finite differer κ_i's in values of the two materials.

In the absence of a current drawn, Eq. 1 leads to

$$\boldsymbol{E} = \frac{\kappa_1}{Te\kappa_0}(\boldsymbol{\nabla}T) = Q\ \boldsymbol{\nabla}T \qquad (4)$$

with Q as Seebeck coefficient.
Eq. 2 leads to heat current because of the/a electrical field as

$$\boldsymbol{U} = e\kappa_1\boldsymbol{E} = \frac{\kappa_1}{e\kappa_0}\boldsymbol{J} = \mathrm{QT}\boldsymbol{J} = \Pi\boldsymbol{J} \qquad (5)$$

Which defines the Peltier coefficient

$$\Pi = QT \qquad (6)$$

For some simple situations termed as nearly free electron metals, the evaluation of κ_i from Eq.3 is greatly simplified. In these metals there is not much scope for altering the coefficient Q. The role of Q or Π requires connecting two different materials, as shown in Fig. 1, having different Q values.

In this situation, the generated thermoelectric field **E** is given by

$$E = (Q_A - Q_B)\boldsymbol{\nabla}T = S\boldsymbol{\nabla}T$$

resulting in thermoelectric power P proportional to E^2/ρ where ρ is the average resistivity of the two materials. The figure of merit ZT is decided by the ratio of power generated to the power absorbed, which in this case is dependent upon thermal conductivity (K) as $\mathrm{K}\boldsymbol{\nabla}T$.

$$ZT = \frac{S^2T}{\rho K} \tag{7}$$

Therefore if we can enhance S, lower down ρ and κ we can enhance the figure of merit. For most metals the product of electronic contribution to the product of $\rho\kappa$ is constant. However, there is a dominant contribution to the thermal conductivity from phonons, too.

$$K = K_e + K_{ph} \tag{8}$$

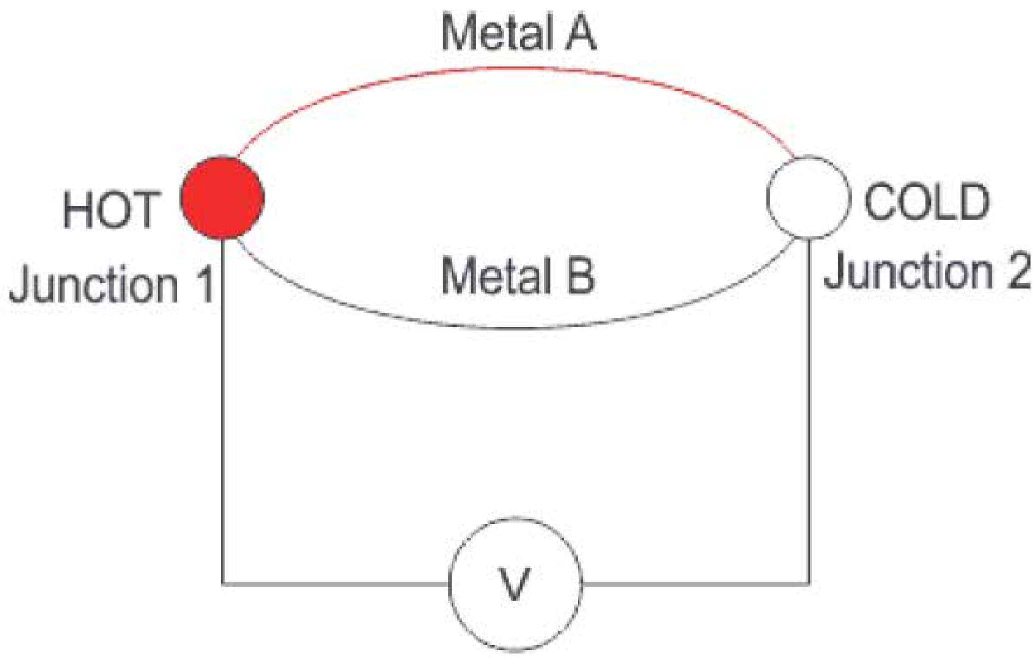

Fig.1 Schematics of thermoelectric effect.

We have no control over K_e but a design of K_{ph} is possible. Therefore, in advanced materials is lowered to raise the figure of merit.

Due to the unique nature of graphene, it is possible to develop a thermoelectric device based on it with an extremely high Seebeck coefficient.

One theoretical study suggests that the Seebeck coefficient might reach a value of 30 mV/K at room temperature and ZT for their proposed device would be approximate.

5.5. Summary and Conclusions

We have brought into focus that our energy requirements are huge and we need to work on conserving energy in order to save the environment and reduce passive effects, which affect living and non-living objects in the neighbourhood receiving unwanted heat. This is necessary along with tapping all possible sources of available green energy. Most of our energy is consumed through heating and cooling our living and working places. We can cut down our energy consumption if we target this area. Ultimately the solution lies in reducing the volume of air conditioning by adopting curtailed body limited spaces. For this we need to design garments and clothing, which have a cooled or temperature controlled layer over a normal clothing layer. How this can be done best is an area of research. Chips based on the Peltier effect, which use modern sophisticated technology to enhance the otherwise inefficient and low figure of merit chips presently available on the market can be sewn into the fabric. If we focus our research efforts on this area some options become available, which introduce hindrance pathways to the transport of phonons and thus reduce the thermal conductivity simultaneously by lowering electrical conductivity. Graphene [1] offers one such material.

If done so, the advantages are tremendous. Most of the traditional drawbacks of the conventional AC units like noisy, ozone layer destroying coolant gases are avoided and hence also passive heating and cooling.

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6. Virtual Reality Environments for Presentation, Elaboration and Evaluation of Autonomous Vehicles for Public Transportation in Singapore

Sebastian Stadler

Design for Autonomous Mobility, TUMCREATE Ltd, Singapore

Stay at Technical University of Munich: since 2017, TUMCREATE Ltd.

Autonomous vehicles (AVs) represent a major innovation for the automotive industry, but their potential impacts regarding their implementation on user perception, behaviour and acceptance remain hazy. Will it really improve future mobility and therefore our daily lives, especially when the technology of autonomous driving is implemented in the field of public transportation, like Singapore foresees? A challenge is therefore to figure out possibilities and opportunities, but also challenges for autonomous driving in the future. Since the technology of AVs is not mature yet, its impact on efficiency, comfort and safety can only hardly be predicted. For a successful implementation of AVs in Singapore, one open field, for example, is the investigation of users' perception and their behaviour in traffic with AVs in order to predict potential risks on the one hand, but also users' acceptance on the other. Based on these challenges, and especially with such a complex topic, how is it possible to remain innovative and work effectively within the conceptional phase of AVs for public transportation without losing time and costs on prototyping? How can justifiable and reliable data be collected in order to predict the impact of AVs in an efficient way?

Due to the fact that real life experiments, involving daily traffic of Singapore, pedestrians, passengers and AVs, are highly complex to set up, exceedingly expensive and potentially dangerous for human test objects, it is planned to use a virtual reality environment like CAVE (Cave automatic virtual environment) systems and Head Mounted Displays (HMDs) for setting up a virtual experiment test bed. Within this test bed, specific scenarios will be simulated with a fully immersion of the test object.

In this context, the main objective of the presented research is the development of a scientific method for elaboration, evaluation and presentation with the help of the virtual reality systems to replace building up a physical prototype. This includes preliminary tests that simulate real-life setups which are compared to actual real-life setups in order to measure the reliability and justification of the collected data within a virtual reality system. Furthermore, the scope covers the analysis of existing virtual reality systems to ensure the usage of the most fitting system for the stated project.

The case studies for the method are based on specific scenarios involving AVs as part of the public transport of Singapore and other traffic participants, such as pedestrians or passengers. One of these scenarios is how pedestrians and AVs can communicate in an active and/or passive way on a junction without traffic lights.

The research is part of TUMCREATE research in cooperation with Singaporean agencies and partners.

6.1. Introduction

Transportation is developing towards level 5 automation1. A study on autonomous vehicles (AVs) by Intel & Strategy Analytics (2017) predicts an economic opportunity of $7 trillion annual revenue by 2050, generated by businesses connected to level 5 AV technology. Furthermore, the study predicts that 585,000 lives could be saved between 2035 and 2045 thanks to this technology. The aforementioned technology is estimated to be implemented into daily traffic by 2030 (IHS, 2014).

Singapore's population grew from 3.5 million in the late 1990s to more than 5.4 million in 2014 (LTA, 2014). Furthermore, it is predicted that until 2030, population will increase to 7 million. An additional fact is that in Singapore, road space is limited. This means that infrastructures for mobility (like streets) only can be expanded to a certain extent. One way to tackle this growth within the circumstances is to enhance the local public transport system, such as the metro.

At TUMCREATE, a joint research institution of the Technical University Munich and the Nanyang Technological University Singapore, a gap was identified between the high speed and high capacity metro with its sparse proximity to destination and low speed and the low capacity bus system with its high proximity to destination. Within TUMCREATE, research is focused on filling this gap with a new public transportation system, the Semi Rapid Transit. The concept constitutes a whole transport system that is well integrated into the existing public transportation systems, as well as the infrastructure. Therefore, an interdisciplinary team consisting of Computer Scientists, Electrical- Mechanical- and Traffic Engineers, as well as Industrial Designers works on this road- based autonomous public transportation system, which is as flexible as busses, but still has a higher speed, thanks to features like autonomous mobility, virtual right of way, lane priority and decreased dwelling time.

6.2. Related Work

The "Design for Autonomous Mobility" department, with its team of Industrial Designers, is focused on the development of the newly proposed system with a user-centred design approach. Main topics are:

1. SRT Mobility Concept (e.g. SRT station, lane design, integrated mobility, payment)
2. SRT Vehicle Concept (e.g. interior and exterior design for autonomous vehicles (AVs) with universal design approach)
3. AV Communication Strategies (e.g. communication between pedestrians and AV)

Especially within the third research scope, validation of concepts is difficult since conducting experiments in real life conditions would imply great efforts in time and money spent, and would still remain potentially dangerous for test participants since AVs still misinterpret situations. One example that underlines this is a misinterpretation of the situation by a Tesla Model S in self-driving mode that resulted in a fatal accident (circumstances of the accident described by The New York Times, 2016).

Therefore, at TUMCREATE, VR is used as a platform for usability tests for concept generation and evaluation of communication concepts. Furthermore, it is investigated how VR can be a platform for concept presentation to an audience.

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[1] In contrast to level 0 automation, which means the human driver has to perform all aspects of the driving task, level 5 automation means that humans do not overtake or influence any task in any driving situation, but act solely as passengers (SAE, 2014).

VR is already being used in the product development process, especially when physical prototypes are not available or the tests can lead to hardware damage or injuries (Berg & Vance, 2016). In certain situations, like for instance training time for pilots, VR can be even more effective than the “actual” training (Mihelj, 2014). With Virtual Reality, conditions like the weather can be changed easily and design variants can be tested and compared without great effort.

VR can be enabled through systems like, for instance CAVE (CAVE Automatic Virtual Environment) (Cruz-Neira, 1992) or Head Mounted Displays (HMDs) (Sutherland, 1968).

This leads to the overall research question: *“How can VR environments support the design process for presentation, elaboration and evaluation in the context of autonomous vehicles for public transportation for Singapore?”*

6.3. Method

Together with the Computer Scientists in the department of Area-Interlinking Design Analysis (AIDA) of TUMCREATE and ARS Electronica Linz, Austria, the department of Design for Autonomous Mobility created a VR platform for elaboration, evaluation and presentation of autonomous driving for Public Transportation in Singapore. For this purpose, the so called Deep Space 8K, a high resolution CAVE system in Linz, Austria, was used.

It consists of two projection areas, one on the wall and one on the floor. Both areas have dimensions of 16 to 9 meters and a resolution of 8000 pixels in width. Thanks to the 8 4k projectors, virtual content can be displayed in 3D and with a 120 Hz frame rate. The floor area is equipped with laser tracking. Together with a HMD this constitutes the Interactive Virtual Research Lab. In this virtual immersive and responsive environment it can be observed how humans interact with a partly real, partly virtual vehicle, and their responses to various AV communication strategies can be easily sensed, tested and verified using the 3D virtual immersive environment. This would not be possible otherwise, unless we make working prototypes with additional sensors and test them in real world situations, which consume far more time, effort and funds. This research tool enables an impressive visualisation and live experience of vehicle concepts, mobility systems and operation strategies at a city scale which is understandable to scientists, students and people from various backgrounds. The setup can be used for research. It is ideal for data exploration and design review without complete isolation from the real world. Additionally, it limits the necessity of physical prototypes and experiments in real-life conditions while it is still capable to validate concepts. As an immersive experience with a shared experience, the Interactive Virtual Research Lab also enables the visualisation of validated concepts in an innovative way (TUMCREATE & Ars Electronica Future Lab, 2017).

6.4. Case Study for Singapore's Public Transportation

One of the case studies for the application of the Interactive Virtual Research Lab is the communication between pedestrians and AVs in situations where there is no traffic light. This includes for example zebra crossings. Since AVs do not have a driver anymore, misunderstandings in and/or misinterpretation of crucial situations become potential issues. Currently, pedestrians communicate directly with the driver of an approaching car. This happens with communication strategies like eye contact and/or gestures (Šucha, 2014). The Interactive Virtual Research Lab is used as platform for the validation of Human Machine Interaction (HMI) concepts. In this case, the visibility and comprehensibility of semantics that are used for HMI with AVs in a multicultural environment like Singapore are tested. To represent the population of Singapore, the recruitment reflects a multicultural distribution between Chinese, Malays, Indians and others. Additionally, a wide array of age groups is represented (children, adults, seniors) and the gender distribution is equal.

To validate the concepts, test objects conduct usability tests inside the Virtual Research Lab with equipped HMD. Methods like error analysis, taking the time to complete a task, and reaction time measuring give insights about the behaviour in the aforementioned scenario. This is supported by interviews before and after conducting the experiments.

6.5. Outlook

As a next step, a calibration of the setup will be conducted in order to ensure the validity of the collected data. To do so an example scenario will be tested within the Interactive Virtual Research Lab, as well as in real life conditions. After the tests, the results are compared for congruence of outcome. Thus, the overlap defines the validity of the collected data.

Furthermore, the transferability of concepts to other cities and/or countries will be tested. The used case of Singapore is a special one, due to the city‘s rapid population growth and limited road space. With the help of the Interactive Virtual Research Lab, the transferability of for instance HMI concepts to other cities/countries can be tested.

Finally, the VR method as a whole will be tested in terms of transferability. This means that the application is not limited to autonomous mobility but has the potential to be applied in several fields.

Acknowledgement

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7. Like a rainbow over city sky — Bike sharing system

Ying Zhang

School of Transportation Engineering, Tongji University, China

Stay at Technical University of Munich: 1999–2003
TUM Department of Civil, Geo and Environmental Engineering

They are different in colours: red, yellow, green, etc., and in many cities it looks like this is the peoples' new favourite mode of transportation. With a range of advantages, such as being eco-friendly, cheap and a convenient connection through information and communication technology, they are regarded not only as a renaissance phenomenon of slow-speed-mobility, but also as a valuable supplement to the system of public transportation in cities, that are seeking to be smarter and more sustainable.

The article consists of three parts. Firstly, the rapid development of this new means or transportation will be introduced. Then, two crucial aspects of the structural framework will be discussed, namely the internet + and shared economy. Last but not least, a potential future of this innovative transport system in the context of smart cities will be predicted.

7.1. Introduction

Bike sharing is not a new concept at all. Like any rental travel tool, it has been used in many places. For example, in Germany the bikes with the symbol of DB have been visible for a long time in front of many big train stations.

However, shared bikes with GPS and mobile payment, without dock, are definitively a new thing. Actually, it has not existed before the end of the year 2015 in China, when it was invented. It has experienced a dramatic boom across the whole country and has been accepted by almost all social groups, including foreigners. People regard it as one of the four most treasured possessions and, next to high-speed railways, online-shopping, third-party payment, as one of the New Four Great Inventions. It possesses great influence on daily life and social development, just like the Four Great Inventions of the Chinese people in ancient times, such as papermaking, printing, the compass, and gunpowder.

Recently, there are numerous companies who engage in this service and supply a range of bicycles in different colours: red, yellow, green, etc., forming a bright rainbow over the city and a new dynamic scenery in many Chinese cities. It has become a new phenomenon amongst means of transportation.

7.2. A Range of Advantages & High Technology

Known as the Bicycle Kingdom, in China the bike was once regarded as the ultimate and most convenient mode of transportation. Cars were few and the bike was definitively one of the most popular purchases. However, bicycles are no longer family necessities because of the radical fast development of urbanization, industrialization and motorization. More and more, cars and metro systems are the main choices in personal daily movement. Less and less cyclists struggle with the urban transformation, which has been overshadowed by four-wheel worship in the past decades and bikes almost seemed to be outdated. According to the Beijing transport authorities, bicycles accounted for 63 percent of trips in the 1980s, but that dropped to 17.8 percent in 2014.

The wave of the current popularity of bike sharing systems has brought the cycling renaissance. The emerging of bike-sharing services, some call it the Uber of bicycles, has reinvigorated the demand for pedal power, which meant a rebirth of bike riding for short, green trips to work, to go shopping and to reach the Metro station.

The new bike sharing systems cover utility models and designs, such as wheel & lock, communication, and app paying. Especially, the distinctiveness of GPS and QR codes, with its technology based on internet connection and big data in order to operate the lock system, enables users to use dock-less shared bikes: after registering as a user you can open a mobile app, find the nearest bike and unlock it by scanning the QR code with a smart phone.

Its popularity regains glory, because these new models integrate the traditional bicycle with the internet era, meeting the demand of modern features. It has always been an issue to promote sustainable transportation to make the last mile of commuting a green one, especially in congested cities and to form a suitable healthy lifestyle. In other words, riding a bike makes you feel good and is good for the environment. It is convenient, cheap, dynamic, eco-friendly, zero-emission, and energy saving. No wonder it has become a favourite choice for transportation.

Cycling is an ancestral culture in China, but with the shared bike era it reached a new level, which has brought the onset of the shared bicycle revolution. The introduction of shared bikes has resulted in most streets being coloured like a rainbow, stimulating many new avid cyclists.

At present, bike-sharing brands have spread all across China. About a dozen major players have penetrated the shared-bike market with more than 16 million bicycles on the streets nationwide and around 130 million users, making shared bikes the hot social trend.

7.3. Essential Structure and Crucial Investigation

Just like any another traffic tool system, the bike-sharing system is still facing opportunities and challenges at the same time. Essential and crucial investigation should cover: scale & size, distribution & composition, arrangement of service, and prognosis in order to find the balance of traffic tools between time & space, demand & supply, multi-level & angle.

Chinese cities are relatively calm, cycling-friendly cities with numerous bike lanes and routes, compared with most cities in motorized countries. However, it is not always safe to cycle here.

“The rules and spaces provided for cyclists are not always respected by everyone. Although the spaces and needs are there, the order and respect are often missing.”
(Volkszeitung vom 08.08.2016, S. 3)

Complaints about the shared bikes also include illegal parking by users and walkways overcrowding with bikes.

As marketing demands constant change and adjustment, the reliable measurement to predicate the total number of shared bikes for a city is complicated and still not available. The city has witnessed arbitrary illegal parking as the bike sharing industry has boomed. The abuse of the shared bikes and parking on walkways not only affects sidewalks for the blind, but has also spread onto the road.

For example, one normal Metro station in Shanghai receives about 300,000 to 400,000 passengers every day. Many are located in narrow streets and have limited parking resources, which can handle at most 70,000 bikes. Besides private bikes, the remaining parking resources can only house at most 20000 shared bikes. Although the local authority aims to increase the parking spots downtown for non-motor vehicle, they have already hit their limit and the number of shared bikes here has largely exceeded the area's capacity. The "peak number" of shared bikes on Shanghai streets this year was about 1.78 million, according to data submitted by the companies.

The Shanghai government will stay active in monitoring the number of shared bikes on the streets by analysing the demand and calculating the capacity. To curb the flood of shared bikes on the streets and a tightened of the management are carried out in August this year. It is estimated that the number of shared bikes on the streets by the end of last month was about 1.1 million. The government has waged a crackdown campaign against illegally parked bikes since September, after which no more shared bikes will be allowed to be added to current fleets, especially in key areas such as transportation hubs, Metro and bus stations, and hospitals.

Based on app operating, it is easy to collect data including bike delivered information such as operation trucks, the operating time and routes. The bike sharing system could be helpful not only for optimizing traffic sign control, but also for intelligent traffic planning. There is a need for a more reliable management and guidelines in order to keep the bike-sharing system on track and to avoid random parking.

7.4. A Potential Future in Urban Mobility

Bike sharing is a brilliant idea. Being a new way of environmentally friendly travel, smart bikes have become a new alternative of transport. Many local residents and travellers have changed their mind and chosen smart bikes to travel, especially when travelling at a short distance, which is of great advantage for riders themselves and the city.
Reinvigorating the spirit is helpful to impel the export of contemporary bike-sharing system to overseas. Now many bike sharing companies are gearing up for global expansion. Mobike and Ofo are two of the key players and the biggest firms. The first one currently runs over 7 million shared bikes in 180 cities in nine countries, including China, the United States, Britain, Japan, Singapore and Italy. The other one has announced a partnership with a leading bike manufacturer to make 5 million bikes for bike sharing in the next 12 months, of which about 1 million is to be shipped to its overseas markets. Their joint goal is to target consumers with features for more flexibility and convenience.

Summary

Yesterday is history, tomorrow is mystery. Today, the bike-sharing system has been compared to a rainbow, and it would certainly be an idea to see it as the new link between the present and the future.

“When we put those colours side by side, now what do you think we’ve done? We’ve made a rainbow, and it’s a really beautiful one.” Just like in this English song we hope that we never run out of the beauty and the benefits of this rainbow over the city sky, which is one of the new mobility trends for life in smart cities.

8. Future Cities Laboratory, Singapore-ETH Centre, Singapore

Armin Gruen

Technical-Scientific Project Leader of “FCL — Virtual Singapore”
Future Cities Laboratory, Singapore-ETH Centre

Stay at Technical University of Munich: 1969–1981
TUM Department of Civil, Geo and Environmental Engineering

3D computer-based city models have become an indispensable basis for a variety of tasks related to issues of urban sustainability. Today they are contributing in an essential way to the concept and realization of Smart Cities.

Applications of city models are manifold. Currently the major users in Europe are in city planning, facility mapping, telecommunication, construction of sports facilities and other infrastructure buildings. Others include environmental studies and simulations, location-based services (LBS), risk transports and analysis, car navigation, simulated training (airplanes, trains, trams, etc.), energy providers (placement of solar panels), real estate business, virtual tourism, and microclimate studies. Interesting markets are expected in the entertainment and infotainment industry, e.g. for video games, movies for TV and cinema, news broadcasting, sports events, animations for traffic and crowd behavior, and many more. Worldwide databases like Google Earth and the ease of access have further contributed to the great interest in landscape and city models.

The need to extend modeling from simple to much more complex buildings and full ensembles and to even generate complete city models (including DTM, roads, bridges, parking lots, pedestrian walkways, traffic elements, waterways, vegetation objects, etc.) requires progress in the automation of the individual steps of the modeling pipeline.
This presentation will describe the R&D work in 3D/4D city modeling that has been performed at SEC-FCL in the past few years. The focus will be on reality-based modeling.

We will show how satellite images, aerial (especially UAV) images, terrestrial images and point clouds from laserscans can be used for model generation. Examples from projects in Singapore, all related to the tasks of the Simulation Platform of the SEC-FCL project, like Punggol, Little India and the modeling of the NUS campus at very high resolution will support the conceptual considerations and demonstrate the status of this technology. We also will give a brief outline of our planned work for the R&D project “FCL — Virtual Singapore”.

9. Bettering the spatial planning of public electric vehicle charging facilities: The cases of Beijing and Hong Kong

Sylvia Y. He

Department of Geography and Resource Management,
The Chinese University of Hong Kong, China

Stay at Technical University of Munich: 2011–2012
TUM Department of Civil, Geo and Environmental Engineering

Electric vehicle (EV) development is one of the most promising ways to advance smart mobility in smart cities. However, the access to charging infrastructure has been a concern for EV users and potential adopters.

In the first part of the presentation, I will present a project that aims to identify optimal locations for public EV charging facilities in Beijing based on a location-allocation model and to evaluate the current deployment scheme in the city. In our location-allocation model, the supply is estimated based on the latest land use information and the demand is estimated based on a recent questionnaire survey (conducted in April, 2017) that carries out a discrete choice experiment where the respondents were asked to choose one of the three choices: conventional cars, hybrid vehicles, and EVs based on a number of attributes of these choices. Moreover, our model incorporates the local institutional and spatial constraints (He et al, 2016) such that the selected locations can be more contextualized and realistic.

In the second part of the presentation, I will present the preliminary result of a research project that aims to understand the supply side of charging facilities in Hong Kong and Berlin (funded by the RGC Germany/Hong Kong Joint Research Scheme 2016/17).

Our results are expected to shed light on the spatial planning of transport infrastructure with implications on the strategies for promoting electric vehicles and e-mobility.

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10. Smart and Universal Education Environment for Life-Long Learning

Jiyou Jia

Department of Educational Technology, Peking University, China

Stay at Technical University of Munich: 2015, TUM School of Education

The popularity of smartphones, Internet, the Internet of things, virtual reality, artificial intelligence and other emerging technologies has created a smart and universal education environment, empowered the education without geographical border and schedule limitation, and improved the life-long learning for all and from all. The learning takes place not only in formal institutions like school and universities, but also at home, in workplace, on the way or anywhere at any time. This speech will address the opportunities and challenges for education in the era of Internet plus or Industry 4.0.

11. The changing structure of urban public health: The past and the future

Meirong Su[1], Jiao Wang[2]

[1] Research Center for Eco- Environmental Engineering,
Dongguan University of Technology, China

Stay at Technical University of Munich: 2015, TUM School of Life Sciences Weihenstephan

[2] National Institute of Environment Health,
Chinese Center for Disease Control and Prevention, China

Urban public health is essential for living and development of citizens. In this paper, we focus on the question whether a certain changing rule for urban public health exists during urban development around the world. In order to answer this question, eighteen indicators were firstly selected to describe the status of urban public health from five aspects including physical health (PH), living condition (LC), social security (SS), environmental quality (EQ), and education and culture (EC). Subsequently, the weighted sum model was applied to quantify and compare the states of urban public health for different cities. Then four typical cities — Beijing, Tokyo, New York, and London with different histories — were chosen as the cases, representing cities in different stages of development. Based on 2000–2009 data, it is found that a pyramid structure existed in urban public health for each city where the pyramids of Beijing and Tokyo were relatively similar to each other while that of New York and London were similar, too. Moreover, a general changing trend in urban public health was revealed and expressed by different pyramid structures, i.e., from the Beijing pyramid to the Tokyo pyramid to the New York pyramid, and finally to the London pyramid, amongst which the relative performance of the five aspects of urban public health was gradually changing. In other words: PH, LC, SS, EQ, and EC are located in different positions of the pyramids at different stages. This indicates the social evolution and the change of the urban development goal to a certain degree. The changing pyramid structure of urban public health can be verified, further developed and predicted to guide healthy urban development.