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THREE TIER INCREMENTAL APPROACH TO DEVELOPMENT OF SMART CORRIDOR DIGITAL TWIN

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ABSTRACT

In the development of smart corridor traffic operations applications that utilize real time traffic and infrastructure data, a digital twin can be a crucial testbed. However, the development of such a digital twin test bed requires the integration of several dynamic components. Existing literature lacks the framework for such a development effort. This effort seek to address this shortfall. Along with needed data investigations, this effort presents a three-tiered incremental framework to digital twin development: 1) development of a prepopulated historic data driven model, 2) development of a pseudo digital twin architecture, and 3) development of a real time data driven digital twin. The three-tiered approach provides guidelines to develop different "mock" digital twin platforms, enabling the execution of multiple trials in faster simulation environments and incremental digital twin architecture updates.

1 INTRODUCTION

This study provides a three-tier incremental framework for development of a real time smart/connected arterial corridor digital twin. With ongoing advancements in emerging technologies, sensors, communications, and computing performance, deployment of these technologies in smart corridors is rapidly increasing in cities across the US and the world. One application that leverages high resolution high frequency data from smart corridors is real time data driven traffic simulation models or digital twins. Digital twin simulations can provide traffic and environmental performance estimates of a corridor at a near real time rate (Saroj et al. 2018). Moreover, these models are also used as testbeds to develop algorithms that improve mobility or traffic operations, such as signal timing optimization, variable speed limits, etc. Development of a digital twin architecture requires development of four key modules: (1) Real-Time Raw Data Processing Module, (2) Dynamic Data-Driven Traffic Simulation Module, (3) Data Request Transaction Management Module, and finally (4) Dynamic Performance Metric Evaluation and Visualization Module, as described in a previous effort (Saroj et al. 2021).

The development and synchronization of these multiple functionalities makes digital twin architecture development a time consuming and effort intensive process. Based on previous efforts, two major challenges in the development of a digital twin are: 1) lack of existing standardized guidelines or frameworks for digital twin architecture development that consider the range of potential intersection layouts, traffic flow pattern, and data stream attributes, and 2) practical data issues in real time field data streams, such as data gaps (Saroj et al. 2022), data latencies, lack of standard data definitions, incorrect data, etc. Based on experiences from the development of a digital twin for the North Avenue Smart Corridor in Atlanta, GA (Saroj et al. 2021) and the Martin Luther King Smart Corridor, Chattanooga, TN, this effort provides a three tier incremental framework for development of digital twins, along with key guidelines for necessary data investigations.

2 THREE TIER INCREMENTAL APPROACH TO DIGITAL TWIN DEVELOPMENT

The three-tiered approach facilitates conducting multiple trials in faster and simpler simulation environments while developing the digital twin model architecture incrementally. In comparison, in a direct approach, where the first or pilot model is driven using real time data streams, multiple potential error and modeling challenges become confounded, greatly increasing the complexity in creating a valid model. In addition, a real-time field-data driven digital twin is often inefficient as a testbed/platform for algorithm development or model validation and calibration.

Tier 1 - Development of Base Simulation Model Prepopulated with Historic Data: In this tier, an offline simulation model is populated with static historic data; one-minute volume, ten-minute aggregate turn movement ratio data, and preset signal control plans in this example. This model enables faster than real-time simulation, allowing for base model calibration and validation, as well as serves as an algorithm development platform.

Tier 2 – Development of Pseudo Digital Twin: This tier develops the architecture to drive the model dynamically using historic data, streamed into the model in the same formats as the real-time data. This effort develops the majority of the dynamic links between the digital twin modules, addressing time synchronization and dynamic data link issues. This platform enables repeatable experiments using pseudo real time data streams.

Tier 3 – Development of Digital Twin: This tier integrates real-time streaming field data into the architecture and drives the digital twin model using the real-time data. The key updates in this tier are to execute: ingestion of real time data streams to server, processing and formatting of real time data streams, and modification functions to fetch volume, turn counts, and Signal Phasing and Timing (SPaT) data from the real time database.

3 CONCLUSIONS, LIMITATIONS, AND FUTURE WORK

To develop digital twins driven using smart corridor real time data a three tier incremental approach that provides a framework to develop digital twin platforms is presented. This framework develops the digital twin architecture incrementally, limiting complexity due to confounding errors. It is noted from the studies that to develop a digital twin testbed four data aspects are crucial: data characteristics, data reliability, data needs, and hardware needs. In future efforts, cloning of the digital twin may be added, thus further expanding the incremental approach.

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