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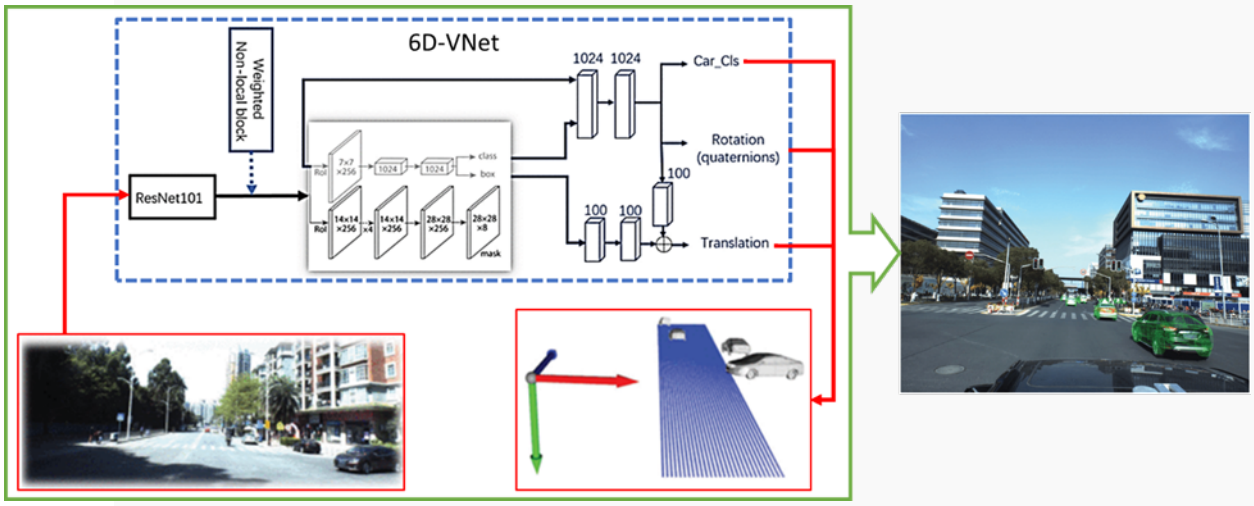

SYSTEM PIPELINE OF END-TO-END 6 DEGREES-OF-FREEDOM VEHICLE POSE ESTIMATION FROM MONOCULAR RGB IMAGES FOR AUTONOMOUS DRIVING SCENARIOS (6D-VNet)

IEEE CTSoc CONSUMER TECHNOLOGY SOCIETY

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EDITOR'S NOTE

On behalf of the Editorial Board of IEEE CTSoc News on Consumer Technology (NCT) editor-in-chief Wen-Huang Cheng and editors, Luca Romeo and Yuen Peng Loh, I am happy to introduce the third issue of the NCT in 2022.

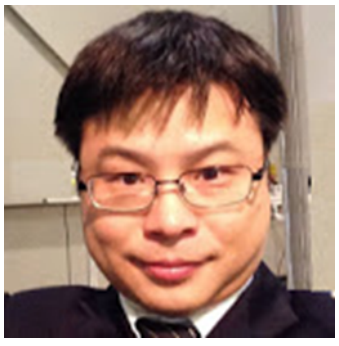
This issue starts with a cover story which shows an end-to-end 6 Degrees-of-Freedom (DoF) pose estimation method using monocular RGB images published in the CTSoc's journal, IEEE Transactions on Consumer Electronics. The detection, estimation, and reconstruction of the 3D shapes of road vehicles are critical for an effective and safe autonomous driving system. This excellent work proposes a deep learning-based 6DoF pose estimation system, namely 6D-VNet, that can estimate vehicle 3D poses from a monocular RGB image.

Next, the feature people provide an interview with research team of ASSETs+ project. ASSETs+ project aims to build a sustainable human resources supply chain for the European Defence Industry, that boosts innovation by both attracting highly skilled young workers and upskilling its employees. Prof. Gualtiero Fantoni and Prof. Filippo Chiarello explain many topics of the project such as the major missions/research directions, usage of AI technologies, the impact on labour market and design of education and training activities.

Finally, this issue presents a featured article brought by Prof. Quang Thang Duong, Prof. Takeshi Higashino and Prof. Minoru Okada of Nara Institute of Science and Technology, Japan, discussing on the technology of inductive power transfer with multiple-input multiple-output (MIMO) transmission. The article overviews the inductive power transfer technology and then explains how to improve power transmission capacity using MIMO technology. It focuses on MIMO transmissions for extending the coverage area, simplifying the power electronic as well as enhancing the power transmission capacity.

We hope you can enjoy your reading!

Yafei Hou
Editor of NCT



ARTICLE TITLE
End-to-End 6DoF Pose Estimation From Monocular RGB Images

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The development of Advanced Driver-Assistance Systems (ADASs) and autonomous driving has been growing with the increasing consumer demand for safer vehicles on the road. In particular, the success of computer vision systems has drawn further attention towards these areas due to their potential for various road related applications such as environment understanding, traffic light detection, as well as road semantic segmentation to name a few. In autonomous driving systems, the distance estimation of traffic users from the vehicle is critical yet challenging due to the variations in real-world scenarios especially from RGB videos and images. Therefore, the detection, estimation, and reconstruction of the 3D shapes of road vehicles are critical for an effective and safe autonomous driving system. This work proposes a deep learning-based 6 Degrees-of-Freedom (DoF) pose estimation system, namely 6D-VNet, that estimates vehicle 3D poses from a monocular RGB image. Leveraging on known state-of-the-art Mask R-CNN with ResNet101 architecture backbone from the object detection and segmentation tasks, the 6D-VNet introduces prediction heads for fine-grained vehicle classes, as well as 3D rotation and translation regression. Additionally, joint losses are also proposed with the incorporation of spatial dependencies from neighboring vehicle information into the model which allows easy end-to-end training and improvement in pose estimation performance. The proposed system shows competitive performance in comparison with most related works in the evaluations of Average Viewpoint Precision (AVP), viewpoint estimation accuracy, and median angular error on the Pascal3D+. Furthermore, this system notably clinched first place in the 3D Car Instance task of the Apolloscape Challenge.

INTERVIEW WITH RESEARCH TEAM OF ASSETS+ PROJECT

Gualtiero FANTONI

Gualtiero FANTONI is Associate Professor at University of Pisa, President of Pisa Leaning Lab, founder of Fablab Pisa and of 3 university spin-off companies. MEng in Mechanical Engineering ("summa cum laude") at University of Pisa in 1999. PhD in Robotics, Automation and Bioengineering from the University of Pisa. His research interests are in industry 4.0, industrial robots, grasping, handling and feeding systems, and Natural Language Processing software applications. Wide experience in patent automatic analysis and technology foresight. His publications include more than 100 peer reviewed papers, co-inventor of 10 patents. Scientific Director of the Advanced Manufacturing District of Regione Toscana (Italy). He led several 7th FP IP, Erasmus+, national and regional research projects. Currently, he is leading ASSETs+ project within Erasmus+ Strategic Skill Alliances implementing the Blueprint.

Filippo CHIARELLO

Filippo CHIARELLO is an Assistant professor at the School of Engineering, University of Pisa. MEng and a PhD in Management Engineering (both "summa cum laude") at the University of Pisa. His research focuses on the use of Natural Language Processing techniques for studying technological and HR-related phenomena. He also has a wide experience in patent and scientific papers automatic analysis and technology foresight. His publications include more than 50 peer-reviewed papers, including international journals like IEEE Transactions in Engineering Management, Technological Forecasting and Social Change and Expert Systems with Applications. For ASSETs+ he is the leader of WP1 "Technology and Skill Analysis", dedicated to map technological evolution in Defence and study the impact of emerging technologies on skills and job profiles.

What are the major missions and main research topics of ASSETs+?

[Fantoni] ASSETs+ aims to build a sustainable human resources supply chain for the European Defence Industry, that boosts innovation by both attracting highly skilled young workers and upskilling its employees. The fast pace of technological evolution leads to challenges in terms of finding workers with the right skills, as these are constantly changing. Our goals are exploring and foreseeing emerging trends in technologies and skills in the Defence sector, translating the results into concrete concepts as a basis for new education and training programs and developing a European Defence Qualification System covering pedagogical and technical aspects while complying with education requirements and industrial needs. The main research topic of the project is the impact of the digitalization on the human resources, focusing on the cutting-edge technologies of Artificial Intelligence, Robotics, C4ISTAR[1] and Cybersecurity.

We live in a world that's constantly changing. So, how to deal with this challenge in foresight analysis in future technological trends and skills' needs?

[Chiarello] The fast technological evolution makes difficult to properly delineate and address its impact in the labour market and in education. Moreover, a complete understanding in such a complex domain like Defence (where the confidentiality of the information is critical) is challenging. The ASSETs+ approach,.

[1] *C4ISTAR is an acronym for Command, Control, Communications, Computers, Information/Intelligence, Surveillance, Targeting Acquisition and Reconnaissance*

leveraging both on qualitative and quantitative techniques and methods, is a feasible way to have near real time monitoring. Big data analysis allowed us to delineate the Defence landscape within the emerging technological domains. Brainstorming sessions with panels of industrial experts lead us to a deeper comprehension of the facets of this complex environment, fostering the possible interrelations among those cutting-edge technologies, the implication on well-suited competences and soft skills, and the good practices to deploy at the organizational level as well as on the regulatory one.

What are the main research directions of the cutting-edge technologies in the Defence areas?

[Chiarello] Research in Defence will be more and more synergic with Civil domains, due to the widespread utilization of emerging and disruptive devices and applications. Defence sector is historically an innovation intensive and knowledge intensive sector. In the last two decades, the innovation paradigm has radically changed, due to the development, within the civil domains, of several disruptive technologies such as Artificial Intelligence and Robotics. Indeed, new spaces of complementarity and collaboration are opening, such as security, mobility, health, information management, cyber and space. In near future, research will focus on autonomous systems and their interaction with human workers in Cyber Physical Systems. Then, we need to develop new strategies and approaches for security issues. A promising area of development will be the integration of AI applications to execute cybersecurity tasks. Finally, R&D projects and programs will be centred on data fusion, to effectively harmonize the great amount of data obtainable near in real-time, and on high performance computing systems, such as Quantum Computing and Fog Computing, to process the data at a reasonable speed.

For next decade, the AI technologies will be the driving forces for future intelligent systems. How do you think European agencies and companies will deal with the ethical and legal aspects of using these technologies in Defence operations?

[Chiarello] We need an internationally shared regulation to deal with the ethical and legal aspects of Artificial Intelligent applications. It is essential to study the behaviour of the algorithm and the logical structure behind the model. The aim is having explainable and testable AI algorithms, to release a certification of the products and procedures. The reliability of AI technologies, particularly to the tactical edge, is strictly related to the FAIR principles for data management (findability, accessibility, interoperability, and reusability). Therefore, future generations of data scientists and machine learning specialists must be aware and apply strategies to mitigate the negative effects of the biases and develop data and AI trustworthiness certification procedure to ensure the robustness of methods and results.

The fast pace of technological evolution is radically changing the labour market. What the impact on skills and job profiles in the context of Defence?

[Chiarello] There is an urgent need of training programmes aligned with current and future technological requirements and a Qualification system based on the best practices in the European Defence industry. Design educational content for the workforce of the near future is essential to keep the pace of technological evolution, anticipating the trends and not just adapting to. Defence sector needs of managerial skills to ensure flexibility, and a collaborative management to promote the synergic integration across different industries. The high-speed and tangled technological development make multidisciplinary fundamental to manage changes and the unsteady direction of innovation mechanisms, together with the ability to collaborate will be key competences for emerging challenges. Finally, workers need analytical skills and cognitive capabilities to manage and process the data collected by the information systems, analysing and evaluating information for the situational awareness.

How can ASSETs+ address digital and transversal skills in the design of E&T Programmes?

[Fantoni] Beside the technical skills, ASSETs+ is also designing and developing courses and programs for data-driven projects and processes management. We have analysed the trend of the phenomenon in the scientific and grey literature, and it seems that there are relevant converging signals towards the figure of the data-driven project manager. This professional profile uses data and information of various types and formats to plan and monitor processes, support decision making, elaborate solutions for problems, and manage complex projects. This figure will be more and more important because we are moving from a single-objective design (typically the cost) to projects that aim to meet several objectives at the same time (i.e., innovation, sustainability, and efficiency). The ambidexterity therefore become a key capability to address in the design of E&T programs especially in the domain of Defence (and Aerospace) as a driving force in digital transformation.

Covid-19 pandemic accelerated the time for a reconstruction of the educational systems, pushing towards a faster digitalization of the service. What is the impact on the design of education and training activities?

[Fantoni] Covid-19 pandemic has pushed through a faster digitalization of education and online learning, causing a disruption in education systems. The traditional face-to-face lectures have inevitably moved online. This implied problems and difficulties in reproducing the same activities in digital environment. However, this situation also proved the feasibility of online training on large scale. New possibilities are opening, especially for reskilling and upskilling activities dedicated to current workers: they typically had to deal with time and location constrains in selecting and attending courses, while they can achieve much more flexibility and can access a lot of educational resources. Nowadays, educational institutions evaluate if the blended or distance mode can be adopted in each learning environment, while just

few years ago this possibility was just not considered. A big challenge for the the design of education and training activities concerns with the level of detail of the program. The largest e-learning providers usually provide fragmented courses, very focused on single topics or skills. Their offers lack broader courses and training activities, that provide a general overview on the connection among the addressed competences and knowledge. Indeed, these have always been carried out in face-to-face mode. But the experiences deriving from Covid-19 have shown that this learning experience can also be realized online. We need to constantly monitor the labor market to find the match between the needs of companies and the training offers and fill in the skills gaps of current and future workforce.

Defence is facing difficulties in attracting young students. What is the ASSETs+ strategy for this problem?

[Fantoni] European Defence industry is struggling in finding well-suited workers to ensure leadership, competitiveness, and sustainability in the medium- to long-term on the international panorama. In addition, young generations are not engaged in Defence issues and usually don't see careers in Defence as promising opportunity. Therefore, Defence companies should develop new strategies to attract and keep young talented workers. There are many prejudices about Defence activities, however this industry is always at the frontiers of innovation offering the more advanced technologies and a very international and multidisciplinary environment. We are working to explode the myths and biases around the Defence sector and are designing new courses and challenges able to attract students' attention. A concrete initiative implemented within ASSETs+ project is the European Defence Challenge (https://assets-plus.eu/challenge/), an open competition to attract young talent to the Defence industry and to encourage them to initiate a career in defence-related technologies. All undergraduate or graduate students from all faculties in European Universities, vocational education and training centres can participate with an essay of a given topic, based on the needs and the challenge of the Defence sector as resulted by the analysis of our project.

How to promote European collaborative upskilling and reskilling initiatives in response to the skills needs of the Defence industry?

[Fantoni] The fast technological evolution discussed above is even more challenging in an international perspective where the collaboration among different actors and stakeholders is fundamental to avoid duplication of efforts. We need new processes and mechanisms and common policies to smooth the collaboration across Defence and Civil sectors. It is important not only having advanced technologies, but above of highly skilled employees to use the advanced technologies and carry-on cutting-edge research. Our goal is to develop demand-led upskilling and reskilling training programmes on the cutting-edge technologies. The strong collaboration among the actors in our Consortium (that encompasses Defence Industry, sectoral organisations, HEIs, VET providers and research centres from 8 different EU countries) will contribute to strengthen coordination between government, industry, and education & training. We are working on developing a sustainable strategy for developing HR in the Defence Sector based on 6 pillars, namely qualifications, policies, project & funds, technologies, human resources, technical standards, and best practices.

INDUCTIVE POWER TRANSFER WITH MIMO TRANSMISSION

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Introduction on inductive power transfer

Inductive power transfer (IPT) [1] is a non-radiative type of energy transmission, where an AC driven coil induces electric voltage in another coil placed nearby. An IPT system can be seen as a transformer with steel core replaced by air or other dielectric material depending on where the system is deployed. IPT efficiency is sufficiently good in short transmission distance but it severely deteriorates with the transmission distance. Originally proposed by Nicola Tesla at the end of the 19th century, this technology only experiences primitive commercialization in late of the 20th century. IPT was used as contactless charger for toothbrush in 1981 by Panasonic Corporation, for an integrated card (IC) in 1995 by Sony Corporation, and for material handling robot in factories by Daifuku Corporation [2]. This technology starts to gain wide recognitions since the innovative invention on resonant inductive coupling introduced by a research group at MIT in 2007 [3]. The resonant

inductive coupling electrically resonates the coils at the signal frequency to drastically improves power transfer efficiency and/or the transmission distance. The resonance concept enables a wide range of IPT applications, including biomedical implants, portable electronic devices, factory automation and electric cars. Today, wireless charger for smartphones can be found in any shop or pre-installed in new cars on sale. Stationary wireless charger for electric car battery is being developed by many car manufacturers and expected to be released soon. Dynamic wireless charging infrastructures for moving electric cars [4] have been widely developed in Japan, Korea, New Zealand, the United States, and Europe.

Research and development (R&D) activities on IPT so far mostly focus on the single-input single-output topology where one transmitting coil sends wireless power to one receiving coil. The next R&D trends may include investigations on larger topologies for better utilization of this technology to bring about more conveniences to everyday life. Single-input multiple-output (SIMO) topology can be introduced in large transmitting coil structure to enable simultaneous charging of multiple devices. Multiple-input multiple-output (MIMO) topology can be exploited to improve the power transmission capacity and realize effective high-power wireless charging. In this article, we would like to briefly introduce our research activities regarding this these IPT topologies.

SIMO IPT with elongated transmitting coil

We are studying wireless charging for material handling robots in factory automation [5][6]. The design objective is to enlarge the coverage area of IPT so that the system can effectively charge the robots while they move from place to place in the factory. Enlarging the coverage area usually comes with concern about electromagnetic interference to other electronic devices as well as impacts to human body. Fortunately, this is not a critical problem in factory application as the IPT system will be deployed in a closed space. Also, the robots are usually programmed to move on determined route, thus possible misalignments between the transmitting apparatus and the receiving coils installed on the robots may not be a critical problem. Here, the important task is how to simplify the transmitting coil structure as much as possible to reduce the manufacturing and maintenance costs.

To this end, we are simply elongating the transmitting coil instead of installing many small coils in an array. Our proposed design is parallel line feeder in Fig. 1, which is in fact a two-wire transmission line driven in the MHz band. The novelty of our design is not the shape of the transmitting coil but its high operation frequency compared to those of typical IPT systems. When elongating the transmitting coil, the coupling coefficient between the transmitting coil and each receiving coil decreases significantly due to severe leaked magnetic flux stemming from the imbalance in the coil sizes. The major purpuse of increasing the operating frequency is to improve the Q-factors of the coils and compensate for the low coupling coefficient. This is because the Q-factors, to some extent, increases linearly with the operating frequency. Another purpose is to simplify and reduce size of the circuitry as required circuit elements become smaller in higher frequency ranges.

On the contrary, our system suffers from standing wave effect as the sizes of transmitting coil becomes significant to the wavelength of the power-carrying signal. For instance, if our system operates at an ISM band of 13.56 MHz the signal wavelength is about 22 m while the feeder should have a length of several tens of meters or longer when deployed in factories. To address this issue, we are currently studying a method of periodically inserting capacitors in the feeder to make it electrically short, resulting in stable output powers for the robots during their operation along the feeder [5][6]. The

remaining problem which usually arises in multiple receiver IPT system is the interaction among the receivers because they are coupling with each other via the feeder. During the charging process, load resistance at each receiver usually varies with time; and this variation changes the output voltages at the other receivers. To solve this problem, we employ a special resonant network consisting of an inductor and two capacitors, namely LCC circuit, at the transmitter side to stabilize the input current in the feeder, resulting in stable out voltages regardless of the load resistances.

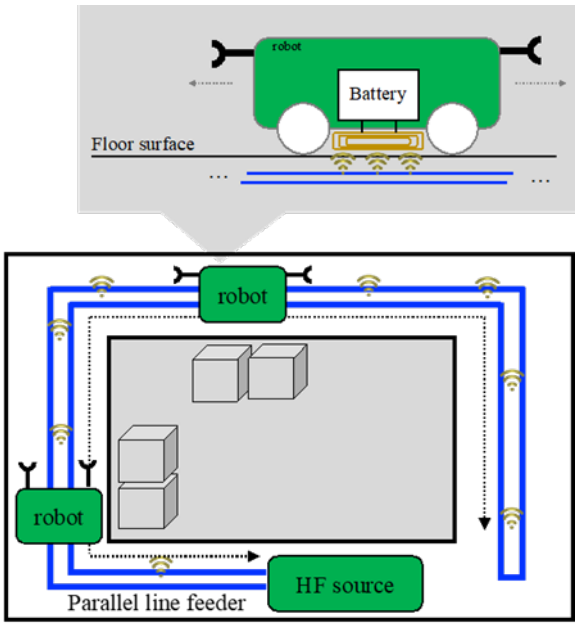


Fig. 1: SIMO IPT using parallel line feeder.

SIMO IPT using transmitting coil array

Another development direction is to realize an IPT system having large coverage area for simultaneous charging of portable devices, e.g., smartphones, table PCs, laptop PCS as shown in Figs. 2 and 3. This system would be installed on the surface of office tables or desks. As the system will be deployed nearby human body and many other communication devices, it should be sophisticatedly design to prevent leaked magnetic field as well as radiation to surrounding space. To this end, we employ a charging pad consisting of many small coils [7] instead of one enlarged transmitting coil as in the parallel line feeder system. An enlarged transmitting coil generates electromagnetic field over all the desk surface. Meanwhile, an array of many small coils is possible of effectively focusing magnetic flux towards the receiver locations by having each coil detect the receiver existence and activates when needed. Typically, a converter circuit is used to change the 50Hz/60Hz AC current to a DC, which then will be converted to higher frequency (kHz, MHz) signal to drive a coil. In implementing a large coil array system, power electronic redundancy becomes a critical problem because the numbers of converter and inverter circuits increase linearly with the number of the coils. To solve this problem, we are currently study a coil array system driven by a common RF feeder which needs only a pair of converter and inverter circuits [8] for activation.

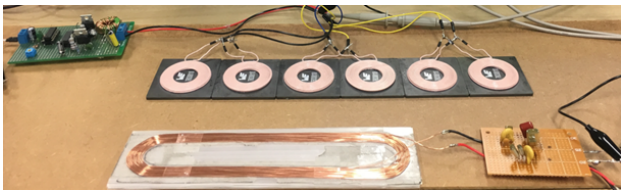


Fig. 2: IPT using coil array without a common RF feeder [7]

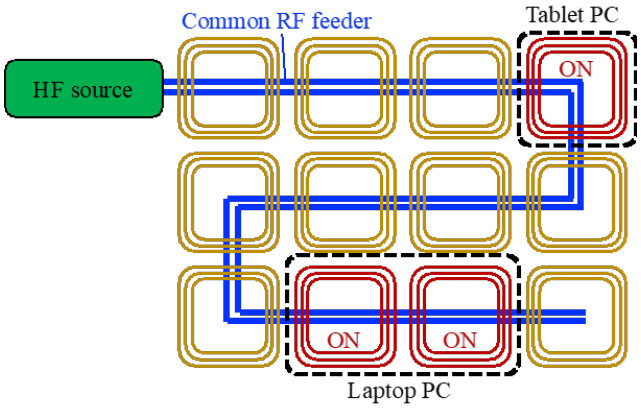
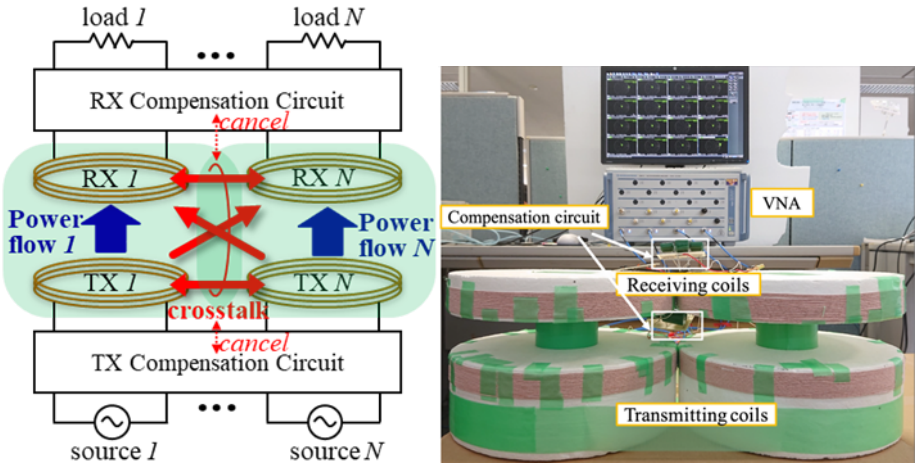


Fig. 3: SIMO IPT using transmitting coil array with common RF feeder

MIMO IPT for improving power transmission capacity

Researches on wireless charging are not only about efficiency and coverage but also about



(a)System model *(b) Experiments with 2x2 MIMO IPT [9]*

Fig. 4: MIMO-IPT for improving power transmission capacity

transferable power. As the power transmission capacity of SISO IPT is bound by physical limitations of materials of the coils and the current power electronic technologies, we are investigating the use of multiple-input multiple-output (MIMO) topology to simultaneously deliver a high power over N parallel flows. In the considered MIMO system in Fig. 4(a), the transmitter side uses a coil array of N elements, each of which is driven by an inverter circuit to deliver power to the receiving coil array having N elements at the receiver side. The MIMO configuration is expected to increase the power transmission capacity by about N times. But, with benefits come challenges. Due to space constraints, the element coils of each array are usually placed close to each other, resulting in inevitable mutual couplings among them. When the operation frequencies of the N inverters are set in the same frequency band to safe the frequency resource, crosstalk among the N power flows occurs and deteriorates the power increasing effect as well as the transfer efficiency. To address this problem, we are investigating compensation circuits for general MIMO-IPT system at any scale, placed in any arrangement and operates at any frequency. Our primitive study in [9] on 2×2 MIMO has shown that the solution effectively cancels the interference and achieves power flow isolation effect. Solution to the problem of N×M MIMO is currently developed and verified by experiments. Comprehensive results are expected to be published in the near future.

Summary

Since the groundbreaking invention of the MIT research group, R&D on the IPT technology has been undergoing a great progress and becomes promising in bring more conveniences to human life. In this article, we have briefly introduced our recent research activities focusing on MIMO transmissions for extending the coverage area, simplifying the power electronic as well as enhancing the power transmission capacity. Although still under development, our research activities will hopefully make contributions to the development of this important technique in the near future.

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