KOREA ADVANCED INSTITUTE OF SCIENCE AND TECHNOLOGY

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다양한 분야에서 우수한 연구 결과를 낸 KAIST의 2013년 연구 성과를 모았습니다.

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Research Highlights of 2013

Research Highlights of 2013

On the Levy-walk Nature of Human Mobility

Song Chong (Electrical Engineering)
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This research reports that human walk patterns contain statistically similar features observed in Levy walks. These features include heavy-tail flight and pause-time distributions and the super-diffusive nature of mobility. Human walks are not random walks, but it is surprising that the patterns of human walks and Levy walks contain some statistical similarity. Our study is based on 226 daily GPS traces collected from 101 volunteers in five different outdoor sites. The heavy-tail flight distribution of human mobility induces the super-diffusivity of travel, but up to 30 min to 1 h due to the boundary effect of people's daily movement, which is caused by the tendency of people to move within a predefined (also confined) area of daily activities. These tendencies are not captured in common mobility models such as random way point (RWP). To evaluate the impact of these tendencies on the performance of mobile networks, we construct a simple truncated Levy walk mobility (TLW) model that emulates the statistical features observed in our analysis and under which we measure the performance of routing protocols in delay-tolerant networks (DTNs) and mobile ad hoc networks (MANETs). The results indicate the following. Higher diffusivity induces shorter intercontact times in DTN and shorter path durations with higher success probability in MANET. The diffusivity of TLW is in between those of RWP and Brownian motion (BM). Therefore, the routing performance under RWP as commonly used in mobile network studies and tends to be overestimated for DTNs and underestimated for MANETs compared to the performance under TLW.

Zero-Blur Camera 적응형 노출 개폐 패턴 집합을 이용한 영상 블러 (Image Blur) 최소화 기술

전기 및 전자공학과 **권인소 / 전해곤 /이준영 /한유덕 (Electrical Engineering)**
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We present a novel computational camera system utilizing the coded exposure technique for the multi-image deblurring. The key idea is to capture video frames with a set of complementary fluttering patterns to preserve spatial frequencies. We develop an algorithm for generating a complementary set of binary sequences adopted from the modern communication theory and implement the coded exposure video with an off-the-shelf machine vision camera. The proposed camera system outperforms the state-of-the-art computational image capturing methods in image deblurring. The effectiveness of the camera system is demonstrated on various challenging examples with quantitative and qualitative validations.

Intelligent Tutoring System Utilizing Collective Intelligence

윤완철/이문용 (Dept. of Knowledge Service Engineering)
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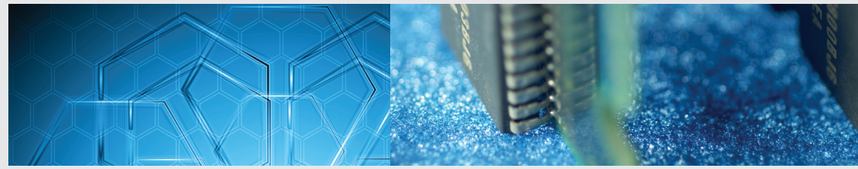
- This research develops a smart tutoring system that enables self-directed and constructive learning by utilizing collective intelligence. It aims at suggesting a major alternative approach to the conventional lecture and one-directional tutoring.
- The system is designed to unleash the dormant energy and the social dynamic potential of learners, enabling constructive interactions among them, which in turn makes it possible for each learner to continue his/her study with sustained self-efficacy. Such a model is expected to drive the future changes that are inevitable in education in general.
- This project involves many innovative ideas, such as study pheromone, study caravan, and creative team interaction. It has been developed for 4 years and now in the last phase before its public release.



Scheduling in Heterogeneous Computing Environments for Proximity Queries

Sung-eui Yoon/ 김동준, 신인식, 김덕수, 이진규, 이정환 (Department of Computer Science)
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We present a novel, Linear Programming (LP) based scheduling algorithm that exploits heterogeneous multi-core architectures such as CPUs and GPUs to accelerate a wide variety of proximity queries. To represent complicated performance relationships between heterogeneous architectures and different computations of proximity queries, we propose a simple, yet accurate model that measures the expected running time of these computations. Based on this model, we formulate an optimization problem that minimizes the largest time spent on computing resources, and propose a novel, iterative LP-based scheduling algorithm. Our method achieves an order of magnitude performance improvement by using four different GPUs and two hexa-core CPUs over using a hexa-core CPU only.

Optimal Pilot Beam Pattern Design for Massive MIMO Systems

Y. Sung (Dept. of Electrical Engineering)
S. Noh/ Y. Sung / M. Zoltowski / D. Love (School of Electrical and Computer Engineering, Purdue University)
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Massive MIMO technology is considered to be one of the key enabling technologies for 5G mobile communication. Massive MIMO technology provides high data rate, high energy efficiency and low-complexity receiver structure. However, one of the hurdles to realizing massive MIMO technology is channel estimation from a very large number of transmit antenna array elements to the receiver. In this research, in collaboration with Purdue team, Prof. Sung's group developed an optimal pilot beam pattern design method for efficient channel estimation for massive MIMO systems by exploiting both channel's spatical and time correlation. The proposed pilot design method reduces the pilot overhead significantly when compared to existing methods and is expected to make a contribution to 5G mobile communication.

ContentPan – Content transfer technology for digital signage

최준균 / **Sungkwan Jung / Sangsik Kim / Yongchul Shin / Junseok Park (Institute for IT Convergence)**
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Today's the rapid growth of the digital signage market are contributing to the increasing need of innovative and convenient signage interaction technologies. In this study, we developed a UI technology with which people can use digital signage contents in a fast and easy way. This technology recognizes and transfers digital signage contents, utilizing a illuminance sensor which the most smart devices have. Hence, additional devices are not required, and its high recognition rate and intuitive UI make users use the contents easily and enjoy them. With this technology widely applied, we expect more consumers will use digital signages and also the Korean digital signage service providers' market power will be enhanced and gain a competitive advantage.

Research Highlights of 2013

Development of STSAT-3 Satellite

In Lee (Satellite Technology Research Center)
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The STSAT-3, a small satellite promoted by Korean Space Development Plan for space science, Earth science and technology demonstration, was initiated in May 2007, fully built-up including spacecraft bus, payloads, ground-station in early 2013, and successfully launched onboard Dnepr launch vehicle in Yasny launch site of Russia on Nov. 21 2013. Spacecraft bus and its ground station for STSAT-3 were developed by the KAIST's own space technology; KAIST ground station is responsible for the satellite operation and the satellite is now being in early operation state. The STSAT-3 has the mass of 170kg, the power of 300W and the precise 3-axis stabilization technique. The spacecraft bus was equipped with core satellite technologies such as hall thruster, Li-ion battery, high performance on-board computer, multi-functional structures, compact solar power regulator, lightweight composite structures and so on. Through the space validation on these technologies, the STSAT-3 can provide us with necessary heritage that is essential for korean space sector to be competitive. In addition, the science payloads of MIRIS(Multi-purpose IR Imaging System) and COMIS(COMpact Imaging Spectrometer) will make great contribution to space/Earth science by performing the mission of galactic plane survey, cosmic background observation in near infra-red region and Earth observation in infra-red range.

Development of STSAT-2C Satellite

In Lee (Satellite Technology Research Center)
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The STSAT-2C is a small satellite with the mass of 100kg which was developed by KAIST for a short period of about 1year in preparation for the 3rd trial of KSLV-1. STSAT-2C has the mission objective of evaluating the orbiting performance of KSLV-1 (Korea space launch vehicle-1, Naro), measuring space radiation environment and demonstrating satellite core technologies made by domestic partners including industry, university and research institute. The STSAT-2C, launched by the KSLV-1 on 16:00 Jan. 30 2013 and initially communicated with KAIST ground station on 03:28 Jan. 31 2013, has successfully performed its desired mission on orbit till now. For the past 11 months, the STSAT-2C has carried out the acquisition of thermal images on Earth surface in infra-red region; the demonstration of attitude control using domestic reaction wheel system; the space validation of solar panels and femto–second laser oscillator; and space environment monitoring using Langmuir probes and space radiation sensors.

Development of synthetic small regulatory RNA platform technology for developing microbial cell factory

Sang Yup Lee / Seung Min Yoo / Dokyun Na (Department of Chemical and Biomolecular Engineering)
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Metabolic engineering is widely used to develop microbial strains for the efficient production of bioenergy, chemicals, and medicine. In this study, synthetic small regulatory RNA (sRNA) was developed for modulating gene expression for metabolic engineering of Escherichia coli. This synthetic sRNA based strategy allows rapid and easy construction of tailor-made microbial cell factory. Using synthetic sRNAs, biofactories that produce tyrosine (21.9 g/L) and cadaverine (12.6 g/L) with high yield were developed. The new strategy is expected to facilitate the development of biofactories that will resolve many inevitable problems stemming from industrialization, and to be widely utilized in industry and medical field.

Three-dimensional textures and defects of liquid crystal material revealed by thermal sublimation

Dong Ki Yoon / Hee-Tae Jung (Graduate School of Nanoscience & Technology / Dept. of Chemical & Biomolecular Eng.)
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Techniques that enable direct visualization in three dimensions of internal nanometer- to micrometer-scale structure are highly prized in materials research and engineering. Here, we demonstrate an effective method for the 3D imaging of soft materials, revealing the alignment, textures, and defects in the organization of their internal interfaces: in this case, of a soft crystal and liquid crystal phase. This method employs combinations of quenching and sublimation generating surface topography that reflects the internal structure, exposing it for visualization using standard techniques.

Fabrication of Thin Film Devices using Optothermochemical Reaction of Nano Materials

MIn Yang Yang / Bong Chul Kang/Jung Hwan Park (Department of Mechanical Eng.)
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Currently, vacuum deposition or photolitho processes are being used for electrode fabrication of RFID, solar cells ofr touch sensors. These are complex and high manufacturing cost processes. In this research, we studied fast and simple fabrication method of micro electrodes through inducing photothermochemical reaction of nano materials using laser. Analysis and experiments of interactions between nano materials and laser are done, and through optimization of process parameters, real electronic devices are made. Finally, their characteristics are evaluated.

Encapsulated Monoclinic Sulfur for Stable Cycling of Li–S Rechargeable Batteries

Do Kyung Kim / San Moon / Young Hwa Jung / Wook Ki Jung / Dae Soo Jung / Jang Wook Choi (Department of Materials Science and Engineering, Korea Advanced Institute of Science and Technology)
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Elemental sulfur (S) is a promising cathode material for a number of desirable properties. Sulfur cathodes have a theoretical specific capacity of 1675 mAh g-1 with very high specific energy density of 2500Whkg-1. Moreover, using sulfur as the cathode material for batteries has many other advantages such as low cost, abundant, environmental benignity and wide spread availability.

Despite the considerable promises, a number of significant challenges need to be solved for the commercialization; intrinsic poor electrical conductivity of sulfur (5x10-30Scm-1at 25oC), dissolution of polysulfides (Li2Sx,x=4~8) in electrolyte and large volumetric expansion of sulfur.

In the present investigation, we developed a sulfur electrode focusing on electrode design. In the electrode design perspective, sulfur was completely covered by minimal amount of carbon, and the carbon coated sulfur nanowire was highly aligned. The electrode design address all of the aforementioned issues at once and result in excellent electrical performance: a specific capacity reaching the theoretical value, substantial capacity retention over 1000 cycles, and rate capability with <1 min discharge time were achieved. Furthermore, these battery performances were achieved under the highest sulfur content to date: ~81 wt% in the active material.

Research Highlights of 2013

Heat transfer enhancement using magnetic nano-fluid and application to severe accidents

Yong Hoon JEONG / Taeseung LEE / Jong Hyuk LEE / Dong Hoon KAM (Department of Nuclear and Quantum Engineering)
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Application of magnetic nano-fluid has been studied to enhance the cooling of the reactor during severe accidents like Fukushima accident in a nuclear power plant. With magnetic nano-particles mixed with water, two times higher enhancement in critical heat flux was achieved, which shows better cooling effect compared with previous nano-fluids. Furthermore, applying magnetic field on the specific location attracted nano-particles on the region which has shown even better results. The amount of nano-particles used in the plant can be dramatically reduced by localizing lowly concentrated nano-particles on the specific region where heat transfer performance will be enhanced.
In addition to the experiment regarding the heat transfer performance, the patent of nano-fluid injection system has also been registered. It has strong points on simple operation and maintenance since small amount of highly concentrated nano-fluid can be injected with dilution.
Magnetic nano-particles has several advantages in addition to the enhancement of heat transfer performance. For example, radioactive materials such as Cs and Sr can be captured with surface-coated and functionalized nano-particles, and nano-particles can be easily collected by applying magnetic field after usage for the enhancement of heat transfer performance and capture of radioactive materials. In other words, during severe accidents like Fukushima in a nuclear plant, heat transfer performance can be improved and radioactive materials can be captured. By using magnetic nano-fluid for a coolant, leakage of contaminated water from a damaged nuclear power plant which is a significant long-term concern for Fukushima can be prevented.
For the first time, it has shown that there is no enhancement in critical heat flux even with nano-fluid at high exit quality. For application of this technology to a real plant under elevated pressure during accidents, pressure effect on the heat transfer performance has also been studied.

VITAMIN BATTERY:
Redox Cofactor from Biological Energy Transduction as Energy-Storage Chemical

Chan Beum Park (Department of Materials Science & Engineering)
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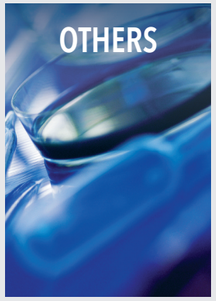
Cellular metabolism comprises energy transduction machineries that operate by a series of redox-active components to store energies from nutrients, which are transduced into high-energy intermediates for cellular works such as chemical synthesis, transport, and movement. Biological energy transduction mechanism hints at the construction of a man-made energy storage system. Herein, we present a bio-inspired strategy to design high- performance energy devices based on the analogy between energy storage phenomena of mitochondria and lithium rechargeable batteries. Flavins, a key redox element in respiration and photosynthesis, facilitate either one- or two-electron-transfer redox processes accompanying proton transfer at nitrogen atoms of diazabutadiene motif during cellular metabolism. We have successfully demonstrated flavins as a molecularly tunable cathode material that exhibits reversible reactivity with two lithium ions and electrons per formula unit. Analysis of both the ex situ characterizations and density-functional theory (DFT)-based calculations revealed that the redox reaction occurs via two successive single-electron transfer steps, which is analogous to the proton-coupled electron transfer mechanism of flavoenzymes. Tailored flavin analogues obtained via chemical substitution on the isoalloxazine ring showed fine tunability of electrochemical properties, exhibiting a gravimetric capacity of 174 mAh g^{-1} and an average redox potential of 2.65 V, and its expected energy density is comparable to that of $LiFePO_4$.

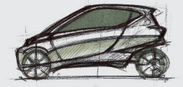


A smart scanning system for green energy infrastructure

Hoon Sohn (Department of Civil and Environmental Engineering)
http://web.kaist.ac.kr/~sohnhoon/

This research develops a smart scanning system that can (1) remotely scan the target structure with lasers to create ultrasonic images and (2) wireless excite embedded transducers and retrieve local ultrasonic data with lasers. The collected data can be used to continuously and/or periodically assess the safety and integrity of energy related infrastructure such as nuclear power plants, wind turbines, and distributed pipelines.

Design of an Urban Personal 3-Wheeler Electric Concept Vehicle



Seibum Choi / Mooryong Choi / Yoonjin Hwang (Department of Mechanical Engineering)
http://acl.kaist.ac.kr

Electric vehicles have drawn a lot of attention because of its high energy efficiency, eco-friendliness and simple structure. But due to high cost and weight of battery packs, EVs have limited driving range and performance. This study suggests a compact-size and light-weight urban 3-wheeler EV with front-wheel independent-driving and rear-wheel steering. With a near-zero minimum turning radius obtained by independently driven front wheels and +/-90 degree plus range of rear steering, limited urban parking spaces can be utilized very efficiently. The 3-wheeler EV can also be operated remotely by a smart device or externally through a rear mounted joy-stick. These features reduce the difficulty of parking at a small space greatly. Also using the joy-tick control device, multiple vehicles can be connected semi-electronically to be self-driven but controlled by a single leading vehicle. This efficient re-distribute method is very crucial for the success of car-sharing systems which are becoming popular in many metropolitan areas.