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SURF Application Form

Principal Applicant*	School	Department/ Division	Other Applicants, if any	Research Title
Kyeong Soo (Joseph) Kim	SAT	CAN	N/A	Scalable Representation of RSSIs for Multi-Building and Multi-Floor Indoor Localization Based on Deep Neural Networks

*Academic staff can be a Principal Supervisor on only one SURF project.

Abstract for Non-Specialists (100 words):

Since the SURF project titled "Indoor localization based on Wi-Fi fingerprinting with deep learning and fuzzy sets" in 2017, we have been investigating large-scale multi-building and multi-floor indoor localization based on a single dataset for received signal strength indicators (RSSIs) and deep neural network (DNN) models for the integrated estimation of building, floor, and location with focus on the scalability of a DNN model and its outputs. In this project, we focus on inputs to a DNN model and study the scalable representation of RSSIs for DNN-based large-scale multi-building and multi-floor indoor localization.

Research Question (Be concise)**:**

- **How can we represent in a scalable way large-dimensional RSSIs (e.g., 520-dimensional vectors in the UJIIndoorLoc database [1]) as inputs to a DNN model for multi-building and multi-floor indoor localization?**

- **What are best DNN architectures for scalable representation of RSSIs (e.g., time series representation)?**

Project Plan (350 words, please brief explicit identification/split work among the students for proposals with multiple students)**:**

We are to carry out this project with the following two work packages (WPs):

- **WP1: Scalable representation of RSSIs.**

  - **To investigate the statistical properties of the RSSIs in the UJIIndoorLoc database.**

  - **To investigate the representation of RSSI data with a smaller dimension.**

  - **To investigate the effects of truncating week RSSI measurements.**

- **WP2: DNN models for scalable representation of RSSIs.**

  - **To implement and evaluate the performance of indoor localization of DNN**

models based on various architectures for the proposed RSSI representation from WP1.

Research Methodology (350 words)**:**

Since the SURF project titled "Indoor localization based on Wi-Fi fingerprinting with deep learning and fuzzy sets" in 2017, we have been investigating large-scale indoor localization and trajectory estimation of mobile users/devices based on DNNs through research projects funded by RISGC, SURF, and KSF programmes of XJTLU [2]–[5]; the research outcomes of these projects have been published as journal and conference papers [6]–[13]

Throughout these projects, we have been working to address the very issue of scalability in large-scale indoor localization centred around the solutions based on a single dataset and DNN models for the integrated estimation of building, floor, and location. Specifically, we formulate the multi-building and multi-floor indoor localization problem as the multi-label classification in [7], instead of multi-class classification, in order to address the scalability issue resulting from one-hot encoding of output classes. In [12], we further reduce the number of outputs of a DNN model by using regression combined with quantization, which allows one output to represent multiple classes.

In this project, in addition to the issue of scalability related with DNN models and their outputs, we tackle the scalable representation of RSSIs for DNN-based large-scale indoor localization, too. RSSI is essential to indoor localization techniques based on Wi-Fi finger-printing [14]. In the context of large-scale indoor localization, i.e., under the multi-building and multi-floor environment like big shopping mall and university campuses where there are tens of multi-story buildings, the number of measured RSSIs from all access points (APs) can easily become 100s to 1000s.

Like the number of outputs, the number of inputs greatly affects the number of hyperparameters of a DNN model. Also, the transmission of raw RSSI data increase the security vulnerability. Therefore, the use of low-dimensional, pre-processed RSSI data

for scalable representation can reduce both the number of hyperparameters of a DNN model and the security vulnerability.

Our preliminary investigation of the statistical properties of the RSSIs in the UJIIndoorLoc database shows that only about 10% of 520 RSSI components are from real measurements and that the rest of the components just indicate lack of signals from the corresponding APs at a given measurement point. Considering the sparsity of 520-dimensional RSSI vectors, we focus on the real measurements (i.e., about 10% of the elements) and study how to represent them as efficient and meaningful input data for a DNN model for indoor localization. Our current candidate is time series representation of the real measurement RSSI data sorted based on their strengths. In this regard, we initially focus on DNN architectures best suited for time series classification including recurrent neural network (RNN) and convolutional neural network (CNN).

References

[1] J. Torres-Sospedra et al., "UJIIndoorLoc: A new multi-building and multi-floor database for WLAN fingerprint-based indoor localization problems," *Proc. International Conference on Indoor Positioning and Indoor Navigation (IPIN)*, Busan, Korea, Oct. 2014, pp. 261–270.

[2] Kyeong Soo Kim et al., "Feasibility assessment and roadmap for XJTLU campus information and visitor service system as a test bed for large-scale location-aware services in SIP," RISGC Seed Grant Programme 2016-2017 (under Grant RISGC-2017-4), XJTLU, Apr.–Aug. 2017. Project Home Page: http://kyeongsoo.github.io/research/projects/campus_information_services

[3] Kyeong Soo Kim and Sanghyuk Lee, "Indoor localisation based on Wi-Fi fingerprinting with fuzzy sets," *SURF-201739*, XJTLU, Jun. –Aug. 2017. Project Home Page: http://kyeongsoo.github.io/research/projects/indoor_localization/

[4] Kyeong Soo Kim and Sanghyuk Lee, "Trajectory estimation of mobile users/devices based on Wi-Fi fingerprinting and deep neural networks," *SURF-201830*, XJTLU, Jun. –Aug. 2018. Project Home Page: http://kyeongsoo.github.io/research/projects/trajectory_estimation/

[5] Kyeong Soo Kim et al., "Feasibility study of XJTLU campus-wide indoor localization system based on deep neural networks," Key Programme Special Fund (KSF)–Exploratory Research Programme (under Grant KSF-E-25), XJTLU, Jan. 2019–Dec./2021. Project Home Page: http://kyeongsoo.github.io/research/projects/xjtlu_indoor_localization/

[6] Kyeong Soo Kim, Ruihao Wang, Zhenghang Zhong, Zikun Tan, Haowei Song, Jaehoon Cha, and Sanghyuk Lee, "Large-scale location-aware services in access: Hierarchical building/floor classification and location estimation using Wi-Fi fingerprinting based on deep neural networks," *Proc. FOAN 2017*, Munich, Germany, Nov. 7, 2017.

[7] Kyeong Soo Kim, Sanghyuk Lee, and Kaizhu Huang "A scalable deep neural network architecture for multi-building and multi-floor indoor localization based on Wi-Fi fingerprinting," *Big Data Analytics*, vol. 3, no. 4, pp. 1–17, Apr. 2018.

[8] Kyeong Soo Kim, Ruihao Wang, Zhenghang Zhong, Zikun Tan, Haowei Song, Jaehoon Cha, and Sanghyuk Lee, "Large-scale location-aware services in access: Hierarchical building/floor

classification and location estimation using Wi-Fi fingerprinting based on deep neural networks," *(Extended version of the FOAN 2017 paper) Fiber and Integrated Optics*, vol. 37, no. 5, pp. 277–289, Apr. 10, 2018.

[9] Zhenghang Zhong, Zhe Tang, Xiangxing Li, Tiancheng Yuan, Yang, Wei Meng, Yuanyuan Zhang, Renzhi Sheng, Naomi Grant, Chongfeng Ling, Xintao Huan, Kyeong Soo Kim and Sanghyuk Lee, "XJTLUIndoorLoc: A new fingerprinting database for indoor localization and trajectory estimation based on Wi-Fi RSS and geomagnetic field," *Proc. CANDAR/GCA'18*, Hida Takayama, Japan, Sep. 2018.

[10] Kyeong Soo Kim, "Hybrid building/floor classification and location coordinates regression using a single-input and multi-output deep neural network for large-scale indoor localization based on Wi-Fi fingerprinting," *Proc. CANDAR/GCA'18*, Hida Takayama, Japan, Sep. 2018.

[11] Jaehoon Cha, Sanghyuk Lee, and Kyeong Soo Kim, "Automatic building and floor classification using two consecutive multi-layer perceptron," *Proc. ICCAS 2018*, Pyeongchang, Korea, Oct. 2018.

[12] Abdalla Elesawi and Kyeong Soo Kim, "Hierarchical multi-building and multi-floor indoor localization based on recurrent neural networks," *Proc. CANDARW 2021*, Matsue, Japan, Nov. 23-26, 2021.

[13] Zhe Tang, Sihao Li, Kyeong Soo Kim, and Jeremy Smith, "Multi-output Gaussian process-based data augmentation for multi-building and multi-floor indoor localization," *accepted for presentation at IEEE Fourth International Workshop on Data Driven Intelligence for Networks and Systems (DDINS) (organized in conjunction with IEEE ICC 2022)*, Mar. 7, 2022.

[14] P. Bahl and V. N. Padmanabhan, "RADAR: An in-building RF-based user location and tracking system," *Proc. 2000 IEEE INFOCOM*, vol. 2, 2000, pp. 775–784.

Anticipated Research Outcomes (200 words):

- **Scalable representation of RSSIs for DNN-based large-scale multi-building and multi-floor indoor localization.**

- **DNN models for the proposed scalable representation of RSSIs**

After completing the SURF project, we plan to submit papers summarising our research outcomes to academic conferences and/or journals.

Student Learning Outcomes and Benefits to Students (200 words):

- **Understand indoor localization based on Wi-Fi fingerprinting and DNNs.**
- **Understand Wi-Fi and Smartphone technology.**
- **Acquire an ability to carry out experiments and analyse the resulting data.**
- **Acquire deep learning programming skills based on Python programming language.**
- **Acquire experience of writing conference/journal papers.**

Statement of Staff Availability - including provisions for supervisor absences (100 words):

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Though the principal applicant will be available throughout the project, the two PhD students under his supervision will cover his absences just in case.

Please indicate below if you are willing to supervise a non-XJTLU international student (enrolled at a top 150 university) in your SURF project:

☒**Yes**

☐**No**

If 'Yes' is selected, your project will be open to applications from non-XJTLU international students. Details of such candidates expressing interest in your project will be passed on to you, during the student selection phase, to allow you to decide on their suitability.

Budget (adjustment might be needed after the fund allocation is determined)

Items	Cost (RMB)
Student Stipend **Please indicate the number of Student(s) in the project here: 6** (It is at the discretion decided of the Principal Supervisor whether and how much to pay students, and the maximum of a stipend is 2,500 RMB per student.)	**15,000**
Consumables and project related traveling (No more than 4,000 RMB per project in total – please provide justification). • **Smartphones for measuring Wi-Fi RSSIs.*** • **Storage expansion (e.g., SSD/HDD) and backup media for experimental data.**** * With models/brands different from those of the smartphones purchased from the past SURF projects (i.e., 201739 & 201830). ** For the engineering workstations from RISGC-2017-4 seed project and KSF-E-25 project.	**4,000**
TOTAL PROJECT COST	**19,000**

Ethical Implications of the Research Project

Will the proposed research involve human subjects, including data derived from human subjects?

☐**Yes**

☒**No**

If 'Yes', please complete the following section on Ethical Assessment of Staff Projects Involving Human Research.

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Ethical Assessment of Staff Projects Involving Human Research

(Tick 'Yes' or 'No' as appropriate)	Yes	No
All research participants are from non-vulnerable groups. Vulnerable groups include children, people with learning or communication disabilities, people in custody or people engaged in illegal activities.	☐	☐
All research participants are able to provide consent.	☐	☐
All participants will be recruited in China.	☐	☐
All participants take part in the study with their knowledge.	☐	☐
The study does not involve deliberately misleading the participants.	☐	☐
The study does not require discussion of sensitive topics that may cause distress or embarrassment to the participant. Sensitive topics may include death, significant illness, sexuality or religion.	☐	☐
The study does not require disclosure of criminal activity or child protection issues.	☐	☐
The study does not require the administration of drugs, or other substances to participants.	☐	☐
The study does not involve invasive, intrusive or potentially harmful procedures	☐	☐
The study does not involve the collection of samples (including blood, urine, sputum) or DNA from participants.	☐	☐
The study does not involve pain.	☐	☐
The study does not induce psychological stress or anxiety, or cause harm or negative consequences beyond the risks encountered in normal life.	☐	☐
The study will not involve prolonged or repetitive testing.	☐	☐
The study does not offer financial inducements to participants other than reasonable expenses and compensation for time.	☐	☐

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Supervisor's Declaration:

- The information in this form is accurate to the best of my knowledge and belief, and I take full responsibility for it.

- I have read and understand XJTLU's 'General Guidelines on Research' and 'Procedures for the Ethical Assessment of Postgraduate Projects Involving Human Research'.

- I understand that I am responsible for monitoring the research at all times.

- In the event of serious adverse events or breaches of protocol, I understand that I am responsible for immediately stopping the research and alerting the University Ethics Committee within 24 hours of the occurrence via ethics@xjtlu.edu.cn.

- I am aware of my responsibility to comply with the requirements of the law applicable to the research and relevant guidelines relating to security and confidentiality of personal data.

- I understand that research records and data may be subject to inspection for audit purposes.

- I understand that all conditions apply to students and personnel involved in the research, and that it is my responsibility to ensure that they abide by them.

- I understand that if I am not able to provide suitable supervision, the University has the right to withdraw all funding for the project.

Name of Principle Supervisor: Kyeong Soo (Joseph) Kim………………………… Date: 16/03/2002

CHECKLIST OF ENCLOSURES

Participant Information Sheet
Informed Consent Form

Incomplete submissions will not be accepted.