Profiling China's AI Developers:

NUDT's State Key Laboratory for Automatic Target Recognition

Summary

Recent review on online Chinese data has identified another research entity at the National University of Defense Technology (NUDT): the **State Key Laboratory for Automatic Target recognition**. This research base is located on the NUDT campus in Changsha, Hunan Province. Founded in 1992, it has been researching target recognition techniques for radar imaging and infrared systems.

Campus of the PLA's National University of Defense Technology in Changsha

Source: 17qq.com

An examination of the ATR Lab's research publications was conducted to answer three questions: are artificial intelligence (AI) mechanisms now part of this development effort; if so, when did AI mechanisms become part of the ATR Lab's research work; and what AI applications for weapons systems are under development now? A catalogue of their AI-related research was created from online journal-article data bases and is presented in the body of this report. This catalogue of publications shows the range of ATR Lab research interests and indicates that since 2016 the ATR Lab has been working on both AI technologies—such as algorithm development—as well as AI application to specific military missions. **The areas of ATR Lab research focus include:**

- **Utility of convolutional neural networks**
- **Unsupervised deep learning**
- **Application to radar image target recognition**
- **Real-time visual target tracking**
- **Aircraft tracking against difficult backgrounds**
- **Seaborne target detection**
- **Space object target tracking**

Background

Since July 2020, China Keyhole research has been focused on Chinese military development of AI-enabled systems. Key military research entities identified to date include the National Innovation Institute of Defense Technology (NIIDT) and its subordinate entity the Artificial Intelligence Research Center (both located in the same compound in Beijing), as well as education and research programs at the National University of Defense Technology (NUDT) in Changsha, Hunan Province. In the course of this research, the name of a separate entity at NUDT was found: the State Key Lab for Automatic Target Recognition. Since automatic target recognition (ATR) seemed like a military function where AI would have application, research was initiated on this entity to determine the nature of its work and whether AI had been incorporated into Chinese ATR systems. This report presents an initial catalogue of that research. A review of this work over time shows the introduction of extensive AI research in the last few years and the military applications that could incorporate these mechanisms.

ATR Lab and Its Mission

The full name of this entity appears to be "National University of Defense Technology State Key Lab for Automatic Target Recognition" (**国防科技大学自动目标识别重点实验室**). Variants include "Automatic Target Recognition Key Lab" and "ATR Lab" using English letters for the abbreviation ("ATR **实验室**"). One NUDT reference called it the "Precision Guidance and Automatic Target Recognition (ATR) National Defense Science Lab." For simplicity's sake, the name "ATR Lab" will be used below.

Although NUDT is fairly public about its education and training programs and does make reference to the existence of the ATR Lab as part of its organization, the references found in Chinese online media to this entity were limited in number. One of the few references was found in an August 2018 article in the Hunan Daily News, which described this dramatic event:

> "Two rays of light are rapidly approaching one another, when suddenly a bright flash lights up the night sky—an intercept missile and an "attacking" missile collide together. At this moment, two instructors from the NUDT ATR Key Lab's Technology Innovation Team are taking part, excited and unable to take their eyes off the big screen. This is a February 2018 test of a land-based mid-course anti-missile carried out in China's northwest Gobi test base by this team. It was completely successful. This sharp sword for air defense, developed with the participation of this team, is again unsheathed."

The author of this article is listed as Zhang Luping (**张路平**), whose name appears in other sources as ATR Lab personnel, so it is likely he was present for this test event and provided the account to the media. The Chinese Ministry of Defense separately confirmed in a statement that "China carried out a land-based mid-course missile interception test within its territory on Feb. 5, 2018 and achieved the desired test objective." The anti-missile system referred to here is not known, but the article said that it had been in development since 2012 and had entered flight testing in July 2017.

Published accounts of the establishment of the ATR Lab state that the National Defense Industries Committee ordered formation of a National Defense State Key Lab in 1992 "to put automatic target recognition for precision guided weapons on a fast track." This involved "organizing a new research office to develop a new type of intelligent ATR through the fusion of millimeter wave [radar] ATR with infrared ATR."

The news account cited above indicates that The ATR Lab's mission includes guidance systems for anti-missile weapons. It further states that the Innovation Team had been working on "military strategic requirements in the field of air defense anti-missile target information processing." The ATR Lab's role was described as research and development of the information processor, the "Big Brain"and the "Eyes" for this guided missile system, that allowed it to "think" much faster, "aim" more precisely, and "to accurately hit the target in several space tests."

Other unofficial media said that the ATR Lab "primarily conducts research in four areas: millimeter wave automatic target recognition technology, infrared ATR, ATR processor technology, and sensor fusion recognition." Other sources differentiate missions for the Lab as assigned to its components, referred to as Offices. NUDT material states that the ATR Lab Third Office conducts "research and development of laser imaging automatic target recognition, deeply embedded information processing, and intelligent image processing, and provides specialized services to the aerospace and security monitoring industries." (The Chinese term used here for "intelligent," "**智能**" [zhineng], is usually employed to mean AI-enabled.) The Lab's Fifth Office is involved "in information systems software and hardware development work for electronic signals, collection, storage, processing, and display."

ATR Lab Location

The address of the ATR Lab appears in recruiting announcements as No. 109 Deya Road, NUDT Compound 1, Kaifu District, Changsha, Hunan Province (**湖南省长沙市开福区德雅路 109 号国防科技大学一号院内**). This indicates it is on the main campus of NUDT (see image below), but it is not clear in which building it is located. Other accounts about this lab state that it "occupies close to 4,000 square meters (about 43,000 square feet)." Multiple sources indicate that the ATR Key Lab is subordinated to the NUDT College of Electronic Sciences. The current Director of the ATR Lab is Li Xiao (**李晓**).

NUDT compound in downtown Changsha, Hunan Province

Source: Google Earth

Application of AI in the ATR Lab

While this lab has been in operation since 1992, artificial intelligence in the modern sense—deep learning mechanisms training algorithms to recognize elements in the environment, identify them, and react intelligently to this environment—is a more recent development. In its early years, the ATR Lab may in fact have been developing ever smarter mechanisms for interpreting radar, visual, or infrared data, yielding target identification and tracking information. Several questions remain: are AI mechanisms now part of this development effort, when did AI mechanisms become part of the ATR Lab's research work, and what AI applications for weapons systems are under development now?

These questions are not discussed publicly in China for obvious security reasons. However, there are information sources available from which the ATR Lab's research history and current efforts can be gleaned. Chief among these are online repositories for academic journal articles that can be accessed from outside China without subscription. These are searchable data bases that make available article titles, authors, authors' organizations, and usually the abstract text. (Full text is generally available to registered users only.)

Search against the holdings of one of the most comprehensive of these data bases (cnki.net) allowed the extraction of articles credited to ATR Lab researchers and the arrangement of these articles along a timeline. A look at the titles over time showed little evidence (with a few exceptions) of AI-related terms up to about 2016. For example, a selection of journal article titles from 2011 to 2016 includes the following works:

"Space Target 3D Radar Imaging Method Based On Compression Awareness" (2011)

"Detecting the Presence of a Towed Decoy Based On Extended Single Pulse Comparison" (2011)

"Target Recognition Algorithm Based On Combination Moments For Laser Imaging Radar" (2012)

"Distortion Analysis On High Resolution Range Profile of Space Target and Motion Parameter Estimation" (2014)

"A Study Of Methods Of Adaptive Cancellations of Radio Frequency Interferences In Radio Astronomy" (2015)

"Mitigation of the Radio Frequency Interference Using An Adaptive Side-Lobe Cancellation Based On Accurate Delay Compensation" (2016)

These titles show research under way for imaging radar and for radio frequency interference problems. They appear designed for application to airborne target and space target imaging. For the most part, they lack elements of the terminology normally associated with AI systems development: "machine learning," "deep learning," "computer vision," algorithm development," or "neural networks." One title above from 2012 does refer to a target recognition *algorithm*, but it was not clear from this article that AI processes were involved.

Past the 2016 threshold, many of these themes continue in ATR Lab research, indicating that traditional target recognition mechanisms were still being developed. However, over the past five years there has been an increasing number of published research papers written by ATR Lab personnel that reflect the incorporation of AI techniques into target recognition mechanisms. Mapping out this body of research work shows the progression of ATR Lab interest in AI-enabled systems, the specific AI techniques that the ATR Lab has been working on, and at least some of the military missions that they foresee these mechanisms being applied to. The next section is a preliminary catalogue of titles, abstracts, and authors of ATR Lab work on AI-related technologies and systems.

ATR Lab Publications on AI Mechanisms

1997-2009

Actually, ATR Lab research on AI started well before this 2016 threshold, with one paper on neural networks published in 1997. AI-related terminology appeared only sporadically from that date for at least a decade. The following section shows text from these earliest research projects.

“Decision Fusion For Target Recognition Based On Neural Network Model” (1997)
“**Abstract:** Compared with normal decision fusion methods, a novel decision fusion algorithm based on modified ART2 (MART) neural network model is presented in this paper. It has advantages of the human brain, and the algorithm uses ‘matching function’ and ‘compromising function’ to remove the correlation of information and to obtain the ability of processing contradictory information. Meantime, the MART model can control the output of belief level by adaptively adjusting the parameters of the network.”

Chinese title: “**决策层信息融合的神经网络模型与算法研究**.”

Authors: Li Xiang (**黎湘**), Yu Wenxian (**郁文贤**), Zhuang Zhaowen (**庄钊文**), Guo Guirong (**郭桂蓉**). All are at the NUDT ATR State Ley Lab.

Comments: This is the earliest paper found that discusses neural networks, a key component of machine learning and a marker for the involvement of artificial intelligence in the process. 1997 seems to be early days for the exploration of AI applications in any country. Li Xiang is the only author that shows up later in ATR Lab research products associated with AI. Li Xiang is now a major general and the current President of NUDT. Guo Guirong was the original Director of the ATR Lab, establishing it in 1992 and remaining in its leadership position until retiring as a Lieutenant General in 2017.

Lt Gen (ret) Guo Guiring in 2020

Source: sc.gov.cn

Maj Gen Li Xiang in 2020

Source: nudt.edu.cn

“An Automatic Target Recognition Algorithm For Aerial Photos Based On Neural Networks” (2001)
“**Abstract:** Due to the complexity of automatic target recognition for aerial photos, this paper describes an automatic target recognition algorithm based on neural networks. It includes two stages, target detection and false-alarm rejection. The first stage operates on the entire image to detect potential targets quickly. The second stage attempts to reject false target-like objects while retaining as many targets as possible. The experimental results show the algorithm is feasible.”

Chinese title: “**一个基于神经网络的航空照片自动目标识别算法**.”

Authors: Li Biao (**李飚**) from the ATR Lab plus five others from other organizations.

Comments: The language of the abstract indicates that the process described is an application of neural network technology for identifying targets from a static image. No specific military application is suggested other than imagery interpretation. The “target” may simply be an object of any kind rather than a target for attack.

“A Fast Algorithm of Time-Delay Neural Network” (2009)
“**Abstract:** A neural network is one of the important research categories of artificial intelligence. It exhibits powerful error tolerant ability, excellent adaptivity and outstanding non-linear mapping capability. A time-delay neural network (TDNN) has the ability of memorizing by integrating time-delay units into a neural network, is more adaptable to sequential information processing and therefore of more practical application value. A TDNN algorithm suitable for hardware implementation is proposed to tackle the tremendous computational complexity in TDNN. The algorithm adopts a sequential process. By appropriate structure decomposition and intermediate variables storage, it decreases the repeated computation to the utmost degree and thus lowering the computational complexity effectively. It is shown that in certain dimension ranges the algorithm as compared with the batch processing method is advantageous both in computational load and memory space.”

Chinese title: “**时延神经网络的一种快速算法**.”

Authors: Xiang Huaitie (**肖怀铁**) and Fan Hongqi (**范红旗**), both identified here as just NUDT but both show up in later research papers as being from the ATR Lab.

Comments: Here the authors are describing a specific kind of neural network without reference to the kind of problem it might be applied to. Their discussion of an enhanced algorithm suggests that refinement of neural network technologies is under way at the ATR Lab.

2016-2018

As mentioned above, AI-related terminology began to appear more frequently starting in 2016. The papers found showed greater specificity in the types of deep-learning mechanisms being investigated and the military missions that could be enhanced by the application of these methods.

"SAR [Synthetic Aperture Radar] Image Target Recognition Based on Convolutional Neural Network" (2016)

"**Abstract:** This study presents a new method of Synthetic Aperture Radar (SAR) image target recognition based on a convolutional neural network. First, we introduce a class separability measure into the cost function to improve this network's ability to distinguish between categories. Then, we extract SAR image features using the improved convolutional neural network and classify these features using a support vector machine. Experimental results using moving and stationary target acquisition and recognition SAR datasets prove the validity of this method."

Chinese title: "**基于卷积神经网络的 SAR 图像目标识别研究.**"

Authors: Tian Zhuangzhuang (**田壮壮**), identified as a graduate student in the NUDT ATR Key Lab. Three others listed as authors, Zhan Ronghui (**占荣辉**), Hu Jiemin (**胡杰民**), Zhang Jun (**张军**), are not identified by organization but are listed as PhD's and are possibly advisers, presumably at NUDT.

Comments: This paper, written just a few years ago, is now addressing the direct application of AI technologies to specific military uses. Synthetic aperture radar (SAR) is a reconnaissance technology that uses airborne or space-based radar targeted at the ground to map terrain and manmade features. SAR as a technology has been available for decades, but this is the first ATR Lab research paper found that described AI use for SAR based on neural networks. The text of the paper describes deep learning processes and states that the purpose of applying deep learning technologies to this problem is to reduce the manual operations involved in feature extraction.

"Vehicle Detection Algorithm Based On SLPP-SHOG [Supervised Locality Preserving Projection – Spherical Histograms of Oriented Gradients] In Infrared Image" (2016)

"**Abstract:** In the past few years, the computer vision and pattern recognition community has witnessed a rapid growth of a new kind of feature extraction method, the manifold learning methods, which attempt to project the original data into a lower dimensional feature space by preserving the local neighborhood structure. Among these methods, locality preserving projection (LPP) is one of the most promising feature extraction techniques. Unlike the unsupervised learning scheme of LPP, this paper follows the supervised learning scheme, i.e. it uses both local information and class information to model the similarity of the data. Based on novel similarity, we propose two feature extraction algorithms, supervised optimal locality projection (SOLPP) and normalized Laplacian-based supervised optimal locality preserving projection (NL-SOLPP). Optimal here means that the extracted features via SOLPP (or NL-SOLPP) are statistically uncorrelated and orthogonal. We compare the proposed SOLPP and NL-SOLPP with LPP, orthogonal locality preserving projection (OLPP) and uncorrelated locality preserving projection (ULPP) on publicly available data sets. Experimental results show that the proposed SOLPP and NL-SOLPP achieve much higher recognition accuracy."

Chinese title: "**基于 SLPP-SHOG 的红外图像车辆检测方法.**"

Authors: Cai Wenjing (**蔡文靖**), Wang Luping (**王鲁平**), and Zhang Luping (**张路平**), all identified as from the "NUDT Electronic Science and Engineering College ATR State Key Lab," indicating specifically where the lab is subordinated.

Comments: As a discussion of the testing of new deep learning techniques, this paper shows further refinement of machine learning for AI applications. In this case, a specific military application—vehicle identification—is indicated by the paper's title, although how this form of computer vision would be used in military operations is not made clear. The language of the abstract also indicates that the ATR Lab's function, at least in this case, is to develop and propose training algorithm improvements and then test their effectiveness in enhancing computer vision technologies.

"Multi-Task Hierarchical Feature Learning for Real-Time Visual Tracking" (2018)

"**Abstract:** Recently, the tracking community leads a fashion of end-to-end feature learning using convolutional neural networks (CNNs) for visual object tracking. Traditional trackers extract feature maps from the last convolutional layer of CNNs for feature representation. This single-layer representation ignores target information captured in the earlier convolutional layers. In this paper, we propose a novel hierarchical feature learning framework, which captures both high-level semantics and low-level spatial details using multi-task learning. Particularly, feature maps extracted from both the shallow layer and the deep layer are input into a correlation filter layer to encode fine-grained geometric cues and coarse-grained semantic cues, respectively. Our network performs these two feature learning tasks with a multi-task learning strategy. We conduct extensive experiments on three popular tracking datasets, including OTB, UAV123, and VOT2016. Experimental results show that our method achieves remarkable performance improvement while running in real time."

Published by IEEE in English.

Authors: Kuai Yangliu, Wen Gongjian, Li Dongdong, all identified as being from the NUDT ATR Key Lab (no Chinese-character names included).

Comments: Moving ahead two years from previous AI-related papers, this report now addresses technologies used for real-time processing and target tracking. The language is esoteric and specific to deep-learning technology, but again is focused on the uses of convolutional neural networks and clearly hints at increasing complexity of the AI processes being applied to military functions.

"Improving Hyper-Spectral Anomaly Detection With a Simple Weighting Strategy" (2018)

"**Abstract:** Numerous hyper-spectral anomaly detection (AD) methods suffer from complex background compositions and sub-pixel objects due to their inadequate Gaussian- [normal] distributed representations for non-homogeneous backgrounds or their low discrimination between sub-pixel anomalies and the background. To alleviate these issues, a novel hyper-spectral AD weighting strategy based on tensor decomposition and cluster weighting is proposed in this paper. Equipped with this simple but effective strategy as a post-process, the detection performances of generic AD methods can be significantly boosted. In this strategy, Tucker decomposition is adopted to remove the major background information. A parameter-adaptive k-means clustering method is then applied on the decomposed anomaly/noise data cube to assemble homogeneous regions. After segmenting the clustering result into a number of non-overlapping eight connected domains, corresponding weights are assigned to large domains according to an improved Gaussian weight function. Finally, the resulting weight matrix is multiplied by the results of the detectors to achieve a performance boost. Experiments on two hyper-spectral data sets validate the effectiveness of the proposed strategy."

Published by IEEE in English.

Authors: Zhu Lingxiao, Wen Gongjian, and Qiu Shaohua from the NUDT ATR Key Lab, plus Zhang Xing from another organization (no Chinese-character names included).

Comments: In the context of the abstract for this paper, anomaly detection is a key element of computer vision. The processes described seem directed at being able to accurately remove the background of an image and thus define an object. It appears that this refers to the ability to identify objects in an image as distinct from the background rather than target detection in a military sense. Thus, the research here appears focused on refinement of a deep learning process and not development of a reconnaissance system.

2019-2020

The increased volume of AI-related research papers found for the past two years suggests an acceleration of AI research at the ATR Lab. Research work on several aspects of deep learning is reflected in these works. Applications being suggested include the identification of airborne, land-based, and seaborne targets.

"Learning Target-Aware Correlation Filters For Visual Tracking" (2019)

"**Abstract:** Discriminative Correlation Filters (DCF) have achieved enormous popularity in the tracking community. Generally, DCF based trackers assume that the target can be well shaped by an axis-aligned bounding box. Therefore, in terms of irregularly shaped objects, the learned correlation filter is unavoidably deteriorated by the background pixels inside the bounding box. To tackle this problem, we propose Target-Aware Correlation Filters (TACF) for visual tracking. A target likelihood map is introduced to impose discriminative weight on filter values according to the probability of this location belonging to the foreground target. According to the TACF formulation, we further propose an optimization strategy based on the Preconditioned Conjugate Gradient method for efficient filter learning. With hand-crafted features (HOG), our approach achieves state-of-the-art performance (62.8% AUC) on OTB100 while running in real-time (24 fps) on a single CPU. With shallow convolutional features, our approach achieves 66.7% AUC on OTB100 and the top rank in EAO on the VOT2016 challenge."

Published by Science Direct in English.

Authors: Li Dongdong, Wen Gongjian, and Kaui Yangliu, identified in this article only as being from NUDT but elsewhere identified as ATR Lab researchers.

Comments: Despite repeated references to targets and visual tracking, it again appears that the technologies described concern the identification of objects in image data and the tracking over time in subsequent imagery. This would appear to have application to real-time tracking of actual targets in radar imagery, but no connection to such operational processes are actually described here.

"A Dataset For Detection and Tracking Of Dim Aircraft Targets Through Radar Echo Sequences" (2019)

"**Abstract:** Radar detection and tracking of dim targets under clutter has been a hot yet difficult issue in the fields of military and civilian applications, such as low-altitude security prevention and control, regional situation monitoring, long-range precision strike, battlefield intelligence and reconnaissance. However, there has been problems related to existing radar data, such as poor pertinence of data scenarios, insufficient authenticity of simulation data, nonstandard formatting of measured data, incomplete scene description and calibration information, etc. To meet the data requirements for studies on the radar target detection and tracking technologies under clutter, we took the fixed-wing UAV under clutter as detection object for radar outfield data acquisition and data processing, through which to generate a standard dataset for the radar detection and tracking of dim targets under clutter. This dataset covers typical scenarios such as strong clutter, low signal-to-noise ratio, high dynamics, strong maneuvering, and changing target number. It consists of 15 radar echo sequences in total, and each echo sequence contains a number of pulse signals of a certain temporal duration, a corresponding gate file and a true-value labeling file. With standardized format and accurately labeled information, the dataset can provide basic data for the design and verification of radar dim target detection and tracking algorithms and for studies of clutter characteristics."

Chinese title: "**雷达回波序列中弱小飞机目标检测跟踪数据集**."

Authors: Song Zhiyong (**宋志勇**), Hui Bingwei (**回丙伟**), Fan Hongqi (**范红旗**),Zhou Jianxiong (**周剑雄**), Zhu Yongfeng (**朱永锋**), and Da Kai (**达凯**), all from NUDT ATR Key Lab, plus seven others from the 25th Institute in 2nd Academy of China Aerospace Science and Technology Group, Beijing.

Comments: The text of this paper also stated: "Requirements for AI development for radar data: along with AI technology development, research on target detection, recognition, and classification based on deep learning has become a hot item. The need for deep networks for radar data is very great, especially standard radar echo data sets in specific application scenarios." This reinforces what is said in the abstract, that the goal of this research is development of deep learning techniques to overcome traditional weaknesses in radar target detection and tracking. The research here is one level of abstraction removed from algorithm testing, however. It appears to be limited to the evaluation of specific radar data sets to see if they would even be useful as a basis for algorithm testing.

"Learning Fully Convolutional Network for Visual Tracking With Multi-Layer Feature Fusion" (2019)

"**Abstract:** Convolutional neural networks (CNN) are powerful models that yield hierarchies of features. In the paper we present a new approach for general object tracking based on the fully convolutional network (FCN) with multi-layer feature fusion. The designed network combines semantic information from deep, coarse layers and appearance information from shallow, fine layers to make accurate pixel-wise objectness [sic] prediction. The network is first pre-trained offline using a large set of videos with annotated heat map ground truth to obtain a general notion of foreground objects, and later fine-tuned using the first frame to adapt to the particular object instance. In online tracking, the location corresponding to the maximum target objectness in the search

image is determined as the new target location, and the scale estimation is handled by incorporating a correlation filter branch into the network. An efficient updating strategy is proposed to further improve the tracking performance. Extensive experiments performed on the widely used tracking benchmark OTB100 show that the proposed algorithm outperforms many other state-of-the-art trackers."

Published by ResearchGate in English.

Authors: Kuai Yangliu, Wen Gongjian, and Li Dongdong, all ATR Lab researchers as identified above (no Chinese-character named given).

Comments: This paper describes algorithm development for object tracking in video data, with a reference to "heat map ground truth" suggesting this is infrared imagery with a ground-clutter background. The targets again appear to be objects in the imagery and not necessarily targets in the military sense.

"Research on the Application of Deep Learning Network to Radar Target Recognition Technique" (2019)

"**Abstract:** Target recognition based on radar is crucial to space target recognition. The manners of extracting features in target classification of the space environments and threat scenarios is complex and dynamic, which requires that space target recognition technology can automatically adapt to these complex and diverse needs. Existing radar target recognition methods, however, usually extract features based on a priori knowledge, and then build a feature recognition algorithm based on these hand-craft features. It is well known that the performance of the feature extraction is greatly dependent on the prior knowledge, which makes it difficult to meet the requirements of the actual combat environment of change and complexity. In order to solve the above problems in radar target recognition, this thesis firstly analyzes the characteristics of specific recognition scene extraction in radar target signal sequence data, designs adaptive feature learning algorithms from radar target data, extracts discriminative features, and builds the classifiers based on these features."

Chinese title: "**基于深度学习网络的雷达目标识别技术研究**."

Author: Xia Jingyuan (**夏靖远**) of NUDT Information and Communications Engineering College, with Li Xiang (**黎湘**) listed as adviser. This appears to be Xia Jingyuan's graduate research thesis. Li Xiang was the primary author of the earliest ATR Lab paper on neural networks in 1997.

Comments: This paper is the first found to refer directly to radar space target detection as well as to "threat scenarios" and "the combat environment" in that context. It starts by highlighting the existing difficulty of meeting real-time operational requirements using radar to do target identification, and then proposes the application of learning algorithms to improve real-time accuracy. It does not indicate whether the researchers have yet found a solutions that works. It does, however, show that the ATR Lab is working on AI enhancements to radar as a targeting mechanism for potential military operations in space.

"Video Anomaly Detection and Localization via Gaussian Mixture Fully Convolutional Variational Auto-Encoder" (2020)

"**Abstract:** We present a novel end-to-end partially supervised deep learning approach for video anomaly detection and localization using only normal samples. The insight that motivates this study is that the normal samples can be associated with at least one Gaussian component of a Gaussian Mixture Model (GMM), while anomalies do not belong to any Gaussian component. The method is based on Gaussian Mixture Variational Auto-Encoder, which can learn feature representations of the normal samples as a Gaussian Mixture Model trained using deep learning. A Fully Convolutional Network (FCN) that does not contain a fully-connected layer is employed for the encoder-decoder structure to preserve relative spatial coordinates between the input image and the output feature map. Based on the joint probabilities of each of the Gaussian mixture components, we introduce a sample energy based method to score the anomaly of image test patches. A two-stream network framework is employed to combine the appearance and motion anomalies, using RGB frames for the former and dynamic flow images, for the latter."

Published by ResearchGate in English.

Authors: Wen Gongjian and Qiu Shaohua of NUDT, identified elsewhere as ATR Lab personnel, plus two others.

Comments: This is the first of four AI-related ATR Lab papers found that have been published in the past year. This work deals with deep-learning algorithm development for application to video anomaly detection.

"Robust Moving Target Localization in Distributed MIMO Radars Via Iterative Lagrange Programming Neural Network" (2020)

"**Abstract:** Moving target localization based on the distributed multiple-input multiple-output (MIMO) radar has attracted great research interest recently. However, the occurrence of outliers in the measurements is always unavoidable in many practical situations, which degrades the performances of ordinary algorithms significantly. In this paper, a robust moving target localization method is proposed to tackle this issue. We first present the relevant maximum likelihood (ML) estimation, and recast it to a constrained optimization problem afterwards. We employ the Lagrange programming neural network (LPNN) framework to solve it due to its effectiveness for non-convex optimization problems. Furthermore, to mitigate the adverse influence caused by

outliers, an iterative reweighting scheme is developed and integrated with the LPNN. The target position and velocity estimations can be refined through an iteration process. Simulation results demonstrate that our proposed method not only has an outstanding performance under the Gaussian measurement noise, but is also very robust against outliers."

Published by IEEE in English.

Authors: Zhu Lingxiao and Wen Gongjian of NUDT, plus two others (no Chinese-character name given).

Comments: The abstract indicates that this work does concern application of a specific type of neural network to improve radar detection of a moving target, a direct military application. MIMO radar is a system of multiple antennas with each antenna radiating a signal independently of the other transmitting antennas and using multiple receiving antennas. MIMO radar systems can be used to improve spatial resolution and provide improved immunity to interference. The specific Chinese radar system under consideration is not clear.

"A Convolutional Neural Network Based Approach To Sea Clutter Suppression For Small Boat Detection" (2020)

"**Abstract:** Current methods for radar target detection usually work on the basis of high signal-to-clutter ratios. In this paper we propose a novel convolutional neural network based dual-activated clutter suppression algorithm, to solve the problem caused by low signal-to-clutter ratios in actual situations on the sea surface. Dual activation has two steps. First, we multiply the activated weights of the last dense layer with the activated feature maps from the upsample layer. Through this, we can obtain the class activation maps (CAMs), which correspond to the positive region of the sea clutter. Second, we obtain the suppression coefficients by mapping the CAM inversely to the sea clutter spectrum. Then, we obtain the activated range-Doppler maps by multiplying the coefficients with the raw range-Doppler maps. Measurement on real datasets verified the effectiveness of the proposed method."

Published by Zhejiang University in English.

Authors: Li Guanqing, Song Zhiyong, and Fu Qiang, all of NUDT ATR National Key Lab (no Chinese-character names given).

Comments: Again, the language in the abstract describing the experimental process is rather opaque for the non-specialist, but is does make clear this technology is intended to reduce sea-surface background clutter from radar systems targeted on small surface vessels. Like cases described above, the AI application is an algorithm based on a convolutional neural network, which has become a typical reference in several of these papers.

"Unsupervised Deep Learning Methods for Representation and Classification of Remote Sensing Images" (2020)
"**Abstract:** Remote sensing images have already played an increasingly important role in practical tasks such as military reconnaissance, mapping, environmental monitoring, geographic information systems, and precision agriculture. The key process for these tasks is the feature representation for remote sensing images. However, due to the limitation of the representational ability, researches have focused on the deep models to obtain more discriminative features from remote sensing images. Among these deep models, convolutional neural networks (CNNs), which are the most famous one, have achieved expressive results in many computer vision tasks. However, the good performance of CNNs requires large amounts of labeled samples. While in traditional remote sensing scenes, marking data is usually time-consuming and costly. Therefore, based on a convolutional neural network, this work mainly focuses on unsupervised learning methods, which don't need labeled data for training, and tries to solve the problem caused by the lack of labeled samples in real-world application. First, this paper proposes a Balanced Data Driven Sparsity (BDDS) method to improve the unsupervised feature representation of CNNs. Second, this paper presents an Unsupervised Convolutional Feature Fusion Network (UCFFN), which realizes the unsupervised learning of the deep model as well as the information fusion in the feature level."

Chinese title: "**基于无监督深度学习的遥感图像表述和分类方法**."

Author: Yu Xiang (于洋) of NUDT with Zhong Ping (钟平) as adviser for a probable graduate thesis. Zhong Ping is identified in other sources as an ATR Lab researcher.

Comments: The proposed application for this research work is the automated identification of objects in remote sensing images which, as stated, has utility in military reconnaissance as well as other operations. As in several previous papers, the author here proposes the use of deep learning on convolutional neural networks, but with unsupervised learning, letting the network train without pre-labeling objects in the data.

"Support Vector Data Description Based Novelty Detection and Kernel Feature Extraction" (2020)
"**Abstract:** One of the most critical problems for machine learning methods is overfitting. The overfitting problem is a phenomenon in which the accuracy of the model on unseen data is poor whereas the training accuracy is nearly perfect. This problem is particularly severe in complex models that have a large set of parameters. In this paper, we propose a deep learning neural network model that adopts the support vector data description

(SVDD). The SVDD is a variant of the support vector machine, which has high generalization performance by acquiring a maximal margin in one-class classification problems. The proposed model strives to obtain the representational power of deep learning. Generalization performance is maintained using the SVDD. The experimental results showed that the proposed model can learn multi-class data without severe overfitting problems."

Chinese title: "基于支持向量数据描述的异常检测与核特征提取方法研究."

Author: Wang Kunzhe (王昆哲) of NUDT with Xiao Huaitie (肖怀铁) as doctoral adviser. Xiao Huaitie is elsewhere identified as an ATR Lab researcher.

Comments: This work appears to be on a more theoretical level rather than striving for development of a specific military application. It describes the use of a support vector data description, a form of support vector machine, a computer algorithm that learns by example to assign labels to objects. Thus, it appears to be related to the previous article training is done without pre-labeling objects. Like several of the papers, its research framework starts with identification of a problem, proposes an algorithmic solution, tests it, and reports how the AI process has been improved.

"Research on Partial Configuration Model Based Partially Occluded Object Detection Methods in High-resolution Remote Sensing Images" (2020)

"Abstract: Object detection is one of important tasks and research hotspots in remote sensing image interpretation. With the great development of sensors, the spatial resolution of remote sensing images is getting higher and higher, and the demand for refined object interpretation makes the frequently occurring problem of object occlusion in remote sensing images increasingly prominent. How to quickly find as many suspicious objects as possible from complex backgrounds and accurately infer the true location of a full object from unoccluded evidence are the difficult points for partially occluded object detection (POOD). To solve these problems, this dissertation uses the deformable part-based model (DPM) as a theoretical basis, and proposes a partial configuration model (PCM) specially oriented for POOD. Through modeling the local features of objects, the spatial and evidential interrelationships between local partial configurations and the full-extent object are built. The fusion of multiple partial configuration evidences will then contribute to the description of the object occlusion state, which ultimately achieves high detection recall, high locating accuracy and high computational efficiency under partial occlusion."

Chinese title: "基于部分配置模型的高分辨率遥感图像遮挡目标检测方法研究."

Author: Qiu Shaohua (邱少华) of NUDT with Wen Gongjian (文贡坚) as doctoral adviser. Both are identified in other articles above as ATR Lab personnel.

Comments: This is further work on automated object detection in reconnaissance imagery, a director military application. The problem to be solved here is the fact that frequently an object cannot be seen in full because it is partially hidden (occluded) by another object. In this case, the researcher is testing an AI process that combines multiple views of a partially hidden object into an accurate identity and location for that object.

Conclusions

The catalogue above shows a development vector of ATR Lab research *interests*, which may not in all cases correlate to AI-enabled *systems* development. To sum up the progression of their work, the following key phase points should be noted:

- Initial discussion of neural networks (1997)
- Exploration of specific neural network types (2009)
- Application to radar (SAR) image target recognition (2016)
- Utility of convolutional neural networks (CNN) (2016)
- Real-time visual target tracking (2018)
- Aircraft tracking against difficult background (2019)
- Space target tracking (2019)
- Expanding discussion of CNN (2019-2020)
- Seaborne target detection (2020)
- Unsupervised deep learning (2020)

It appears clear that the ATR Lab is a research entity that currently has both AI techniques and applications development missions. Put another way, the ATR Lab's published research shows that it has been working on AI technologies—algorithm development—as well as AI application to specific military missions. It also appears to be a research element distinct from the other NUDT entities, such as its graduate and doctoral research bases, that are also conducting AI research. As such, the ATR Lab merits continued monitoring to help track what AI-enabled systems China may try to put into operation.