TITLE: LOGISTICAL ARTIFICIAL HOMEOSTASIS - Software-Based Artificial Homeostasis Controller to Maintain Integrity of Logistical Networks

CRITICAL TECHNOLOGY AREA(S):: Trusted AI and Autonomy, Advanced Computing and Software

OBJECTIVE: Develop a software-based artificial homeostatic controller to optimize and maintain the integrity of logistical networks. The artificially intelligent agent identifies critical nodes, network features and constraints, and provides prescriptions for improving network availability and reliability. The agent performs its work on the basis of an internal balance of learned synthetic drives derived from gradients calculated from network features per available sensor modalities. Prescriptions can be integrated with existing digital network infrastructure via purpose-built adapters or application programing interfaces.

DESCRIPTION:

In recent years, numerous world events have exposed the vulnerability of modern logistical networks to both endogenous and exogenous disruption. Simultaneously, the promise of highly digitized and connected devices from the factory floor, to the warehouse, and final-mile delivery have begun to deliver increasing volumes of digital signals. Smart inventory management and tracking systems can make use of simple digital-physical tracking, which at minimum include bar codes. Through implementing user-centered approaches proven with vaccine distribution supply chain systems, software-based homeostatic controllers can manage the largely siloed available information isolated among distinct systems, formats, and vendors.

The rise of flexible deep learning systems with multi-modal input and output owing to internal attention mechanisms has the potential to integrate and streamline interoperability between the myriad sources and formats of available logistical traces. Logistics systems that apply digital twins can augment the data processing pipeline and inform stakeholders while also tracking mission critical materials effectively. Sophisticated multi-modal models of logistical systems are capable of responding appropriately given a wide range of available sensor-derived features through the use of artificial intelligence and machine learning techniques. These systems are also capable of automatically learning constraints from historical and open data sources for informing the analysis and prescriptions of decision-making systems.

The central goal is to develop a framework and prototype for supply chain optimization as an instance of artificial homeostasis. Integrating data across systems to improve resilience in supply chains can provide mission critical capabilities for US defense and civilian priorities.

Critical success factors for supply chains include availability, reliability, scalability, and predictability. Supply chain features include functional redundancy, cost efficiency, mission efficacy, transparency for stakeholders, high availability, cost effective utilization rates, and adaptability. In operational environments, statistical analysis of the distance between key locations, geographic obstacles and bottlenecks, and the spatial relationship between industry and deployment factor into the success of the logistic network. Key production cities and locations are important considerations. Algorithmic approaches can represent the size of the production zone, the surrounding supporting logistical network infrastructure, the pre-existing facilities inclusive to the geographic zone, and the specialized labor and industries supporting the entire supply chain. Adequate supply chain oversight and control addresses concerns including resiliency to adverse events. Predictive algorithms can ameliorate single points of failure and realign primary path times to provide predictable average path times, low overhead, rapid scalability, repeatability, and quality assurance.

PHASE I: Develop a general format-invariant framework for handling logistical data and for providing analyses and prescriptions. Execute a study of appropriate data processing, feature extraction, and network architecture. Deliver a proof-of-concept algorithmic artificial intelligent decision-making system that makes prescriptions, adjustments, or recommendations to improve network resilience and availability. Initial system-level capabilities include identifying key nodes in targeted supply chains, offering diagnosis of constraints and limiting factors, and prescriptions for possible operational adjustments. Phase I will include developing technical documentation and design specification for a more general platform-independent (i.e., containerized) prototype to be developed in Phase II.

PHASE II: Develop a prototype platform-independent and format-invariant logistical model capable of integrating with existing industry-standard application programming interfaces to accept input from deployed sensors and digital signatures. Develop an approach to provide additional software interfaces output from the model inclusive of web-based application programming interfaces.

PHASE III: Deploy the model to production environments to enable government and commercial operations. Demonstrate real-time fine-tuning and automated responses to adapt to concept drift. Demonstrate decreases of logistical costs in terms of key performance indicators inclusive of time, money, personnel, or equipment. Demonstrate increase of uptime and reliability of system-equipped networks.

KEYWORDS: Digital Twin; Simulation; Logistics; Artificial Homeostasis; Network Infrastructure; Critical Success Factor; Recommendation System; Artificial Intelligence/Machine Learning; Deep Learning

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