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TRAINING AND VALIDATION
OF ARTIFICIAL INTELLIGENCE ALGORITHMS
AND LOGIC OF SWARMS UNMANNED SYSTEMS
IN VIRTUAL REALITY ENVIRONMENTS

Abstract: Dynamic development of Unmanned Aerial Systems (UAS) and Artificial Intelligence (AI), along with their increasing significance in cosmic, maritime and military sectors, is nowadays more than obvious. Aside from this overwhelmingly growing trend, the Virtual Reality (VR) market is also expanding exponentially.

**Keywords:** Artificial Intelligence, Virtual Reality

1. VIRTUAL REALITY
SIMULATION SYSTEMS' CAPABILITIES

Virtual Reality simulation systems capabilities, 3D and engineering tools, have been mentioned in an earlier article titled "Swarming Tactic and its Implementation in Virtual Reality Environment", published in the monograph "Implementation of unmanned aerial platforms in operations for public safety"[1], which was issued in 2019 year by CNBOP-BIP[2].

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[1] CNBOP-PIB, bryg. dr inż. Mariusz Feltynowski, Implementation of unmanned aerial platforms in operations for public safety (polish Wykorzystanie bezzałogowych platform powietrznych w operacjach na rzecz bezpieczeństwa publicznego), www.cnbop.pl/pl/wydawnictwa/ksiazki/wykorzystanie-bezzaogowych-platform-powietrznych-w-operacjach-na-rzecz-bezpieczestwa-publicznego_14839, bit.ly/3yq9VW9 [access: 2019]

[2] CNBOP-BIP, Centrum Naukowo-Badawcze Ochrony Przeciwpożarowej – Państwowy Instytut Badawczy (eng. Scientific and Research Center for Fire Protection – National Research Institute), www.cnbop.pl
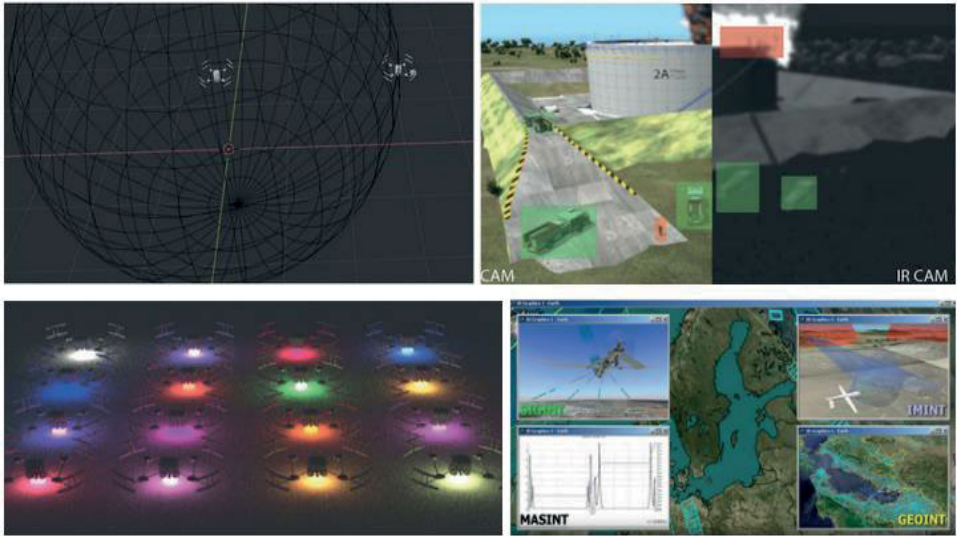
Figure 1. Illustration source: "Swarming Tactic and Its Implementation in Virtual Reality Environment"
Source: own materials / "Implementation of unmanned aerial platforms in operations for public safety" (2019).

The main idea of the cited article is that real actors and sensors communicating with a real (or simulated) on-board system should be replaced with simulated ones in the VR[3] environment.
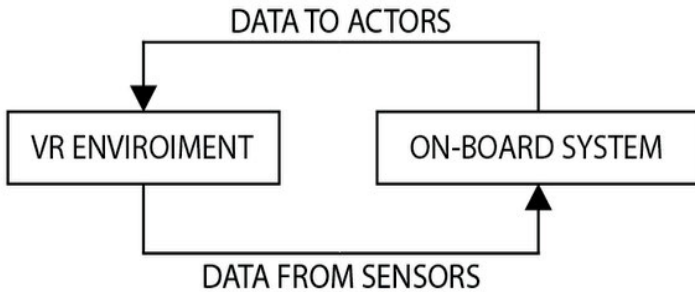
Figure 2. Simulation idea diagram.
Source: Self study.

In addition, we divide this information into **basic** (e.g. regarding the navigation of the unit and information exchange) and **utility** (concerning the purposes of the study).

The provided division is universal and intuitive, and can be read differently depending on usage purpose (type of mission) or installed additional components.

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[3]   VR – Virtual Reality.

Table 1. Division of Sensors and Actors based on their purpose.

BASIC	
SENSORS	**ACTORS**
accelerometers, gyroscopes, pressure gauges, magnetometers, GNSS receivers, communication receivers, …	control surfaces, rotors (UAV)/propellers (USV), vehicle wheels, communication transmitters, lighting, …
UTILITY	
SENSORS	**ACTORS**
cameras, radars, sonars, lidars, air composition sensors, Geiger counters, …	gimbals, manipulators, grippers, laser cannons, weapon (bomb) release, …

Source: Self study.

2. SIMULATORS, TRAINERS, DEMONSTRATORS

When it comes to application of Virtual Reality environments in relation to Unmanned Aerial Systems they are implemented mostly in simulators, trainers and demonstrators.
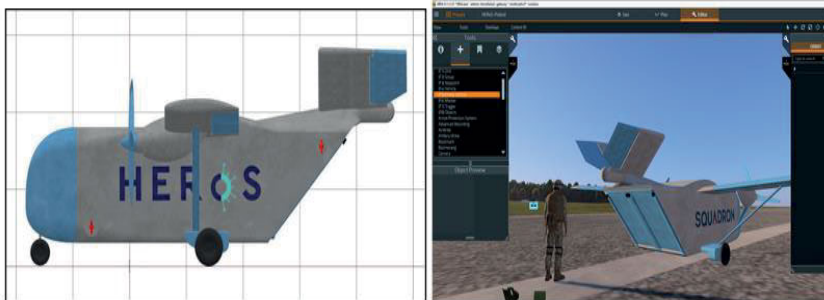
Figure 3. Project 3D "HEROS" (left), "HEROS" in VBS4 (right).
Source: self study.

From own study, a good example is a demonstrator of UAS project "HEROS"[4] accomplished in 2022. Our task was to design an UAS model based on three different existent aircrafts: Short SC.7 Skyvan[5], C-130H Hercules[6], B-2[7]. The outcome combines all advantages of the three aircrafts according to "HEROS" project requirements.

We have also delivered a fully functional app that visualizes the state of the "HEROS" aircraft behavior. The control panel was designed based of Bayraktar

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[4]   HEROS – heros-project.eu, bit.ly/3T1xP3L [access: 2022]
[5]   Short SC.7 Skyvan – British turboprop transport aircraft, pro.duced in the years 1963–1986.
[6]   C-130 Hercules – American medium military transport aircraft, produced since 1956
[7]   B-2 – Polish project of an unmanned, reconnaissance, jet aircraft from 2002

TB2[8] control station layout (Fig.4). The aircraft simulation was implemented in VBS[9] 4 environment.
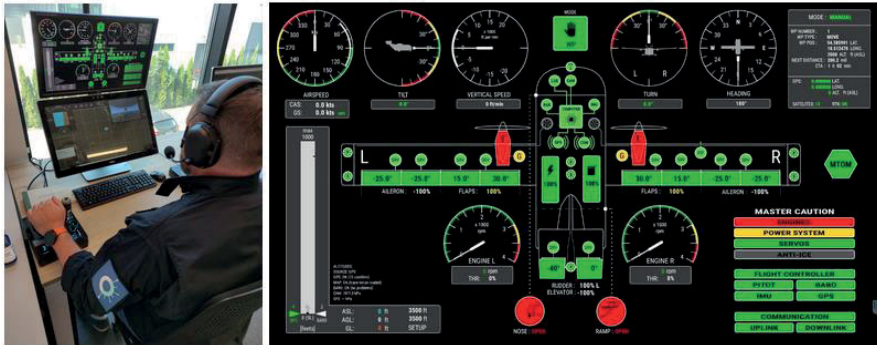
Figure 4. Control station view (left), UAC control panel layout (right).
Source: self study.

Another simulation system we are currently developing is the UAS and JTAC Combat Mission Support Simulation Kit by the name SUCK-ME[10]. The simulation system is developed to provide essential combat mission representation for Special Operations Forces (SOF) JTACs and JFOs providing complex training environment for all applicable procedures when conducting precision-guided munition strikes such as MLRS, APKWS, GBUs, LGMs, Excalibur etc. along with terminal guidance by GLTDIII[11] (Fig. 5). One accomplishment that we can boast about as being unique is a VDL transmitter that provides real

Figure 5. Our project of GLTD (left), Video Downlink (VDL) transmitter (right).
Source: self study.

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[8]   Bayraktar TB2 – Turkish unmanned combat aircraft produced since 2014.
[9]   VBS (Virtual Battlespace) – Czech, NATO-certified VR environment for military training, www.bisimulations.com/products/vbs4, bit.ly/41WEOPD.
[10] SUCK-ME (Special operations forces Utility Combat training Kit – Mission Emulator) – Polish, JTAC training, our production system, www.suck-me.fun [access: 2023].
[11] GLTD - Ground Laser Target Designator – target illumination device.

time data streaming from any simulated aircraft, for instance UAV or Fighter Jet being a part of SUCK-ME. The VDL from the simulation environment can be received directly onto any tactical receiver such as L3 Harris ROVER (ISR, TNR)[12] during virtual simulation training (Fig.5).

3. PHOTOREALISM IN VIRTUAL REALITY ENVIRONMENT

The VR environment is mainly under development thanks to the commercial market, with the primary input from the entertainment sector being the gaming industry. The competitive character of the industry forces the pursuit of providing more realistically looking synthetic 3D environments. In 2020, a new game engine, the Unreal Engine, was launched on the market[13]. The fifth version of the engine introduced revolutionary quality of graphics rendered in real time thanks to the Nanite[14] and Lumen[15] technologies.

Figure 6. UE5 real time rendered image.
Source: www.unrealengine.com/en-US/unreal-engine-5 [access: 13.05.2020].

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12   ROVER L3 Harris – Tactical video signal receiver from the air platforms, product of L3 Harris www.l3harris.com
13   Ureal Engine 5 – amerykański silnik VR, www.unrealengine.com/en-US [access: 13.05.2020]
14   Nanite – a virtualized geometry system introduced with Unreal Engine 5
15   Lumen – a system that creates realistic, global lighting introduced with Unreal Engine 5, also known as "hardware Ray Tracing"

The development of simulation engines and GPUs is parallel. The Nvidia RTX[16] series of Graphic Cards contains RT cores[17] which processes Ray Tracing[18] in real time.

Figure 7. TV broadcast screenshots from TV GCM – www.gdansk.pl (left), vrEXperience gameplay screenshot (right). Source: www.gdansk.pl self study

All technologies implemented in our commercial projects, such as the virtual TV studio for GCM (gdansk.pl)[19] and an educational game for Inspectors of Explosion-Endangered Zones vrEXperience[20], released in 2021 (Fig. 7), were built with Unreal Engine. At this point, it is worth mentioning that the Ray Tracing technology was first anticipated already in the XVI century. Within the realm of digital technology, Ray Tracing is being used by the V-Ray[21] engine, which was first introduced in 1997. The engine, however, does not allow to render real time pictures without using powerful computing units.

In the video titled "When the computer graphics will be mistaken with reality"[22], produced and accessible on the Youtube channel "To Znowu Oni"[23], the result of an experiment is being described, which consists in recognising frames from Video graphics and pictures of the real world. The invited subjects

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[16]   RTX (Ray Tracing Texel eXtreme) – graphics platform, American company Nvidia, www.nvidia.com/pl-pl/geforce/rtx/, bit.ly/41WIVex

[17]   RT cores – cores in RTX platforms, real-time Ray Tracing

[18]   Ray Tracing – a technique of creating a virtual image by tracing rays of light

[19]   GCM (Gdańskie Centrum Multimedialne, eng. Gdańsk Multimedia Center) – company of the City of Gdańsk, city portal operator (www.gdansk.pl)

[20]   vrEXperiecne – Polish game training inspectors of explosion hazard zones, our production, www.neptunstudio.com/vrEXperience, bit.ly/41XCYxQ [access: 2021]

[21]   V-Ray – rendering engine created by a Bulgarian team in 1997

[22]   Kiedy grafikę pomylisz z rzeczywistością (eng. When you confuse graphics with reality) – www.youtube.com/watch?v=lyOXK4wzf2Y, bit.ly/3ymjwxo [access:: 4.10.2022]

[23]   To Znowu Oni (eng. It's Them Again) – Polish video game channel, www.youtube.com/@ToZnowuOni, bit.ly/3ZPbWaN
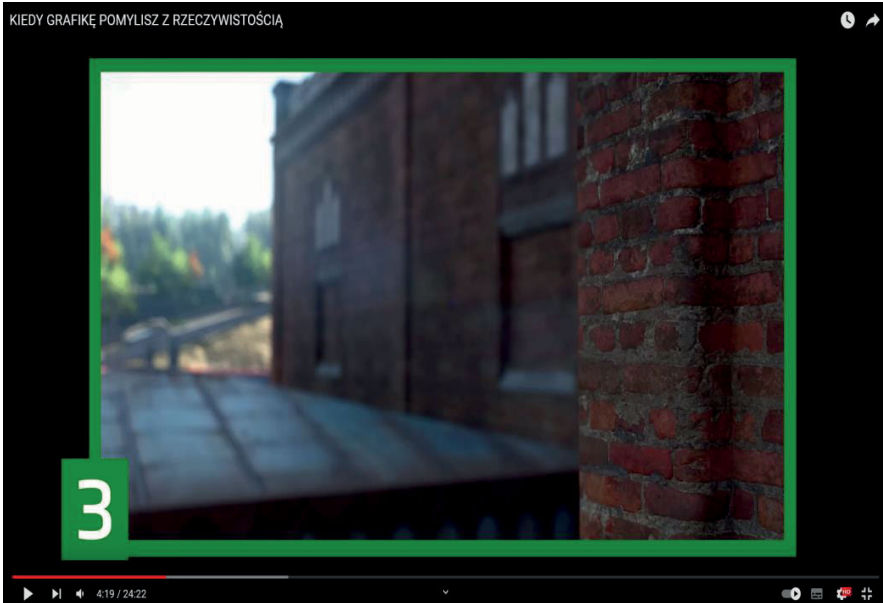
Figure 8. One of the virtual images presented to experiment subjects.
Source: www.youtube.com/watch?v=lyOXK4wzf2Y, bit.ly/3ymjwxo, time=4:19 [access: 4.10.2022]

Figure 9. MBT Merkava Mk.IV[24] from content (Unreal Engine 5)
Source: www.unrealengine.com/marketplace/en-US/product/modern-tanks-advanced-tank-blueprint-four-pack, bit.ly/3l0Aq1l [access: 27.01.2022]

are being asked to assess and point out which of the presented pictures are real and which ones are frames from the game. The subjects, of course, are confused, and they repeatedly make mistakes.

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[24]   Merkava Mk.IV – Israeli main battle tank, produced since 2002

An additional advantage of Unreal Engine is a large amount of support from the community of game developers who use this game engine. Figure 9 shows the Main Battle Tank Merkava Mk.IV[25] available as ready to implement assets available to purchase from "Modern Tanks A 4pk"[26].

4. VIRTUAL REALITY VS. ARTIFICIAL INTELLIGENCE

As shown by the experiment, if people get deceived and are not able to distinguish real image from the virtual one, the quality of the latter is good enough to be used in teaching and testing neural networks; in image processing and validation.
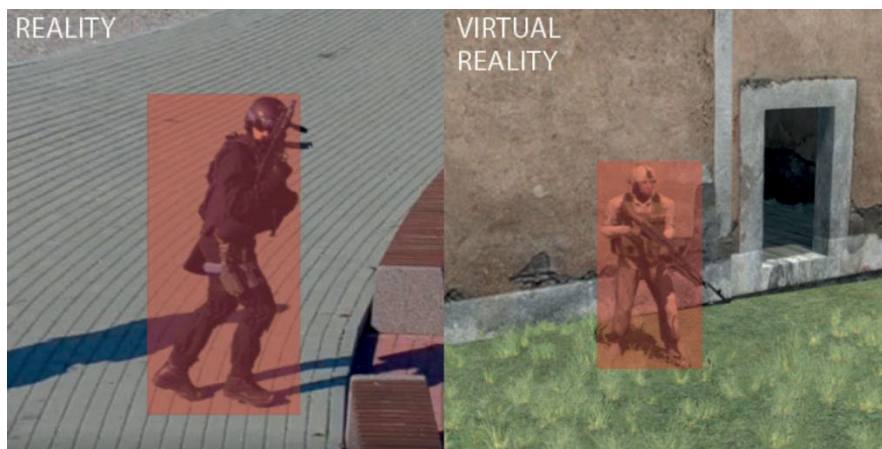
Figure 10. Neural network image validation for real picture (left) and image from VBS3 simulation system (right).
Source: self study.

In our project from 2019, we have proven successful deception of one of the algorithms created to recognise and validate humans in a provided picture (Figure 10). This experiment was based on pictures extracted from the VBS3 simulation environment. The tool used to process and validate pictures was Computer Vision Toolbox[27], based on Matlab & Simulink[28] computing environments.

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[25] Assets – ready objects (software, 3D models, etc.) to be placed in the environment
[26] Modern Tanks A 4pk – www.unrealengine.com/marketplace/en-US/product/modern-tanks-advanced-tank-blueprint-four-pack, bit.ly/3l0Aq1l [access: 27.01.2022]
[27] Computer Vision Toolbox, MathWorks, uk.mathworks.com/products/computer-vision.html, bit.ly/2VtHPs2 [access: 4.09.2019]
[28] Matlab Simulink, MathWorks,uk.mathworks.com/products/matlab.html, bit.ly/2JiR343 [access: 4.09.2019]

Recently, we focused on implementing Unreal Engine 5 because of the open nature of the environment and its simplicity, as well as effectiveness of implementing desired technologies within the engine. Work will also progress with AI-based tools, such as PyTorch[29] or TensorFlow[30].
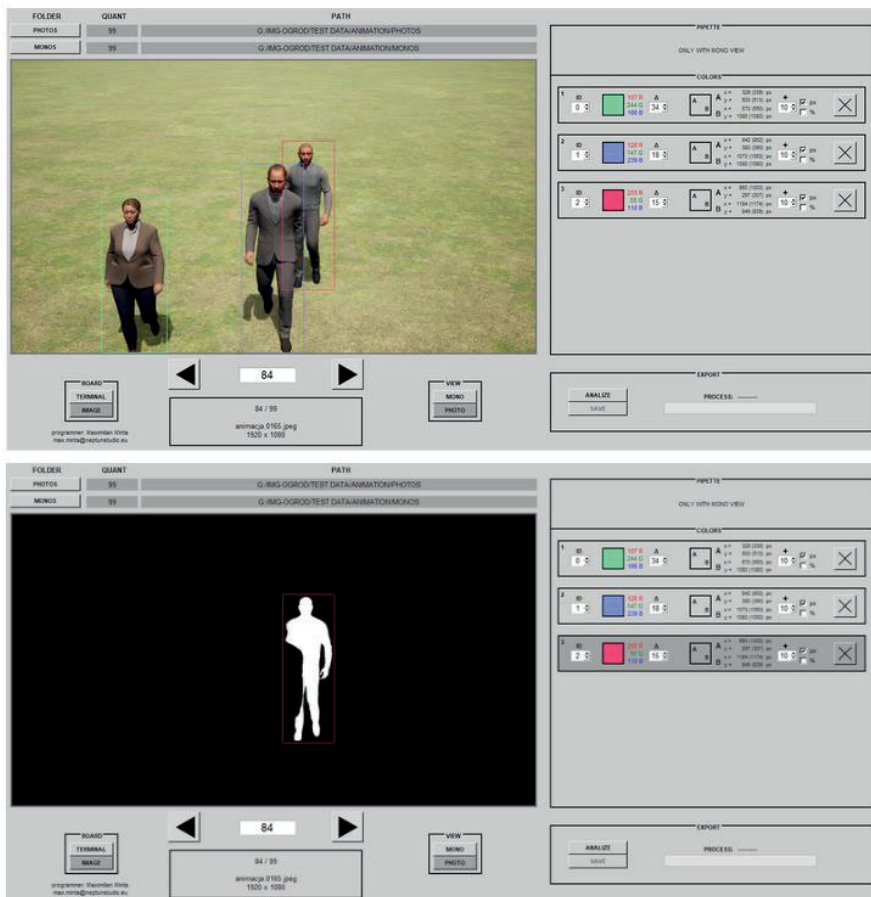

Figure 11. Screenshot from application allowing to automate content flow between Unreal Engine and neural networks.
Source: self study.

We are developing a set of tools assisting in teaching and validation of neural networks, using the Unreal Engine 5 environment. Figure 5 shows screenshots from an application used to automatically process images from UE5 to be implemented in further learning of neural networks, such as the YOLO[31]

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[29] PyTorch – machine learning platform, www.pytorch.org
[30] Tensor Flow – machine learning platform, www.tensorflow.org
[31] YOLO – artificial intelligence algorithm – www.ultralytics.com/yolov5

algorithm. A good example of that is animation of people moving around. Data provided to this application are extracted from UE5, by means of specially modified set of shaders[32].
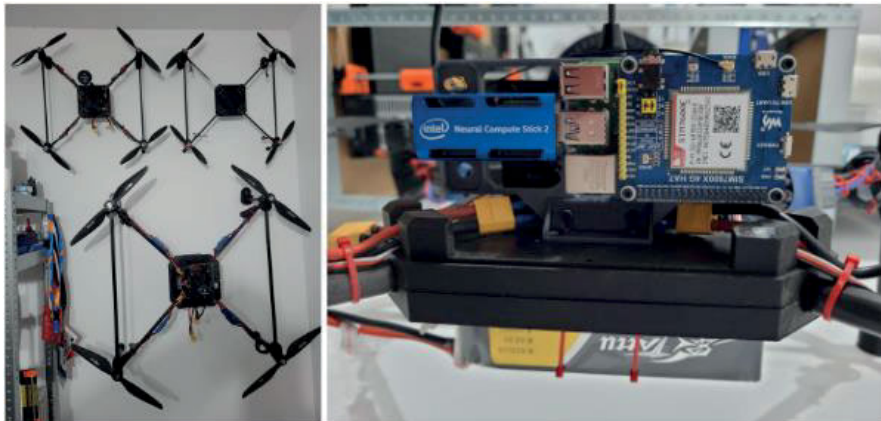
Figure 12. Our make of UAV (multi-rotor) with applied AI (Intel Movidius – Neural Compute Stick 2) on board
Source: self study

For testing purposes and for validation of teaching effectiveness of the neural networks, we manufacture multi-rotor type UAVs (Figure 12), which are equipped with the Intel Movidius[33] Neural Compute Stick 2[34] combined with the flight computer. Additionally our drones are modified and customized to be able to act as a swarm.

An example of our mechatronic projects is an educational stand[35] located in the Epi-Centre of Science[36]. The project of a platform is based on visual processing regulator PID[37], delivered in 2020 (Figure 13).

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[32]   Shader – a program responsible for producing 3D graphics
[33]   Intel Movidius – Vision Processing Units (VPUs) manufacturing by Intel, www.intel.com/content/www/us/en/products/details/processors/movidius-vpu.html, intel.ly/3ZVeEeh
[34]   Neural Compute Stick 2 (Intel NCS2) – USB 3.0 stick with Intel Movidius Unit, www.intel.com/content/www/us/en/developer/articles/tool/neural-compute-stick.html, intel.ly/3l1H6wk
[35]   Realization movie – www.neptunstudio.com/PORTFOLIO/PID_PLATFORM.mp4, bit.ly/3yt56M2
[36]   Epi-Centre of Science – center of education and entertainment in Białystok – www.pi-centrum.bialystok.pl, bit.ly/3ysS1SE [access: 2020]
[37]   PID (Proportional–Integral–Derivative) – automation controller algorithm

Figure 13. Educational stand in Epi-Centre of Science
Source: self study / www.neptunstudio.com/PORTFOLIO/PID_PLATFORM.mp4, bit.ly/3yt56M2

5. PROJECT DEVELOPMENT

In our earlier projects, we were striving to produce our own solutions simulating flight computer using Matlab & Simulink based on Quadcopter Simulation and Control example[38] (for flight stabilization). Currently we have suspended further development in that area, due to off-the-shelf solutions already
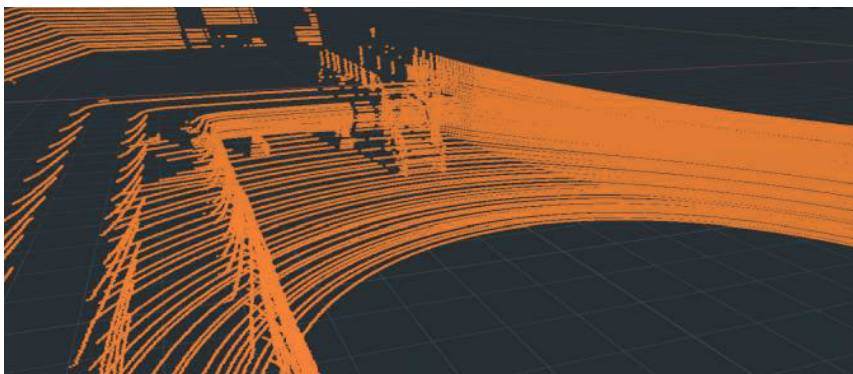
Figure 14. LIDAR cloud point output test created in Blender
Source: self study

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[38]   Quadcopter Simulation and Control, MathWorks, uk.mathworks.com/videos/ introduction-to-simulink-quadcopter-simulation-and-control-100476.html, bit.ly/2PYsREC [access: 25.03.2015]

existing on the market such as Pixhawk[39] and MAVlink[40]. However, experience in implementing flight computers may be very beneficial when engineering more dynamic unmanned systems.

In earlier works pre 2019, the author has shown a concept of LIDAR simulation using Blender[41] (Figure 14), whose further development has also been suspended. Currently we focus on using Unreal Engine 5 environment to implement drone swarm tactics when making autonomous decisions based on visual recognition. We are developing our own set of assets supporting the above-mentioned implementation of Unreal Engine, as well as putting into practice FDMs[42], such as JSBSim[43] for aerial platforms.

Built assets are being equipped with DIS[44]/HLA[45] nodes and gateways; thus they are preset to be integrated with simulation environments used by the military sector and are ready to conduct LVC[46] training events. Working with Unreal Engine 5 alongside RTX technology, followed by validation through our mechatronic constructs that use cameras and AI Intel Modivus accelerators, is very cost efficient. This is a big advantage, because all our inventions are self-financed.

6. THE ADVANTAGES OF CREATE COMPETENCES

Keeping in mind that data collected from most of the sensors can be presented in 3D and then generate 2D views and sections out of it gives the ability to put them to further processing using AI algorithms for 2D vision processing (Figure 15). Based on that assumption, the competence made this way is transferred as if it would originate from highly-priced and specialized sensors. These rules are universal for all sensors and became the basis of our development when engineering unmanned systems and the swarms of such. Shortly, we intend to pursue developing algorithms specifically used to perform three-dimensional analysis of four or even n-dimensional data (including, for example, time).

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[39]   Pixhawk – open source flight computer, www.ardupilot.org/copter/docs/common-pixhawk-overview.html, bit.ly/41ZGPKV

[40]   MAVLink – protocol for transferring information between drones, mavlink.io/en/

[41]   Blender – 3D environment, bledner.org [access: 4.09.2019].

[42]   FDM (Flight Dynamics Model) – aircraft flight simulation algorithm

[43]   JSBSim – Open-source FDM, jsbsim-team.github.io

[44]   DIS (Distributed Interactive Simulation) – standard for transferring information between simulations, NATO

[45]   HLA (High Level Architecture) – standard for transferring information between simulations, NATO

[46]   LVC (Live Virtual Constructive) – combining field training with partial simulation of positions in virtual reality
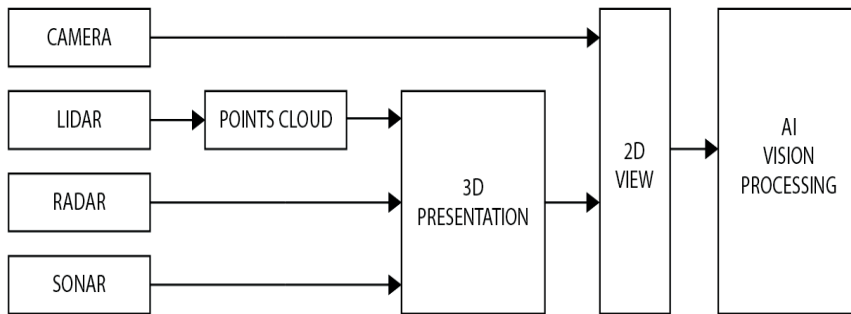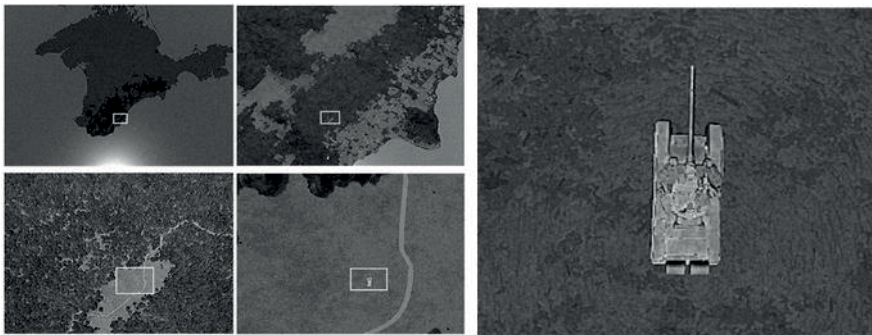
Figure 15. The idea of processing any data for 2D image processing
Source: self study

7. FINAL REMARKS

Figure 16 represents an experiment conducted via VBS4. In the southern part of Crimea, a T-90[47] tank has been placed. The sensor simulated in the system creates a satellite image of the area of the peninsula.

**Figure 16.** T-90 on the southern part of Crimea (Ukraine) - VBS4
Source: self study.

Figure 17 shows the outcome of an AI recognition system taught to identify the T-90 tank, and was taken with three different image resolution sensors (0.5 m , 0.2 m, 0,05 m per pixel). Creating such simulation environments provides the opportunity for virtual testing and validation of algorithms for other global imaging satellite implementations.

Lately, games where the player can become a virtual pilot of a military fighter jet are increasingly popular. One of the most known and played are WarThunder (Fig. 18)[48] and advanced. The physics of their game engines
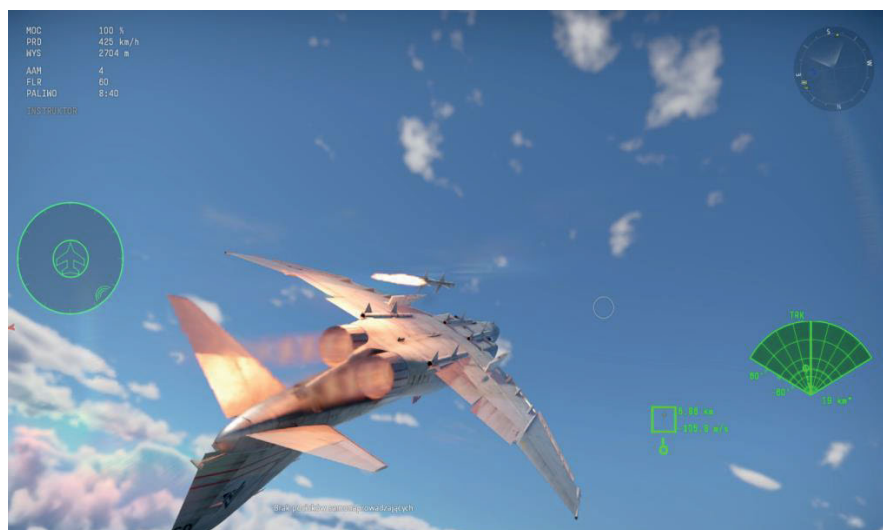
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[47] T-90 – Russian main battle tank, produced since 1992
[48] WarThunder – Hungarian air battle simulation game, www.warthunder.com
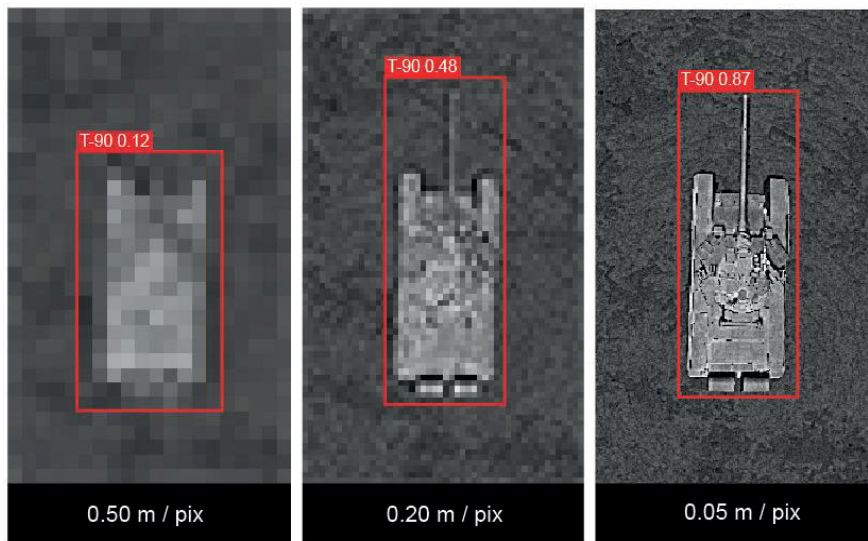
Figure 17. AI recognition on the generated image conducted with different resolution (VBS4 generated image)
Source: self study

Figure 18. F-4S Phantom II[49], AIM-7F Sparrow[50] rocket, tracking by radar and attacking MIG-15bis[51] from 7km (Screen from the game War Thunder)
Source: self study

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[49]   F-4S Phantom II – American supersonic, interceptor jet, produced 1958–1981
[50]   AIM-7F Sparrow (Air Intercept Missile) – American Semi-Active Air-to-Air Missile, Steady Guided Radar, produced 1950s–1990s
[51]   MIG-15bis – Soviet fighter aircraft, produced since 1949

provide an exact representation of fighter jets and their armament, and the level of realism in that matter is very high. While produced mainly for entertainment, games like that can also be exploited to collect data about the best players' performance. flight simulators such as DCS[52]. Such data can be stored and processed for modelling actual unmanned combat aircraft behaviour model development. We look forward to creating a specific military-civilian hybrid using Unreal Engine. Looking more deeply at the development of this idea is not a science fiction but rather a necessity arising from the future of the modern battlespace.

BIBLIOGRAPHY

Feltynowski: Mariusz Feltynowski, Implementation of unmanned aerial platforms in operations for public safety (pol. Wykorzystanie bezzałogowych platform powietrznych w operacjach na rzecz bezpieczeństwa publicznego), www.cnbop.pl/pl/wydawnictwa/ksiazki/wykorzystanie-bezzaogowych-platform-powietrznych-w-operacjach-na-rzecz-bezpieczestwa-publicznego_14839, bit.ly/3yq9VW9;

www: www.unrealengine.com/marketplace/en-US/product/modern-tanks-advanced-tank-blueprint-four-pack, bit.ly/3l0Aq1l;

www: uk.mathworks.com/products/computer-vision.html, bit.ly/2VtHPs2;

www: www.pytorch.org;

www: www.tensorflow.org;

www: www.ultralytics.com/yolov5;

www: www.intel.com/content/www/us/en/products/details/processors/movidius-vpu.html, intel.ly/3ZVeEeh

www: www.neptunstudio.com/PORTFOLIO/PID_PLATFORM.mp4, bit.ly/3yt56M2

www: www.pi-centrum.bialystok.pl, bit.ly/3ysS1SE

www: www.ardupilot.org/copter/docs/common-pixhawk-overview.html, bit.ly/41ZGPKV

www: www.warthunder.com

www: www.digitalcombatsimulator.com/

YouTube: Kiedy grafikę pomylisz z rzeczywistością (eng. When you confuse graphics with reality) – www.youtube.com/watch?v=lyOXK4wzf2Y, bit.ly/3ymjwxo;

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[52]   DCS (Digital Combat Simulator) – www.digitalcombatsimulator.com/