Optimize Fleet Operations using Samsara Telematics and Machine Learning

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Abstract:
Fleet operations optimization is very crucial for logistics, transportation and supply chain management companies. It helps with reducing costs, increasing efficiency, enhancing safety, and improving customer satisfaction. This paper proposes Predictive Analytics framework which integrates Samsara telematics ecosystem (which collects real-time data on GPS location, speed, engine status, fault codes, and other sensor data) with Databricks ML pipelines to enable predictive maintenance, route optimization, driver performance analysis, and safety enhancements. The implementation of Predictive Analytics Framework (PAF) resulted in significant reduction of fuel consumption, emissions, accident likelihood, vehicle downtime and insurance costs. The implementation of PAF had significant improvement in customer satisfaction due to on-time delivery. Predictive analytics framework helps organizations by predicting the downtime/failure of the vehicles way ahead and reducing the emergency repair costs, extending the vehicle life span with efficient vehicle usage, improving the driver safety risk scoring and provides AI-powered route planning which minimizes fuel consumption and mileage[5].

Keywords: Machine Learning, Databricks, Predictive Maintenance, Samsara, Telematics, REST API, Feature Engineering.

INTRODUCTION

Traditional fleet maintenance strategies rely on either reactive intervention (repair after failure) or preventive schedules (service at fixed intervals). Both approaches are inefficient: reactive maintenance leads to costly downtime and expensive emergency repairs, while preventive maintenance leads to premature replacement of the parts not effectively utilizing the remaining useful life of the equipment [1]. Whereas Predictive maintenance uses real-time data from sensors and IoT devices to continuously monitor the condition of critical assets. By analyzing this data with machine learning and AI, it predicts potential equipment failures before they happen, allowing maintenance to be scheduled precisely when it's needed to prevent unexpected downtime and extend asset lifespan. Samsara is a cloud-hosted platform that uses Internet of Things (IoT) technology and offers a unified telematics and diagnostics platform, with APIs exposing onboard diagnostics (OBD-II) / Controller Area Network Bus metrics, GPS traces, health indicators and driver behavior events like sudden acceleration, harsh braking and closely following other vehicles.

Samsara integrates with vehicles by connecting to them through aftermarket telematics devices or via direct OEM (Original Equipment Manufacturer) integrations with vehicle manufacturers. This data-sharing establishes a unified "Connected Operations Cloud" platform, providing near real-time data on vehicle location, usage, diagnostics, and fuel status to be leveraged within Samsara's ecosystem.

Whenever a real-time event like HOS Violation, Crash, Harsh brake, Speeding, Geofence entry or exit occurs, Samsara sends a HTTP request to the registered application using Webhook mechanism. Webhooks exist in Samsara's product as part of two features:

- Alert Webhooks (examples include geofence alerts and speeding alerts)
- Event Subscriptions (examples include document submitted and vehicle updated)

To create a webhook you must:

1. Define a webhook handler in your application
2. Register the webhook handler with Samsara
3. Configure Alerts or Event Subscriptions to send the webhook notifications

Samsara provides robust set of APIs to import vehicle telematics and diagnostics information. These APIs cover all of Samsara's major product areas, including telematics, safety & cameras, connected driver, and assets as shown in the screenshot below.
Following asset types are managed using Samsara REST API /assets endpoints. Using these endpoints will be able to list, create, retrieve, and update asset data.

Asset Types

- **Vehicle** – Examples include trucks, buses, etc.
- **Trailer** – Examples include dry vans, reefers, flatbeds, etc.
- **Powered Equipment** – Examples include dozers, cranes, etc.
- **Unpowered Equipment** – Examples include containers, dumpsters, ladders, etc.
- **Uncategorized** – Any other assets that do not fit the above categories

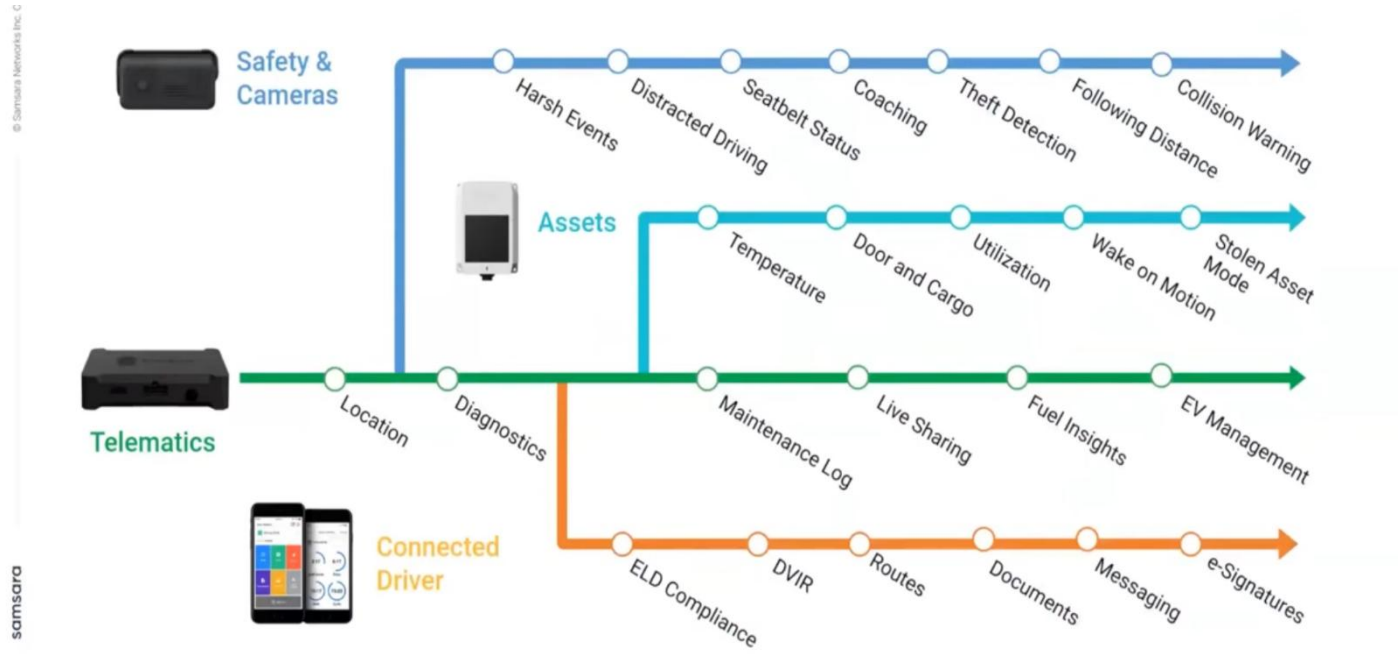

Figure 1: Samsara REST API Endpoints

Samsara Data Sources for Predictive Maintenance
Samsara provides multiple categories of information which are useful for Predictive Maintenance [4]

Telematics
Samsara has different telematics devices for different types of assets:

- **Vehicle:** The Vehicle Gateway (Cellular vehicle gateway with GPS and CAN bus interface) is an advanced sensor platform that captures real-time vehicle and driver data in the cloud to improve fleet efficiency, safety, and productivity. To capture the vehicle information below REST API endpoints, need to be queried: **Get** https://api.samsara.com/fleet/vehicles - Returns a list of all vehicles belonging to an organization (also has endpoints for retrieving a vehicle or to update it)
- **Heavy equipment:**AG53 Asset Gateway monitors off-highway vehicles, heavy equipment, and high-value mobile assets. Get https://api.samsara.com/fleet/equipment - Returns a list of all equipment in an organization.
- **Trailers:** The Powered Asset Gateway monitors powered assets as well as dry-van and flatbed trailers. **Get** https://api.samsara.com/fleet/trailers - List all trailers.
- **Reefers**: Customers who have a subscription with ThermoKing or Carrier can leverage our direct API integration without the need for a telematics device. **Get** https://api.samsara.com/v1/fleet/assets/reefers

- **Unpowered Assets**: The Unpowered Asset Gateway is a wallet-sized tracker ideal for monitoring assets like intermodal containers, construction equipment, dumpsters, light towers and other mobile assets etc. **Get** https://api.samsara.com/v1/fleet/assets

Drivers
Drivers can be created and managed through both the Samsara dashboard and the API. A driver entity will contain all the metadata relevant to that driver: **Get** https://api.samsara.com/fleet/drivers

Routes
Samsara provides you the ability to create routes that are automatically tracked using the Samsara Vehicle Gateway. Samsara refers to **loads** as ***routes***. A route is a planned sequence of stops assigned to either a vehicle or a driver. **GET** https://api.samsara.com/fleet/routes

Compliance & ELD
Samsara provides a complete ELD compliance system that allows you to track drivers' hours of service and duty status. **Get** https://api.samsara.com/fleet/hos/daily-logs

Addresses
The Addresses API allows you to manage known locations for use in routes, time-on-site reports, and more. **GET** https://api.samsara.com/addresses

DVIRs
The Samsara platform allows you to create and manage DVIRs through the Samsara Driver App and Dashboard. **Get** https://api.samsara.com/defects/stream

Tags
Samsara provides the ability to organize your data using Tags. Tags can represent different regions, departments, or other organizational structure. **Get** https://api.samsara.com/tags

Safety
Samsara's platform allows you to track safe driving. You can retrieve a list of safety-related driving events and pull safety scores at the driver or vehicle level. **Get** https://api.samsara.com/fleet/safety-events

Sensors
Samsara provides various types of environmental sensors to augment the data provided by IoT gateways. Examples include temperature, humidity, door, and cargo monitors. **Get** https://api.samsara.com/v1/sensors/list
The above sources of information from Samsara is ingested into Databricks data lake using Predictive Analytics Framework for further processing.

Predictive Analytics Framework Architecture
Framework consists of the following 5 layers:
Data Ingestion Layer: The Telematics, Drivers, Routes, Compliance & ELD, Addresses, DVIRs, Tags, Safety & Sensors information collected from Samsara REST API & Webhooks will be synced as per the defined schedules.
Raw Data Storage: The information collected from Samsara, persisted in Databricks Data lake in the form of JSON objects and time-series data and later transformed into Unity Catalog tables.
Feature Engineering: The UC tables data will be transformed into useful features like rolling statistics (mean, variance, max) for engine temperature, RPM, Fault Frequency, number of harsh brake events when distracted, when following closely, due to driver fatigue, when aggressive driving etc.
Model Training: During this stage ML algorithms (Remaining Useful Life regressors, Anomaly Detectors and Classifiers) learn from a dataset to identify relationships and predict outcomes and create a ML model representing the identified relationships and corresponding outcomes [3].

Model Registry: ML model registration involves recording and managing machine learning models within a centralized system, often called a model registry. This process facilitates versioning, tracking, and lifecycle management of models throughout their development and deployment. The model registry serves as a central hub, much like a software package repository, providing features such as model versioning, metadata storage, traceability, and stage management (e.g., staging, production, archived) to ensure accountability, governance, and efficient deployment.

Model Serving

The trained ML model is made accessible for real-time or batch predictions through a deployed API or service.

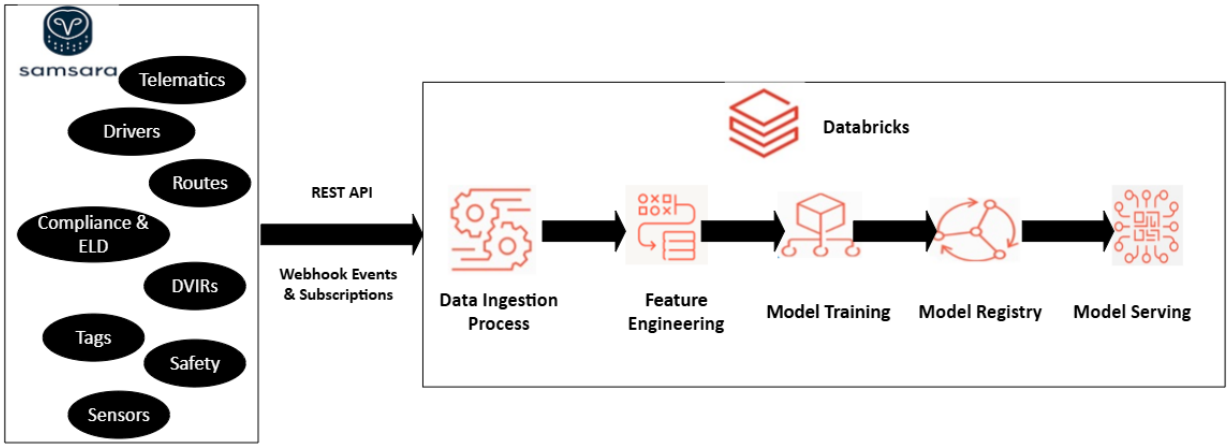

Figure 2: Samsara Predictive Analytics ML Pipeline

USE CASES

Proactive Maintenance Scheduling:

Algorithms analyze Samsara Telematics, Safety & Sensor data to forecast when specific parts might fail, enabling timely replacement before a breakdown occurs. Instead of fixed schedules, maintenance is scheduled only when data indicates a need, allowing managers to combine multiple services efficiently, reducing shop visits and minimizing downtime.

Driver Behavior Analysis

Using the accelerometer data which captures events such as harsh acceleration, braking, turning, speeding, and crashing. This accelerometer data is combined with AI-powered image processing data provided by the dash-cams[2] along with HOS(Hours of Service) to predict the likelihood of the accidents.

Fuel System Efficiency

Using Samsara OBD Odometer/GPS Odometer readings, routes & accelerometer data along with other telemetry data will be used to identify the opportunities to reduce fuel consumption & emissions.

CONCLUSION

This paper demonstrates that Samsara telematics provides a strong foundation for predictive maintenance analytics. With proper preprocessing, feature engineering, and machine learning, fleets can significantly reduce downtime and maintenance costs.

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