Research Statement

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Introduction

I am a computer scientist specializing in mobile computing, focusing on wireless networks, edge intelligence, Internet of Things (IoT), on-device AI, distributed learning, computer vision, drones, and robotics. My research aims to address significant research problems in the areas of unauthorized drone detection, crowd surveillance, next-generation wireless networks including the Internet of Things (IoT), and autonomous vehicles. This statement outlines my research background, current work, and future directions. Throughout my academic career, I have developed a strong foundation in these areas and have actively contributed to the fields through my research endeavors.

Past Research

I have demonstrated proficiency in conducting research in multidisciplinary areas in my previous research. Below, I am briefly describing these areas along with my specific contributions:

(i) **Crowd Analysis using Computer Vision:**
As part of my postdoctoral research at QMIC (2022-2024), I worked on visual crowd analysis, crowd counting and density estimation, and deep learning optimization for faster training and inference. I developed extremely lightweight CNN models suitable for deployment over resource-limited edge devices such as drones and stand-alone cameras. To improve the accuracy of shallow models and their generalization capabilities, I explored several approaches including self-operational neural networks (Self-ONNs) to replace CNNs, curriculum learning to replace standard training and dataset pruning to train on subsets of data. I proposed novel methods to boost the performance of DL models, leveraging dataset reduction, curriculum learning, generative adversarial networks (GANs), and knowledge distillation (KD) aiming to reduce the training time and improve model learning and generalization capabilities. I also developed proof of concept (PoC) prototypes on edge devices at a metro station during a football match. I used several tools during this research including PyTorch, OpenCV, NVIDIA Jetson edge devices, TensorRT, TensorFlow.

(ii) **Drone Detection:**
As part of my postdoctoral research at QMIC (2021-22), I developed experimental testbeds using RF, acoustic, and computer vision methods for accurate drone detection. I also developed an encryption-based sensor fusion (RF+vision) method for unauthorized drone detection in the presence of authorized drones in no-fly zones. I used several hardware and software tools including Raspberry Pi, E312 USRP, ReSpeaker microphone arrays, NVIDIA Jetson Xavier edge device, and PyTorch.

(iii) **Edge Computing:**
As part of my work as a postdoctoral researcher at Qatar University (2020-2021), I focused on the optimal resource allocation strategies in multi-access edge computing networks using mathematical optimization and machine learning. Our work named CODE (Computation Offloading in D2D Edge). I proposed collaboration among edge-server and end devices in the event of unprecedented load to minimize the end-to-end latency in video streaming services. The primary motivation of this work is to solve the "thundering herd" problem that occurs in live streaming of large events or when a video goes viral. The idea is to utilize the distributed resources of the end user devices using device-edge collaboration to alleviate the congestion on the edge server. I proposed an efficient model-splitting strategy for distributed inference in IoT networks. The intersection of ML/AI in mobile computing and networks has been interesting to me. Our collaborative work (named RL-CEALS) uses reinforcement learning (RL) for edge-assisted crowd-sourced live streaming. RL is used for resource sharing among edge servers to minimize the streaming delay, the bitrate mismatch, and the computational and bandwidth costs. I developed and used rigorous analytical models, computer simulations, and machine learning. I used various tools such as Python, TensorFlow, Scikit-learn, and cvxpy.

(iv) **Mobile Computing and Wireless Networks:**
In my Ph.D., I worked on device-to-device cooperative networks and self-organizing networks using integer programming and supervised learning. My works on enhanced P2P Group formation in Wi-Fi Direct, and extending Wi-Fi Direct to aerial communication between drones were significant contributions in the field. I also solved some very challenging problems i.e., throughput estimation, handover prediction, and AP selection in dense Wi-Fi networks using supervised machine learning. I used several tools including Matlab, Python, ns-3, Perl, Mininet, Mininet-Wifi, and Scikit-learn.

(v) **Transportation**
As part of my work as a graduate assistant at Qatar University (2014-2015), where I worked on several interesting problems including highway traffic congestion mitigation, ramp metering, and emergency vehicle signal preemption. I used traffic simulators (i.e., PTV VISSIM and Sumo), Matlab, Python, and Perl.

Current Research Work

My current research (2024-Present) is centered on connected and autonomous vehicles (CAVs). This involves the security of CAVs from sensor and network attacks. Specifically, I am working on intrusion detection systems (IDS) for in-vehicle networks (IVNs) and defense strategies against sensor attacks on AV cameras and LiDARs. The work will extend further to improve the efficiency and security of battery charging systems (BCS) for EVs and AVs.

Future Work

The intersection of AI, communication, and sensing has been a topic of significant interest with huge potential to solve real-world problems. In my future work, I will focus on self-supervised learning (SSL), federated learning (FL), and reinforcement learning (RL) for real-time learning and network configuration in 6G and IoT. However, I'm open to working on other interesting problems in other related areas. I am eager to delve deeper into my research interests, expand my expertise, and mentor aspiring researchers. I am confident that my dedication, interdisciplinary mindset, and strong research skills make me well-suited for the academic role of faculty and scientist/researcher position.

Looking forward, I plan to expand my research to the intersection of AI, communication, and sensing to solve real-world problems in several domains. Specifically, I am interested in:

(i) **AI in Communication:**
Resource allocation in 6G and IoT networks using deep reinforcement learning (DRL) for real-time and dynamic network configuration with potential integration with network slicing for reliable QoS delivery. Furthermore, investigates self-supervised learning (SSL) to learn from raw network data.

(ii) **On-device Learning:**
Exploring on-device learning, TinyML, and federated learning (FL) for edge devices and distributed computing use cases in vertical domains (networks, healthcare, smart cities, etc.)

(iii) **Autonomous Vehicles:**
Robust anomaly detection in in-vehicle networks (IVN) in real-time (frame-by-frame), securing AV from both physical and digital sensor attacks (e.g., cameras, LiDARs) using physics-inspired, consistency-based, and sensor-fusion methods.

(iv) **Neuromorphic Computing:** I'm eager to explore neuromorphic computing and spiking neural networks (SNNs) and their applications in computer vision. I'm also open to working on interesting problems in other related areas.

Conclusion

In conclusion, my research seeks to solve problems of significant impact in multi-disciplinary domains. I am committed to advancing the field of computer science, and artificial intelligence in the particular areas of my expertise through rigorous and innovative research. I am eager to expand my expertise and contribute to the academic and scientific community.

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