Man-Portable Optical Target Tracking (OTT) Platform

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Abstract

Systematic has built an autonomous, man-portable, optical target tracker (OTT) platform. Systematic used a novel digital-twin-first development approach to dramatically reduce time, expense, and risk compared to traditional development. Systematic demonstrated that the digital twin matched the performance of the physical twin. OTT was tested by tracking people, but is fundamentally target-agnostic. Systematic demonstrated the feasibility of detecting and tracking small unmanned aerial systems (sUAS) using OTT's digital twin. With additional funding, OTT could become a low cost, man portable, detect, track, and ID platform for sUAS.

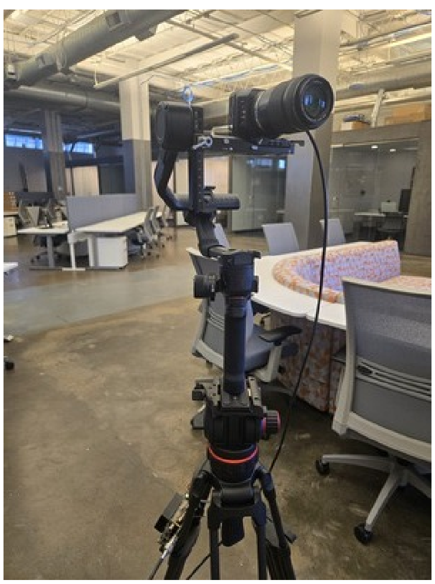

Figure 1: The prototype optical target tracking platform, or OTT, built using commercial off the shelf components and designed using a novel digital-twin-first development process.

Small Unmanned Aerial Systems

The future of warfare is autonomous and cheap.

In Ukraine, commercial drones costing ~$100 with autonomous terminal guidance are killing tanks.[1] In Israel, Iran launched ~170 UAS as part of a massive swarm attack.[2] While the technology exists to defeat these threats, defenders cannot afford to deploy $1M platforms on flatbeds everywhere that $100 drones will pose a threat.

Figure 2: Iran's airstrike on Israel on October 1, 2024. By Hanay - Own work, CC BY-SA 4.0

Although UAS will certainly become a ubiquitous threat to tomorrow's warfighter, current counter-UAS (CUAS) solutions are expensive, bulky, betray positions by emitting detectable EM, and cannot be re-tasked to serve more than one purpose. Based on conversations with DoD stakeholders, Systematic's OTT strikes a unique balance between performance, portability, stealthiness, and modularity which will fit the needs of tomorrow's warfighter.

Optical Detect, Track, and ID

Radar is the classic tool for detecting, identifying, and tracking aerial vehicles. However, radar is generally expensive, bulky, and power hungry. Even micro doppler radars specially designed for CUAS can weigh 60 lb, and consume 200 W. [3]

Electro-optical cameras are comparatively low cost,

[1] Why FPV Drones Are Still Ukraine's Biggest Tank Killers. Forbes. 2025-01-14.

[2] October 2024 Iranian strikes against Israel. Wikipedia. 2025-02-11.

[3] IRIS 3D 360 UAS Detection Product Sheet. Robin Radar Systems. 2025-02-11.

portable, and power efficient, but were traditionally held back by the quality of their software algorithms and the power required to run them. However, modern neural networks like YOLO are capable of detecting people "out of the box" at real time frame rates when paired with modern hardware acceleration.[4] These networks can be retrained to detect nearly any target, and can subsequently be reconfigured in the field and on the fly. [5]

Systematic's OTT uses Ultralytic's YOLO, which robustly detects people "out of the box", but this model can be swapped at runtime to re-task the system to track, e.g., sUAS.

Hardware Acceleration at the Edge

Machine learning (ML) in general and neural networks (loosely called "AI") in particular require hardware acceleration to be practically useful. The most recent compute platforms from NVIDIA enable running inference in real time, on very small power budgets, in remote locations (i.e., "at the edge").

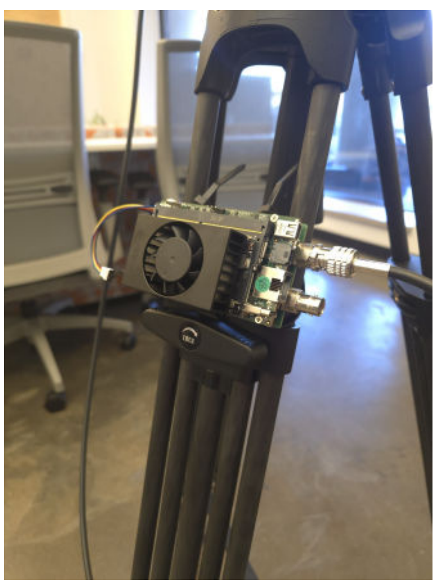

Figure 3: The extremely small, low power, but high performance NVIDIA computer Systematic plans to integrate with OTT.

Simulation and Digital Twins

Digital systems that interface with the physical world are notoriously difficult to design and build. A state of the art design loop may incorporate a simulation in software like Gazebo, finite element analysis (FEA) for complex physical phenomena, or model-based engineering software like Simulink. Each simulation domain requires its own file types, input file formats, and engineering expertise to use effectively.

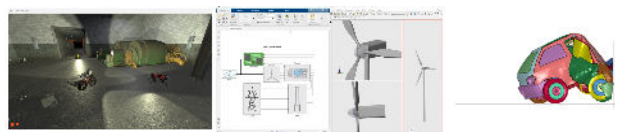

Figure 4: From left to right: A robotics simulation scene in Gazebo, a control system model in Simulink, and a finite element model of a crashing Geo Metro in LS-DYNA FEA.

Systematic modeled OTT's hardware and control software in NVIDIA's Isaac Sim. Systematic was able to drag and drop different environments and tracking targets into the simulation while developing the control software. This made iterating on the design substantially faster, cheaper, and lower risk than a traditional physical-system-first approach.

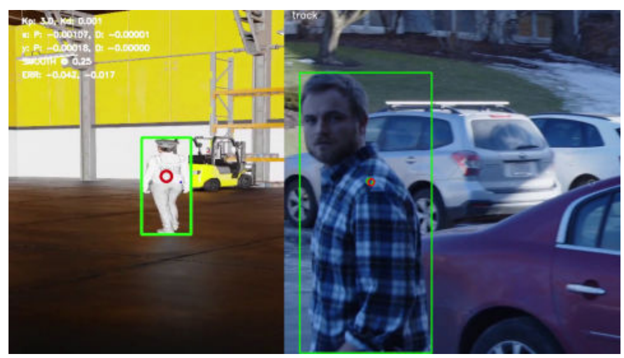

Figure 5: The tracking camera feeds from the digital twin (left), and physical twin (right) tracking a synthetic policewoman and the author, respectively. The software developed using the digital twin "just worked" when plugged into the physical twin through the hardware-specific bridges. The same PD controller gains work in both the digital and physical twins. Video of this testing can be found here and here.

The same robot operating system (ROS) software that controlled the digital twin was reused to control the physical twin. OTT's real world performance matched the predicted performance of its digital twin.

Systematic then demonstrated that OTT's digital twin was capable of detecting and tracking sUAS.

[4] YOLO: A Brief History. Ultralytics. 2025-02-12.

[5] Model Training with Ultralytics YOLO. Ultralytics. 2025-02-12.

Automated Training Data Generation

Obtaining useful training data for a neural network is difficult. In order for your model to generalize across different environments and situations, you must cover many environments and situations of interest in the training data. Traditionally this meant laboriously recording photos and video in diverse physical environments (e.g., recording and flying a drone at different times of day or different weather conditions) and then annotating that footage by hand (e.g., marking drone positions on thousands of individual frames).

Omniverse offers Replicator, which generates training data by rendering a virtual world in different configurations and automatically annotating objects. Changing weather and daylight conditions is as easy as changing which file is used for the environment. You can also do things that aren't easy or practical in real life. Flying a drone close to people, or flying a drone without lights at night can all be done trivially in Omniverse, which means our models can be trained on real world situations that matter, but might otherwise require time-consuming approvals or travel to achieve.

C2 Integration

One theme we've heard from DoD contacts across branches has been the need for integration with established command and control (C2) solutions. Systematic has invested substantially in understanding and testing TAK. In fact, Systematic has set up a local TAK server for testing purposes, and plans to send TAK Cursor on Target commands from a ROS module attached to OTT.

Natural Language Interface

One of the most astonishing developments of the last decade has been the proliferation of natural language interfaces driven by large language models (LLMs). LLMs are very large neural networks trained on incredibly large sets of data which can be interfaced with using natural language. ChatGPT is the quintessential example.

In the very near future Systematic anticipates that command-style interaction with devices through natural language interfaces will become the new norm. These natural language models can be constrained to generate response that are relevant to a particular domain (retrieval augmented generation), or constrained to a particular output language or API, making them suited for controlling devices in situations where picking up a controller or finding the right menu commands would be impractical.

Systematic plans to explore adding voice command control to OTT.

About Us

Systematic Consulting Group, Inc. is a small business located in Saint Louis, MO. We are a small team of multidisciplinary experts in software, hardware, firmware, cloud backends, mobile applications, and simulation.

Systematic has decades of experience choosing commercial-off-the-shelf hardware for different purposes, and designing and building custom hardware when the application calls for it. Systematic is responsible for the brains of Full Swing Golf's KIT launch monitor, and the central control software behind TMRW Sports' TGL.

Training machine learning models requires a robust pipeline for ingestion, storing, preprocessing, and annotating training data, and powerful dedicated hardware to support long training runs. Systematic has invested in the development of an automated pipeline and has an on-premises machine learning server.

Systematic is excited and honored to support tomorrow's warfighter.