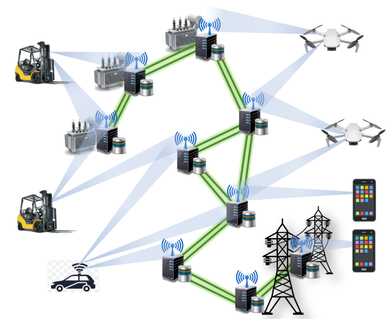
Phase I IUCRC Center for Smart Spaces Research

Executive Summary: Infrastructure-informed, Tiered Edge-Computing Architectures for Smart Spaces

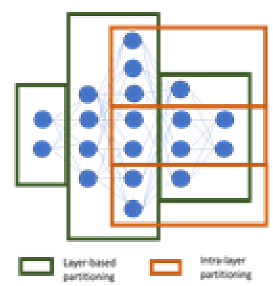
PIs: A. Ganguly (RIT) M. Levorato (UCI), M. Kuhl (RIT), A. Kwasinski (RIT), A. Rahmani (UCI), and N. Venkatasubramanian (UCI)

Introduction: We propose a design methodology for novel, multi-tiered edge-computing architecture for smart spaces. In the near future, several application areas such as autonomous material movers, unmanned aerial vehicles and infrastructure such as smart grids and smart healthcare will be in need of higher automation and data-driven decision-making. Driven by this need, edge computing servers will be deployed close to end users to provide computational support with low latency while reducing the energy demands on the mobile node. We envision a design methodology that will be informed by the specific infrastructure of the space and the requirements of performance, resource management, security and privacy and create the topology, interconnection network including communication protocols along with application and contextual data partitioning to achieve goals of the specific vertical.



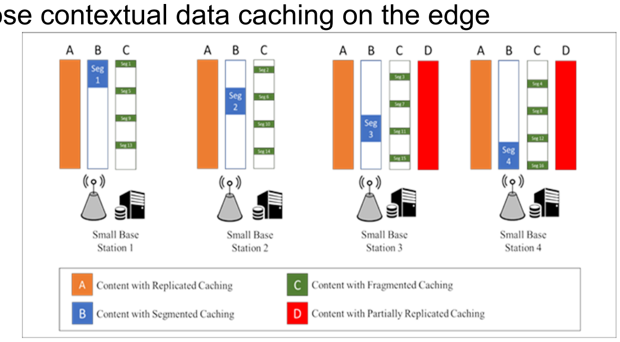
Approach: We will pursue the following research thrusts:

● We will create an event-driven simulator that will be capable of evaluating architectures in terms of latency, energy consumption and security by modeling the execution of applications distributed among the mobile nodes, communication latencies based on network connectivity and definitions of the edge servers while considering the impact of partitioning of applications such as Neural Networks as well as contextual data caches. This simulator will be validated using the HYDRA test-bed. This simulator will be used in an iterative approach using genetic algorithms (GA) to optimize composite metrics capturing all the design goals.



● As opposed to the common layer-based partitioning of Deep Neural Networks (DNNs) we propose to investigate intra-layer partitioning to preserve model privacy especially when deployed on mobile or edge nodes that are more vulnerable to physical compromise. We propose to split layers of DNN into segments and deploy multiple segments in different edge servers so that the entire model is not vulnerable if the server is compromised.

● Similar to the DNN model partitioning, we propose contextual data caching on the edge servers based on several policies achieving trade-offs between performance, Quality of Experience, reliability and security/privacy such as, duplication, interleaving and segmented. Segmented caching is analogous to the intra-layer DNN partitioning mentioned above.



The project is multi-disciplinary involving distributed computing, edge computing, networking and deep learning.

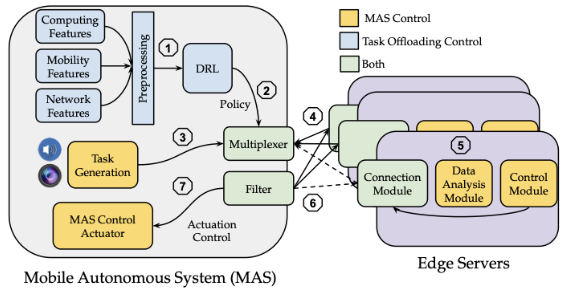
Timeline: **Year 1**: (i) define smart space/infra- structure specifications, (ii) define design goals measurement metrics, (iii) edge computing architecture design using the simulator iteratively with GA and (iv) validate the simulation tool with the HYDRA test-bed. **Years 2-5**: Evaluate DNN and context data partitioning algorithms for performance, energy and security goals and incorporate those into the simulator and validate solutions using the test-bed for known applications.

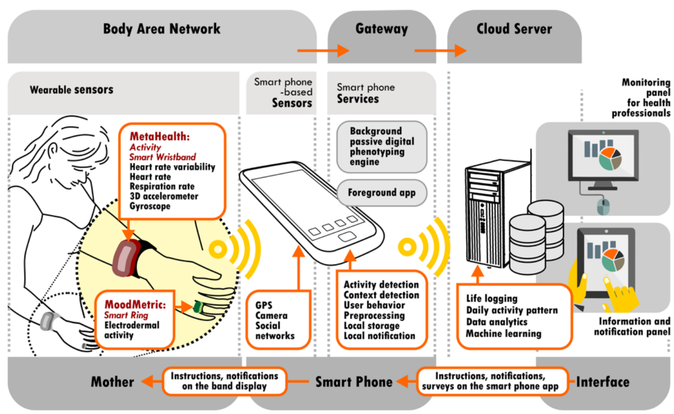
Phase I IUCRC Center for Smart Spaces Research

Executive Summary: Dynamic Neural Pipelines for Real-Time IoT Systems

PI: M. Levorato (UCI), A. Ganguly (RIT)

Introduction: Many modern applications require the real-time analysis of information-rich signals. The analysis algorithms often take the form of large Deep Neural Network (DNN) models with millions of parameters. Examples of such applications include vehicular autonomy, healthcare and augmented reality (for instance for remote work). The key challenge is that mobile devices and vehicles have limited computing, energy, and communication resources, so that the execution of large DNN models is often either unfeasible or impractical. A possible solution to this problem is to offload heavyweight computing tasks to external compute-capable edge servers. However, the latter strategy suffers from the impairments of the wireless channel, which can lead to undesirable large delays or high delay variance. The overarching objective of this project is to develop flexible AI-empowered flexible computing pipelines that dynamically adapt how information is processed to different operational and technological contexts. The core of the proposed solution is a flexible and modular middleware capable of directing individual computing tasks to internal and external computing resources (CPU, GPU, edge server) based on an AI-engine. We aim at developing proof of concept demonstrations for three key applications: 1) IoT healthcare; 2) lightweight autonomous vehicles, and 3) augmented reality and telepresence.





***Approach*:** The starting point of the project is the HyDRA platform developed by PI Levorato under grants from DARPA and NSF to enable flexible collaborative computing for autonomous aerial vehicles. We will expand the platform to enable dynamic selection of internal resources, as well as dynamic selection of DNN models to increase computing adaptivity and signal preprocessing to provide seamless support to a broad range of applications. We will develop lightweight predictive control logics taking as input crosslayer logging information to determine task routing. The proof of concept demonstrations will use the following resources available to the PIs: (i) the HyDRA 5G multi-drone testbed (to be extended to include Lidar capabilities and MU-MIMO communications); (ii) UNITE platform for the clinical-level monitoring, online active labeling and intervention maternal care applications.

***Timeline*:** **Year 1 deliverables: (i)** Middleware platform for the dynamic routing of tasks (CPU, GPU, Edge); **(ii)** Complete demo for the autonomous vehicles usecase; **(iii)** Proof of concept on datasets collected through the UNITE platform; **(iii)** preliminary characterization of AR devices and needs.

Long term vision: multimodal sensing; support to DNN partitioning; automated adaptation to applications/settings.

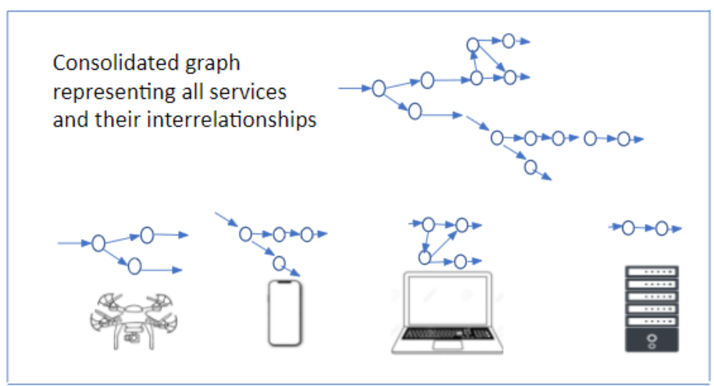
Phase I IUCRC Center for Smart Spaces Research

Executive Summary: Interoperability in Heterogeneous Smart Spaces

PIs: M. Kumar (RIT), N. Venkatasubramanian (UCI), I. D. Nunes (RIT)

Introduction: Heterogeneous devices often manufactured by disparate companies make interoperability a major challenge in smartspaces. User and application requests, as well as event-driven approaches, require support of multiple services in smartspaces. It is a complex task to dynamically combine available basic services to create application-/event-specific composite services, due to the heterogeneity of devices, protocols and software. This project aims to create a framework to identify devices, facilitate interoperability, and to mask unevenness among heterogeneity in smartspaces. Device resources are manifested as services and middleware algorithms make services available to users and applications. Integration and interoperability of services provided by in-situ devices, drones, and handhelds, on-the-fly has applications in real-time reconnaissance missions, surveillance, building construction, crisis assessment and management, supply-chain management and others.

Approach: A service depicting a resource can be abstracted as a node or a subgraph. Resources available in smart spaces are represented by service graphs, with nodes and links depicting services and relationships among them respectively. Mobility, connectivity, and residual energy of devices, and properties of services will be captured in weighted, attributed graphs. In addition, existing black-box services will be incorporated into service graphs. Essentially, the graph model allows employment of graph-theoretic algorithms to perform a variety of tasks, for example: identify most suitable services using graph search; find most appropriate compositions in a given situation using shortest path algorithms; alternative ways to compose services in the event of a failure or disconnection; explore syntactic extensions of graphs to meet user needs. In critical environments, services can be composed proactively, in anticipation.



Spatio-temporal reachability graphs developed by PI Kumar for opportunistic networks have the ability to abstract services and data that change with time and space, to find available paths for service compositions in dynamic smart spaces, including robotic, manufacturing, and/or UAV scenarios. Multi-level graphs, with bipartite connections can capture semantic and syntactic features of services. The framework's security and dependability demands assuring software integrity of devices implementing these services. To that end, attestation techniques will be incorporated to detect and remediate violations to service integrity.

Deliverables and Timeline: **Year 1 Deliverables**: (i) algorithms for device identification in homes, smart grid, and hospitals; (ii) service composition in UAV networks, smart grid, and hospitals; (iii) (i) and (ii) with attestation techniques. **Long term research/developments**: framework for seamless interaction and collaboration among heterogeneous components in opportunistic networks; Adaptive mechanisms to mask heterogeneity; Algorithms to detect useful patterns, detect events and make intelligent decisions to deploy services proactively; and incorporate security and privacy features into the framework.

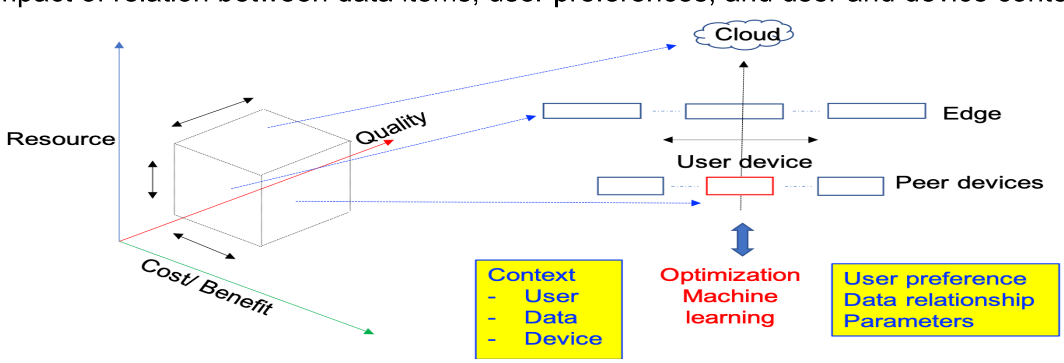
Phase I IUCRC Center for Smart Spaces Research

Executive Summary: Data Staging in Smart Environments

PIs: M. Kumar (RIT), N. Venkatasubramanian (UCI), M. Kwon (RIT)

Introduction: Remote participation saves time and cost in manufacturing, building construction, fire fighting, hospital at home, and others. Experts interact with colleagues/users remotely to provide feedback, comments, or advice. For example, time-/space- sensitive images of a spreading forest fire captured by a drone should be made available to personnel to enable timely actions. Time-/location-sensitive data generated at a user device may be staged in close vicinity to ensure privacy and ensure timely processing, whereas the cloud may be appropriate for delay tolerant applications with relaxed privacy constraints. Fire personnel, managers, remote experts, EMS, and civic authorities need access with varying levels of memory capacities and quality requirements. This is further exacerbated by mobilities of drones and personnel, and the dynamicities associated with data quality, cost and available resources. This project develops a framework for data staging under varying resource conditions and quality requirements, with an objective to satisfy cost/benefit constraints.

Approach: Location and time are critical to acquiring, distributing and processing data in smart spaces. Multi-parameter optimization methods, including integer programming will be investigated to identify what data is needed where, when, and in what form, under varying conditions of computing power, data size, communication bandwidth and memory/storage capacities. The second challenge is to develop techniques for data staging, subject to quality requirements and existing resources. Data staging takes into account: resources such as memory/disk size, available bandwidth, computing power; quality parameters such as latency, security, privacy, accuracy; and cost/benefits, to determine appropriate location for data in the hierarchical network spanning the user device, peer devices, edge devices and the cloud. Optimization mechanisms will be supplemented with machine learning algorithms to incorporate impact of relation between data items, user preferences, and user and device contexts.



Deliverables/Timeline: **Year 1 Deliverables:** (i) Multi-parameter optimization algorithms for caching data items at the user and peer devices; (ii) prototype testing with synthetic/data in smart hospital and forest fire situations. **Long term developments:** privacy-preserving data staging optimizations; machine learning algorithms to determine contexts (user, device and data) and relationships among data items; RDMA techniques for efficient data transfers; and algorithms incorporating opportunistic delay-tolerant connections. Prototype testing for specific application cases in healthcare, building construction, manufacturing, and smart grid.

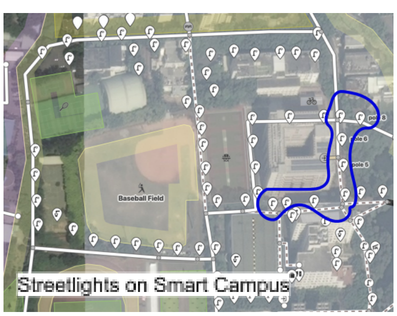
Phase I IUCRC Center for Smart Spaces Research

Executive Summary: Creating Digital Twin Toolkits for Smart Spaces

PIs: N. Venkatasubramanian (UCI), S. Mehrotra (UCI), M. Kumar (RIT), A. Ganguly (RIT)

Introduction: The design and deployment of flexible, resilient and sustainable infrastructure of the future requires an in-depth understanding of factors that influence its operation under diverse conditions. This project will systematically address the design and use of realistic and accurate digital twins (a digital representation of space/events and its evolution) at different phases of the smartspace lifecycle - from conceptualization and design to planning and deployment, to smartspace operation maintenance, and evaluation. Additionally, digital twins can be used to conduct long-term resilience and sustainability analysis of smart space design choices. A key component of creating such digital twins are accurate models and datasets that capture the geo-spatial attributes of the smart space and the evolution of events and activities over time. Often, real-world data is difficult to obtain due to the lack of fine-grained sensing; privacy/ security concerns also prevent the release and sharing of individual and spatial data across organizations. Digital twins offer the potential to examine design options at different granularity, from the smart building level to the smart city/community level. These design options can be used by stakeholders to (re)configure buildings for more efficient and sustainable operation. We argue that incorporating IoT as part of the planning process can revolutionize future urban communities - the observable smart spaces thus created can then be adapted as conditions and requirements change.

Approach: We propose to develop an integrated toolkit to create accurate digital representations of homes, buildings, public spaces and communities. These tools will allow us to plan and deploy system components while considering budget constraints and community needs. We highlight two prototypes: (i) *SmartSPEC* to create digital twins and synthetic datasets and (ii) *SmartParcels* to explore design options for infrastructure instrumentation. SmartSPEC incorporates a novel event-driven approach to generate digital twins using semantic aspects of a smartspace. The tool extracts a semantic model that represents the highly interrelated concepts of spaces, people, events and sensors. An input seed dataset captured by sensors is used to learn higher-level patterns with ML-based techniques, and extract knowledge of the embedded people and their activities. This is then used to generate synthetic data for complex scenarios that abides by physical and semantic constraints. Ultimately, this data can be utilized by different organizations to understand concerns associated with scalability of smart spaces, as well as reliable operation and sustainability. SmartParcels is a next-generation urban planning tool to enhance smart communities with IoT by generating a comprehensive and cost-effective plan. The methods used distinguish between the smartspace infrastructure layer (sensing, networking, and computing devices) and the associated information units (data and analytics) to realize a range of applications. The design considers applications, information/data, infrastructure, and geophysical layout as interdependent layers. Planners and decision makers can explore design options in a plug-and-play manner to explore trade-offs like cost optimality and sensing coverage. SmartParcels offers multiple design choices: *clean-slate* that designs communities from scratch, and *retrofit* to support reusability of existing infrastructure in design.



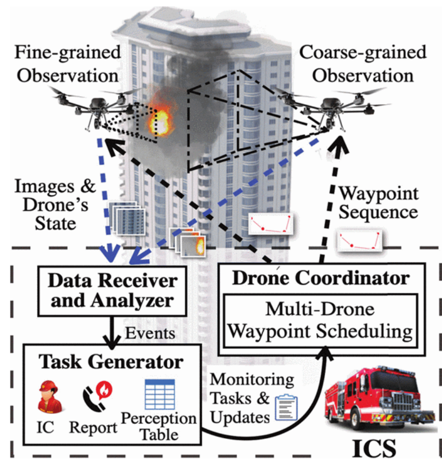
Deliverables and Timeline: **Year 1 Deliverables:** (i) Design of a synthetic public smartspace (e.g., high-rise) with simulated devices and data to model a complex activity (e.g evacuation) (ii) Case study to utilize integrated heterogeneous sensors, and activity information with existing building management data for green and sustainable buildings. **Long term vision:** Integrating model-driven and data-driven approaches with limited instrumentation for exploring resilience and adaptation in smart spaces under complex scenarios.

Phase I IUCRC Center for Smart Spaces Research

Executive Summary: Automated Drone Infrastructure Inspection

PIs: M. Levorato (UCI), N.Venkatasubramanian (UCI), A. Ganguly (RIT)

Introduction: The inspection of buildings and infrastructures often requires access to dangerous or impervious areas. For instance, even in simple roof inspection workers expose themselves to danger, while power lines may be placed in remote areas not even served by drivable roads. The objective of this project is that of developing and testing systems capable of automatically inspecting hardly accessible infrastructures with or without human assistance using autonomous aerial or ground vehicles. We will take as starting point the HyDRA platform and testbed developed by PI Levorato - which includes several autonomous Unmanned Aerial and Ground Vehicles (UAV and UGV), and relevant recent projects from PI Venkatasubramanian on wildfire inspection using drones.



Approach: At the core of the envisioned applications are computer vision pipelines transforming visual input from onboard cameras into control actions for the autonomous platform, both in terms of navigation and application-level decisions. The drones will be capable of taking a series of pictures autonomously optimizing coverage of the whole infrastructure and details of detected issues. We will develop proof of concept demonstration in the two applications mentioned above. In roof inspection, the human operator will select a building or a portion of a building to become the focus of the drone inspection, which will deploy autonomously. In power line inspection, the drone will autonomously follow the lines, taking pictures capturing the whole structure, while focusing on critical areas. Drone navigation, position and time of image capture are critical.At a conceptual level, the main challenges are the extreme constraints of these platforms in terms of energy reservoir, computing power, and communication capabilities. We will explore approaches to reduce the computational complexity of the whole sensing-to-control pipeline, not only using ideas from model compression, but also using modern techniques stemming from dynamic neural networks, such as early exit, to eliminate unnecessary onboard execution. However, memory constraints make such an approach challenging, and we will strive to find innovative solutions minimizing overall resource usage.

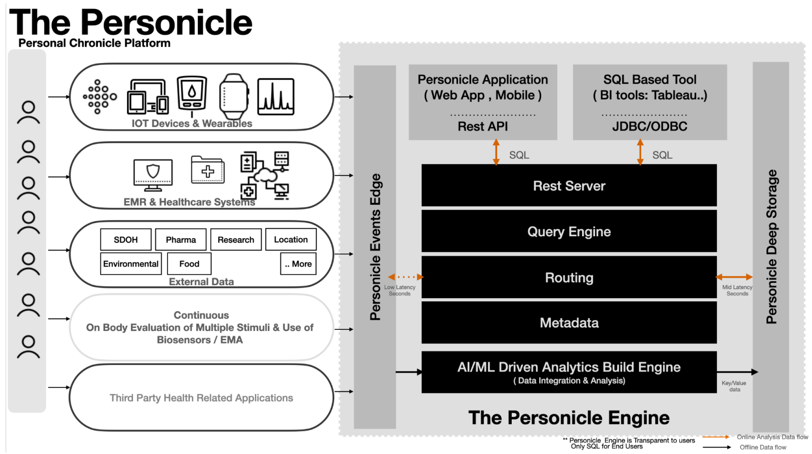
Timeline: **Year 1 deliverables: (i)** development of middleware connecting image capture to navigation and application control; **(ii)** fine-tuning of the HyDRA navigation software suite to application specific navigation needs; **(iii)** proof of concept of the roof inspection application; **(iv)** proof of concept demonstration of power line application in a simulated environment.

Long term vision: Future efforts beyond the first year will focus on the development of a universal application platform, where the operator can define specific mission targets across different application scenarios. Conceptually, the key challenge is the rapid adaptation of the pipelines to different domains and targets while minimizing model complexity. The tools developed can be extended to other application areas, such as detection/mitigation of forest fires or any other crisis scenario.

Phase I IUCRC Center for Smart Spaces Research

Executive Summary: The Personicle: Personal Chronicle Platform

PIs: A. Rahmani (UCI), R. Jain (UCI), N. Venkatasubramanian (UCI), C. Homan (RIT)



Introduction: Personicle is a personal chronicle of one's lifestyle, health, social, environmental, and other events alongside all associated information and data for a person. Personicle is a time-indexed database of events and their attributes for a person. Earlier versions of such systems with limited applications and scopes have been called lifelog and digital twins. A Personicle System, however, is a collection of Personicles available for the benefit of a population or society. Better disease models could be built for sub-populations by aggregating individuals in a population that share certain individual attributes. Thus, many different population groups may be studied based on appropriate collection of individuals. This has become especially important given the power of technology allowing for the personalization of medical interventions and management. The overarching objective of this project is to develop Personicle, a person-centric healthcare data platform that registers Individual events of lifestyle, health, social, environmental, and other related events to provide highly personalized and preventive health insights in real time. The platform offers services such as interactive event mining, scalable and agile event repository and processing, automated lifelogging and activity recognition for behavioral studies, and data visualization and dashboards for different stakeholders. These services will be used to build individuals' models for understanding the underlying causes for various health outcomes: such as what caused the food allergy, or what resulted in major emotional upset. Such a model combined with their current situation(s), may help in the prediction of future situations as well as ways to prevent those situations.

Approach: This project will build on top of the existing collaboration between the PIs and industrial partners (e.g., ClearSense and Xavor) as part of the open-source Personicle project. In this IUCRC project, we will i) expand the Personicle platform to be able to support data integration from more diverse set of devices such as home robots, environmental sensors, etc. to better capture the contextual and environmental factors, ii) provide interoperability to interface with clinical EHR systems by implementing Fast Healthcare Interoperability Resources (FHIR) standard APIs, iii) address security and privacy challenges involved in this process, iv) integrate event mining capabilities to build personal models (digital twins), and v) test the platform in the other related projects in the center for iterative enhancements.

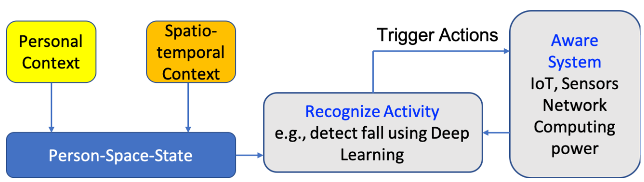
Timeline: **Year 1 deliverables:** Complete demo with the ability to **(i)** ingest data from home robots (e.g., Xavor's CareCompanion Robot) and a set of environmental sensors, and **(ii)** integrate FHIR interfaces for data export and import. **(iii)** Prepare a report on privacy and security challenges and requirements of the platform. **Long term vision:** Holistic data integration (e.g., exposome, food, genomics, etc.); offering robust and secure services while offering interoperability and privacy; full integration of event mining and personal model building services.

Phase I IUCRC Center for Smart Spaces Research

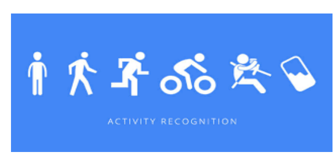
Executive Summary: Robust Infrastructure for Activity Recognition and Awareness

PIs: N. Venkatasubramanian (UCI), A. Rahmani (UCI), M. Kumar (RIT), L. Wang (RIT)

Executive Summary: Recognizing human activities and building systems with a sense of *awareness* is a challenge to creating everyday smart spaces - homes, offices, hospitals, classrooms, etc. The IoT revolution has provided a promising opportunity to build powerful perpetual sensing to recognize activities, characterized by continuous monitoring of spaces, people and events; they are essential to many safety and mission- critical applications, e.g. assisted living, healthcare and public safety. Broadly, human activities may comprise one or more basic forms: sequential, concurrent or interleaved; one person or multiple persons; and with or without technology. Activity recognition combined with data related to location, time, and mobility, leads to awareness. Heterogeneous devices generate data that may be communicated, processed locally onsite or at a remote server/cloud to create information and knowledge for applications. Many end-to-end challenges arise due to perpetual operation including system reliability, residual energy on device, communication disruptions, security and privacy issues, and increased processing overhead for multimodal data (e.g video and acoustic processing). An added challenge is that different applications require data at different levels of quality; e.g. fall detection applications utilizing diverse multi-modal sensory data such as tri-axis accelerometers, video image data deliver different fall detection accuracy levels. Sensor data processing algorithms vary in complexity and consume significant resources. In this project, we utilize our experience in past projects (SCALE, SAFER, CAREDEX) to address challenges in the creation of a robust sensing, communication and computation infrastructure for activity recognition and awareness.



Approach: In our work, we will explore the use of the application, individual, and space semantics (abstracted as personal-space-states) to extract events and trigger actions. We observed that different awareness applications require different levels of - (i) data quality, (ii) communication bandwidth, (iii) computing power, (iv) privacy and (v) accuracy. For example, different fall detection applications utilize diverse multi-modal sensory data such as tri-axis accelerometer, video image data, thermal camera, RF signals, etc. We can capture data with different sensors, including ambient sensors, acoustic sensors, visual sensors, etc. Different sensors capture data at different levels of quality and have different coverage. For example, visual sensors usually have higher accuracy, but they might have a narrow field of view and invade people's privacy. Different types of Machine Learning and Deep Learning Algorithms yield different accuracies. Resources consumed for sensing, computation, and communication vary based on the desired quality. We model quality tolerances as "space-states" and intelligently leverage the dynamic space-states to select and provision resources (access networks, device capabilities, processing location) to reduce energy and processing overhead while preserving desired privacy levels and ensuring application quality. We model diverse needs of people as "personal-space-states" and leverage the dynamic workload to reduce processing overhead while ensuring an efficient perpetual aware system. The context information will drive an AI-based approach for sensor activations, messaging, and compute processing to enhance system lifetime without loss of application quality/accuracy.



Deliverables and Timeline: **Year 1 Deliverables:** (i) Gather and analyze healthcare datasets (e.g. from UCI collaboratory) (ii) Model space-state design algorithms (iii) Validate with use cases from real-world assisted living smarthomes with multiple personal and in-situ devices for a target services, e..g elderly fall detection. ***Long-term vision:*** Through detailed testbed measurements and complex scenarios, understand deployment and operation challenges. Provision set of services and system settings including device, systems and network failures, and address privacy issues. The project will culminate in the creation of (a) aware classrooms in K-12 schools for students needing special assistance and (b) aware hospital waiting rooms, by deploying necessary infrastructure and software services.

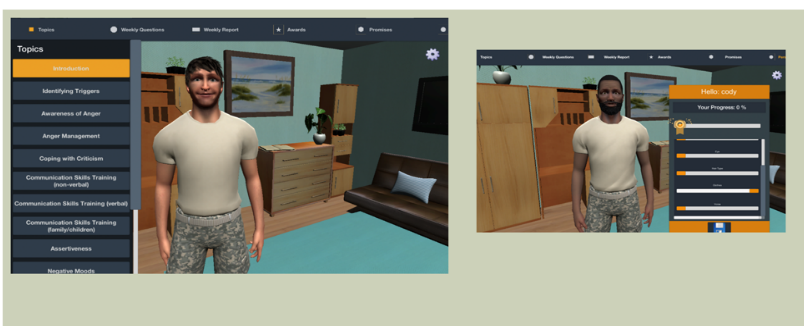
Phase I IUCRC Center for Smart Spaces Research

Executive Summary: Integrated At-Home Physical and Mental Health

PIs: Linwei Wang (RIT), Caroline Easton (RIT), Chris Homan (RIT), Amir Rahmani (UCI), N. Venkatasubrmanian (UCI)

Introduction: Approximately 75% of the total health expenditures in this country comes from managing chronic illnesses such as heart diseases, diabetes, and cancer. An estimated one-third of people living with these chronic illnesses also experience symptoms of mental health disorders such as depression. The current practice of health care, however, falls short of addressing the increasing societal burden of chronic conditions: its heavy reliance on intermittent clinic visits resulting in limited and disparate access to care, and the separate management of physical and mental health. The proposed research envisions a future of integrated at-home health where a person's needs of interventions – both physical and mental – are continuously monitored, quantitatively assessed, and timely addressed outside clinics.

Approach: This research investigates an at-home digital intervention platform for triggering and delivering mental health and behavioral interventions to individuals living with chronic conditions. This will be built upon PI Easton's pioneering work in RITch®CBT, a user-friendly downloadable digital interactive therapy platform that uses a human avatar to deliver rigorous therapy outside clinical environments (see Fig). The platform is currently equipped with evidence-based cognitive behavioral therapy for substance use intervention, with rule-based intervention design. In this project, we will extend the capacity of this platform in two major directions: 1) we will enhance the platform with abilities to personalize the intervention (*e.g.,* doze and content) to meet a person's need, utilizing facial and voice data collected from the individual as they interact with the platform along with other wearable and social media data available from other sources; and 2) we will extend the intervention capacity of the platform to include interventions for mental health needs *(e.g.,* depression and anxiety) and behavioral (*e.g.,* medical adherence and physical activity) interventions. The first direction will be led by PI Wang and focuses on advanced ML/DL developments for forecasting health decomposition and counterfactual intervention reasoning. The second direction will be led by PI Easton focusing on designing and integrating evidence-based therapeutic modules.



Deliverables/Timeline: In the first year, we will enhance the functionality of the current RITch®CBT platform to enable collection of facial and voice data, integrated with other home monitoring data from other sources. In years 2-3, we will focus on machine/deep learning developments and extending the intervention capacity of the platform in parallel. In years 4-5, we will carry out a feasibility human study to test the efficacy of the proposed at-home health systems in improving the medical outcome (both physical and mental health) and quality of life for individuals living with chronic conditions.

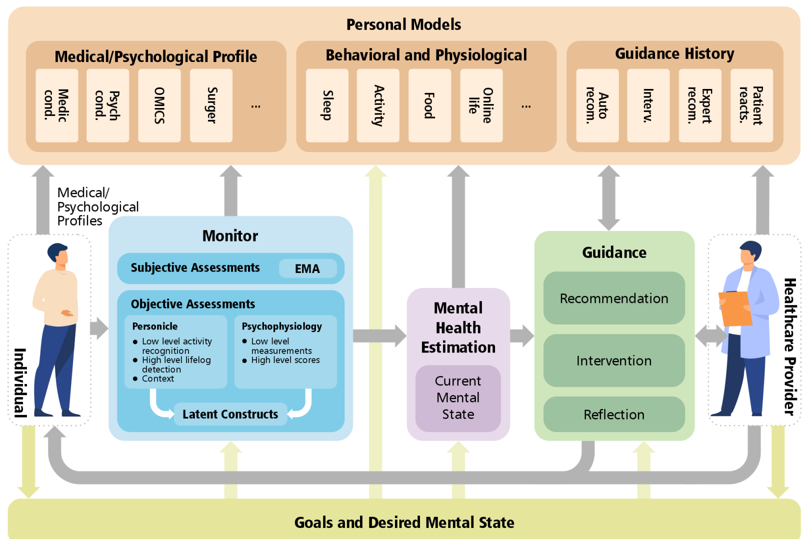
Phase I IUCRC Center for Smart Spaces Research

Smart Spaces for Behavioral Health

PIs: A. Rahmani (UCI), N. Dutt (UCI), J. Borelli (UCI), N. Venkatasubrmanian (UCI), M. Pinto (UCI) C. Easton (RIT), L. Wang (RIT)

Executive Summary

Existing digital behavioral and mental healthcare solutions commonly take on a reactive approach, requiring individuals to self-monitor and document symptoms. Recognizing the need for more comprehensive, objective monitoring and that each individual may benefit from personally tailored treatment, we present the notion of Personalized Mental Health Navigation (MHN): a cybernetic goal-based system that deploys a continuous cyclic loop of monitoring, estimation, and guidance to steer the individual towards mental flourishing.



The overarching objective of this project is to develop different components required for realizing the notion of MHN at behavioral health centers. In particular, we will implement services for objective mental health assessment (the Monitor component in the figure) where a multimodal stream of subjective and objective information (e.g., behavioral, affective, social medial, and user self-reported data) is collected from an individual to better understand his/her/their current mental state, context, lifestyle, and behaviors. Using AI and the Internet of Things (IoT) technologies for capturing experiences in real-time, we will leverage an individual's subjective experiences, behavioral and physiological experiences, and contextual situations to further understand phenomena that are difficult to capture (i.e., latent constructs such as loneliness or depression).

Approach

This project will build upon the existing collaboration between the PIs and behavioral health facilities in California and Georgia, and will focus on supporting adolescents struggling with emotional regulation as the case study. Emotion regulation skills are critical for adaptation to stressful life events and are particularly important in adolescence, as it is traditionally a time of emotional volatility. Changes in daily activity and physiology have been shown to correspond with fluctuations in one's emotional experience. We will use sensors in smart spaces (e.g., cameras, companion robots) and wearables (e.g., smart rings and watches), and mobile applications to continuously capture and create a record of one's daily activities and psychophysiological responses (e.g., resting heart rate, heart rate variability). Data captured by these devices will be used to build models to describe patterns of behavior and physiological responses as they relate to adolescents' emotional experiences. Identification, monitoring, and intervention to help adolescents improve emotional regulation in real-time, as they become dysregulated, is predicated on our ability to characterize these patterns of adolescents' emotional experiences. The team has already obtained IRB approval to conduct a small-scale human study in a behavioral health facility.

Timeline

Year 1 deliverables: **(i)** The first demo of the Monitor module for objective mental health assessment. (ii) A deidentified multi-modal dataset of mental health-related measurements, (iii) A data processing and machine learning pipeline for objective mental health assessment.
Long-term vision: The complete realization of the MHN as a goal-based closed-loop guidance system.

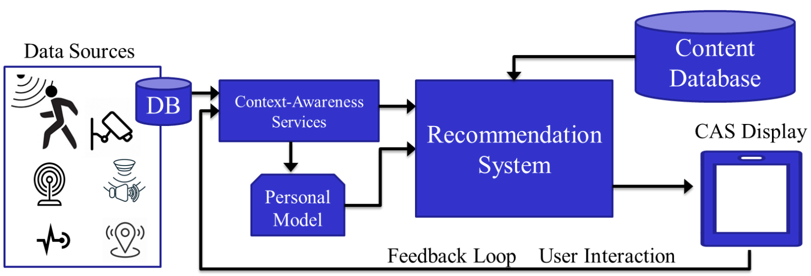
Phase I IUCRC Center for Smart Spaces Research

Executive Summary: Context-aware Data Rendering for Smart Spaces

PIs: S. Gago-Masague (UCI), N. Venkatasubramanian (UCI), M. Kumar (RIT), A. Ganguly (RIT)

Introduction: The widespread availability of computing devices and sensing capabilities enables the creation of innovative ways for data rendering including visual, audio and tactile, which may also include new delivery platforms such as virtual reality (VR) and augmented reality (AR). The type and amount of content given and its shape, regardless of the delivery platform, have generally been predefined and constant for specific applications. There are a variety of applications where the type of content, as well as the form of that content, must dynamically adapt to meet the needs of a certain user or event. This is especially true when it comes to communicating actionable and relevant information in a timely and effective manner. We propose implementing context-aware user interfaces that can identify and adapt to the needs of specific users, including persons with special needs, and settings to offer the appropriate information at the right time and in the right form using real-time sensing and artificial intelligence.

Approach: Previous research has emphasized the need for deploying real-time sensing-based context and context-awareness services (CAS), as well as artificial intelligence-based recommendation engines (RE). In general, this project focuses on prototyping (a) context-aware computing models, which focus on identifying user, location, time, and activity based on a variety of sources of information such as internet services, local cameras and sensors, and (b) recommendation engines that can use CAS to adapt the content and form of information to display in any given situation.This includes the creation of databases that RE can utilize to rank information in certain domains or applications based on CAS, such as personalized food menus, interactive instructions in worker training, guidance of person with special needs, autonomous car driving assistance, and building emergency response and evacuation. In the design of these proposed systems, neighboring applications in the internet of things, crowdsensing, and computer vision may play a critical role. Their efficiency, scalability, integrability, privacy, and security should all be given special consideration.



Deliverables/Timeline During the first year, the primary focus will be on prototyping computing models that will leverage sensing data to create CAS in a specific area. Testing and implementation of learning algorithms to determine context, including user recognition in the specified domain, application, or space, will be part of this. We also want to create the schema and underlying data structures needed to populate databases with the specific content for that domain. During the second year, we will focus on designing and prototyping RE to rank information for the study case based on CAS, linking all modules, and testing the entire system with traditional displays. During the next three years, we plan to generalize the project findings to other domains, as well as evaluate user interaction and usability of the proposed platform and asses alternative delivery platforms, such as AR and VR.