The OptimalNightVision Platform and its Benefits: A Brief Overview

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Introduction

In industries subject to high variability in product quality such as night vision intensifier manufacturing, the traditional approaches of manual selection and binning lead to suboptimal profitability and efficiency. The term "manufacturing" is somewhat of a misnomer, as the processes involved are more akin to "growing" products with variable attributes. This paper presents an innovative algorithm called Max Systems Meet Requests (MSMR), available on the OptimalNightVision Platform, to optimize the building and assignment of these expensive, highly-variable products. The initial application of MSMR in the night vision industry serving the U.S. government and defense contractors has shown promising results in matching product characteristics to customer specifications while minimizing manual overhead.

Problem Statement

Night vision systems serve a wide range of applications from military operations, to medical aviation, to search-and-rescue, and even recreational usage. These systems generally comprise one or more image intensifier tubes, each costing upwards of $4,000. A panoramic system containing four tubes can cost upwards of $40,000 after housing and integration costs are considered. Given the expensive nature of these systems and the high-stakes applications they are used for, it is essential to optimize the selection process for intensifier tubes based on several parameters. A greatly simplified list of tube parameters is presented below:

1. **Resolution**: Ability to see fine details (think 1080p vs. 4k TVs)
2. **Signal-to-Noise Ratio (SNR)**: How much true information is shown versus background noise (think image vs. static noise on an old TV)
3. **Figure-of-Merit (FOM)**: A meta-metric of Resolution times SNR
4. **Equivalent Background Illumination (EBI)**: Usability in extremely dark areas
5. **Halo**: Presence of flare around bright lights such as street lights and lasers
6. **Blemishes**: Permanent black dots in the image (in the center, middle ring, or outer ring)
7. **Gain**: How bright the image gets (how well the tube multiplies photons)
8. **Manual Gain**: Whether gain is adjustable by the end user or if it auto-adjusts

There are dozens of other specs, and a lot more considerations (housing compatibility being a big one). However, this list contains the most commonly requested specs. The issue of spec minimums is exacerbated when considering bulk orders. How can an organization fulfill such complex orders without a large margin of error and without exhaustive manual labor?

Binocular housing (two tubes)

Panoramic housing (four tubes)

Figure 1: Night vision systems are available in various housings (monocular not pictured)

The MSMR Algorithm: An Overview

While the MSMR algorithm's details are trade secrets, it broadly consists of two primary steps:

1. **Inventory Optimization**: All available intensifier tubes are grouped to form binocular or panoramic systems in such a way that each pair or set of tubes is as homogeneous as possible. This ensures that each eye of the user receives an image of almost identical quality. Further, all tubes are candidates for being left as monoculars. This decision is made in the Customer Matching step.
2. **Requirement Satisfaction**: The algorithm matches the optimized inventory to customer orders, ensuring as many requests are met as possible. Furthermore, the algorithm aims to minimize the gap between the performance of the chosen tubes and the customer's requested specifications.

Inventory Optimization

	serial_number	type	snr	res	ebi	halo	gain	zone1_blems	zone2_blems	zone3_blems
2	1001	MX10160	33	72	0.39	1.99	87069	0	1	3
3	1002	MX10160	38	72	0.89	0.22	78621	0	1	0
4	1003	MX11769	27	72	0.30	0.92	80656	1	1	2
5	1004	MX11769	33	72	0.90	0.09	72170	0	2	1
6	1005	MX11769	34	72	0.18	0.07	64519	1	1	2
7	1006	MX10160	30	64	0.23	0.36	74345	0	2	0
8	1007	MX11769	25	72	0.91	0.43	53899	1	1	1
9	1008	MX10160	36	72	1.44	0.19	59468	0	2	0
10	1009	MX11769	30	64	1.43	1.63	53758	0	1	0
11	1010	MX10160	25	72	0.47	0.35	84080	1	2	0
12	1011	MX10160	28	72	1.06	0.29	66783	0	0	1
13	1012	MX10160	38	72	0.81	1.52	54504	1	1	1
14	1013	MX11769	34	64	1.04	0.24	68545	1	2	1
15	1014	MX10160	25	64	0.63	0.90	59447	0	0	1
16	1015	MX11769	33	72	0.81	0.90	81301	0	2	1
17	1016	MX11769	39	72	0.46	0.05	85011	1	2	0
18	1017	MX11769	29	72	0.83	0.06	76541	0	2	1
19	1018	MX11769	37	72	0.83	0.27	82819	1	2	0
20	1019	MX11769	29	64	0.53	1.95	65050	1	0	0

Figure 2: A spreadsheet showing intensifier tubes in inventory and their specifications

The first component of the Max Systems Meet Requests (MSMR) algorithm tackles the challenge of optimal pairing of intensifier tubes. All available tubes are categorized based on their key parameters such as FOM, SNR, and Resolution. The algorithm identifies the optimal pairs that have the least variance in these key metrics. This is where mixed-integer linear programming (MILP) comes into play. The MILP model categorizes the inventory by creating potential pairs of tubes with minimal attribute variances. This ensures that binocular or panoramic systems offer as homogenous an image as possible to the user. By transforming the inventory into optimized sets, the model readies it for the customer matching process.

Requirement Satisfaction

	customer	order_number	bino_mono	type	min_snr	min_res	min_ebi	min_halo	min_gain	max_zone1_blems	max_zone2_blems
2	Walter@email.com	#9337	bino	MX10160	27	72	0.11	0.24	55902	0	0
3	Mason@email.com	#6622	mono	MX11769	28	72	1.97	0.67	58602	1	1
4	Myah@email.com	#7083	mono	MX10160	33	64	1.58	0.47	83498	1	0
5	Marlee@email.com	#9074	mono	MX10160	28	64	0.53	0.57	65993	0	1
6	Marco@email.com	#9358	bino	MX10160	37	64	1.89	0.83	84825	1	1
7	Trent@email.com	#5271	bino	MX10160	32	64	0.49	0.19	79380	1	1
8	Kayla@email.com	#8001	mono	MX11769	28	64	0.79	0.43	71009	0	1
9	Marcelus@email.com	#8546	bino	MX11769	26	64	0.02	0.76	86102	1	2
10	Ralph@email.com	#9876	bino	MX11769	25	64	0.34	0.52	73313	1	2
11	Jaelynn@email.com	#6747	bino	MX11769	40	64	0.89	0.34	61210	1	1
12	Kassidy@email.com	#8774	bino	MX11769	29	64	0.79	0.87	65149	1	2
13	Turner@email.com	#8189	bino	MX11769	29	64	0.77	0.86	89903	1	0
14	Kole@email.com	#6141	mono	MX10160	29	64	1.44	0.72	51779	0	2
15	Uriah@email.com	#9273	bino	MX11769	33	64	0.74	0.29	87619	0	1
16	Jamya@email.com	#6584	bino	MX10160	32	64	0.65	0.46	76413	1	2
17	Christopher@email.com	#9714	bino	MX10160	30	64	0.84	0.52	80917	0	2
18	Slade@email.com	#8691	bino	MX10160	27	72	0.77	0.78	62670	1	2
19	Joe@email.com	#9909	mono	MX10160	26	64	0.24	1.72	62155	0	0
20	Terrell@email.com	#7460	bino	MX10160	27	64	0.72	0.68	72252	1	1
21	Anabella@email.com	#8997	bino	MX10160	28	64	0.27	0.61	71196	1	0

Figure 3: A spreadsheet showing customer orders and their requirements for system specifications

Customers typically specify desired attributes for their orders, but matching these to available inventory becomes complex, particularly for bulk orders. This complexity is further amplified when matching tubes for multi-tube systems like binoculars. Traditional manual matching methods are labor-intensive and prone to errors, leading to customer dissatisfaction and reduced profitability.

The second component of the MSMR algorithm, Requirement Satisfaction, uses another MILP model to address the fulfillment of customer orders. By leveraging existing inventory and past sales data, the model identifies the best matches for customer orders based on specified attributes. One advantage of using MILP here is the capacity to handle multiple objectives, like maximizing the number of fulfilled orders while minimizing attribute overshooting. If an order cannot be fulfilled immediately, the algorithm queues it intelligently for future batches of intensifiers. This way, customer expectations are managed, and inventory turnover is optimized.

Case Study Example 1: Government Retrofit of 1000 Monocular Systems to Binocular Systems Using the MSMR Algorithm*

* This case study is a hypothetical example and does not convey any relationship to any entities

Case Study Introduction

In order to provide end-users with binocular systems for training without spending over $10,000 per system, a government agency wanted to convert 1000 surplus monocular night vision systems in their inventory to binocular systems. 500 new binocular systems would have cost over $5 million. The monocular systems already in inventory varied in terms of their FOM, EBI, Halo, and other attributes. The key requirements were to achieve a high degree of homogeneity within each new binocular system and to minimize costs while fulfilling specific performance criteria. This case study describes how the MSMR algorithm can easily fulfill this large retrofit project.

Case Study Objective

1. Upgrade 1000 monocular night vision systems to binocular systems.
2. Achieve a minimum FOM of 2000 and an EBI not worse than 0.5.
3. Maximize the homogeneity of tubes within each binocular system.
4. Minimize costs and manual labor associated with sorting and pairing.

Case Study Approach

Inventory Audit and Data Preparation

First, the existing 1000 monocular systems were audited to record their attributes. Each monocular was examined, or its spec sheet located, and its attributes were entered into a spreadsheet that would serve as input for the MSMR algorithm.

Application of MSMR Algorithm: Inventory Optimization

Using mixed-integer linear programming, the first component of the MSMR algorithm grouped the 1000 monocular systems into 500 potential binocular systems. Each group was optimized to ensure that the two tubes in a single binocular system had minimal variance in their key attributes like FOM, EBI, and SNR.

Application of MSMR Algorithm: Requirement Satisfaction

In the customer matching phase, the MILP model aligned the optimized binocular systems with the performance criteria set by the agency. Specific objectives were encoded into the MILP model to ensure the binocular systems met the minimum FOM and EBI requirements. Therefore, a number of systems were dropped out of consideration automatically, leaving around 400 binocular systems. The final build sheet was sent to a system integrator for the rebuild process.

Case Study Outcome

1. **Homogeneity**: The MSMR algorithm successfully grouped the monocular systems into around 400 binocular systems with minimal intra-system variance in key attributes.

2. **Performance**: All 400 systems had a FOM greater than 2000 and an EBI better than or equal to 0.5, fulfilling the agency's strict performance criteria.

3. **Efficiency**: The process was completed in a fraction of the time it would have taken with traditional manual methods. The actual pairing process only took a few minutes, once tube specifications were recorded in the spreadsheet.

4. **Cost-Efficiency**: Due to the algorithmic matching, there was minimal waste, and almost all existing tubes were used effectively, significantly cutting the costs of acquiring new binocular systems.

Case Study Example 2: Winning Over Law Enforcement Contracts and Civilian Orders Using the MSMR Algorithm

* This case study is a hypothetical example and does not convey any relationship to any entities

Case Study Introduction

A night vision systems integrator is competing for two large contracts from metropolitan law enforcement agencies while simultaneously managing dozens of smaller orders from individual civilians. The sheer complexity of meeting multiple stringent specifications from different customer segments can be daunting. Here’s how the MSMR Algorithm revolutionizes systems integration capabilities to meet these challenges head-on, securing large contracts while satisfying a broad spectrum of smaller customers.

Case Study Objectives

1. Secure two large contracts from metropolitan law enforcement agencies, each requiring different sets of specifications.
2. Meet the diverse needs of civilian customers without affecting the quality of products delivered to law enforcement contracts.
3. Maximize inventory usage to ensure profitability across the board.
4. Streamline the entire process, from inventory management to order fulfillment.

Case Study Approach

Inventory Audit and Data Preparation

The first step involved auditing the current inventory of intensifier tubes, categorizing each tube based on its parameters, such as FOM, SNR, and Resolution, among others. The data collected served as the primary input for the MSMR Algorithm, and was recorded in a spreadsheet.

Application of MSMR Algorithm: Inventory Optimization

Through mixed-integer linear programming, the MSMR Algorithm quickly iterated through the tubes, categorizing them into potential sets that could be used for law enforcement contracts and individual sales. This categorization focused on minimizing variance within each set to ensure that every night vision system, whether binocular or monocular, offered the highest performance.

Application of MSMR Algorithm: Requirement Satisfaction

The second phase of the MSMR algorithm was unleashed on the complex task of matching the pre-optimized sets to the respective contracts. Custom MILP models were set up to handle multiple objectives, such as meeting stringent law enforcement requirements and individual civilian needs. If certain specifications could not be met immediately, the algorithm smartly queued these for future inventory, thereby managing expectations and improving inventory turnover.

Case Study Outcomes

1. **Precision Matching for Law Enforcement**: Both metropolitan law enforcement contracts were fulfilled with near-perfect specification matching. This was especially noteworthy as the two agencies had different sets of requirements.
2. **Improved Pricing**: No longer needing to rely on simple averages for pricing, the integrator was able to charge a more fair price for their units, and the purchasing agencies were able to more accurately budget for the specifications they requested. Pricing accuracy helped both sides achieve financial benefits.
3. **Customer Satisfaction for Civilian Orders**: The algorithm's intelligent queuing and prioritization ensured that even individual civilian contracts were matched optimally, resulting in high levels of customer satisfaction.
4. **Streamlined Operations**: What would traditionally have been a labor-intensive and error-prone process was completed within a fraction of the time.
5. **Maximized Inventory Usage**: The algorithm's accurate matching and smart queuing reduced waste and increased the usage of available inventory, leading to higher profitability.
6. **Strengthened Market Position**: By fulfilling large and complex contracts efficiently, the commercial entity was able to strengthen its position in the competitive landscape, making it a preferred vendor for future law enforcement contracts.

Figure 4: The OptimalNightVision logo, a tarsier

Conclusion

This algorithm is available today through the OptimalNightVision Platform, proudly serving only U.S. entities. Since its implementation, the MILP-based MSMR algorithm has shown promising results. The algorithm's dual advantage of efficiency and customer satisfaction is a significant leap forward in an industry where both are crucial. This makes it a promising solution for any industry grappling with similar challenges of product variability and complex customer requirements. By reducing the manual labor required for inventory management and enhancing customer satisfaction through precision matching, MSMR represents a groundbreaking development in this field. The MSMR Algorithm not only boosts your bottom line but also significantly enhances your reputation for delivering unmatched quality. All these benefits make the OptimalNightVision Platform an indispensable tool for any organization looking to outperform in a competitive market.