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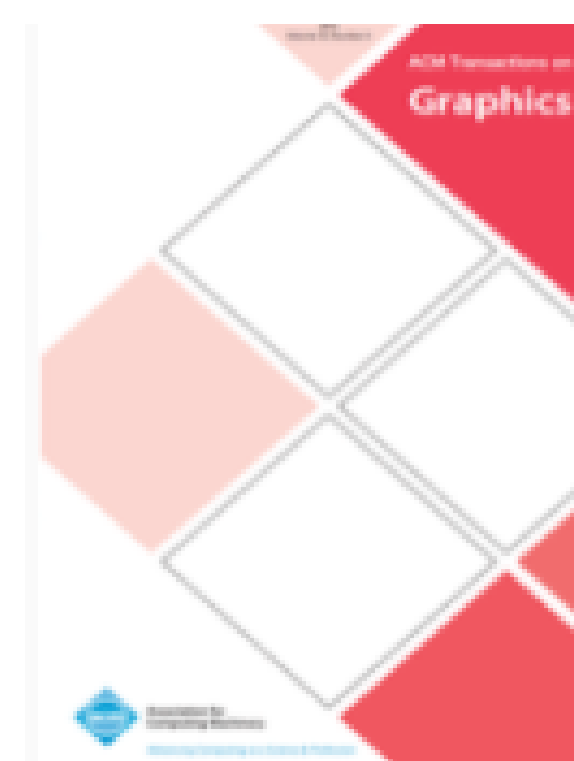


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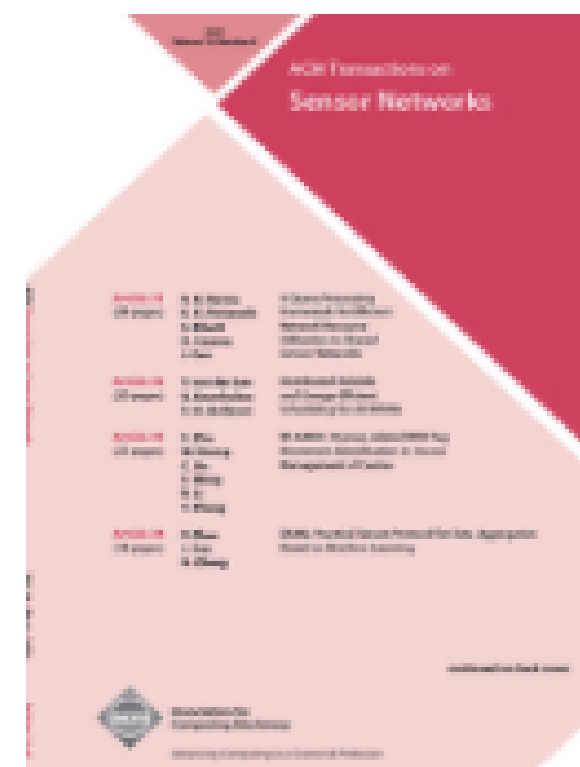


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Machine Learning Predictive Analytics for Player Movement Prediction in NBA: Applications, Opportunities, and Challenges

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ABSTRACT
Recently, strategies of National Basketball Association (NBA) teams have evolved with the skillsets of players and the emergence of advanced analytics. This has led to a more free-flowing game in which traditional positions and play calls have been replaced with player archetypes and read-and-react offenses that operate off a variety of isolated actions. The introduction of position tracking technology by SportVU has added the analysis of these patterns by offering a vast dataset of on-court behavior. There have been numerous attempts to identify and classify patterns by evaluating the outcomes of offensive and defensive strategies associated with actions within this dataset, a job currently done manually by reviewing game tape. Some of these classification attempts have used supervised techniques that begin with labeled sets of plays and feature sets to automate the detection of future cases. Increasingly, however, deep learning approaches such as convolutional neural networks have been used in conjunction with player trajectory images generated from positional data. This enables classification to occur in a bottom-up manner, potentially discerning unexpected patterns. Others have shifted focus from classification, instead using this positional data to evaluate the success of a given possession based on spatial factors such as defender proximity and player factors such as role or skillset. While play action detection, classification and analysis have each been addressed in literature, a comprehensive approach that accounts for modern trends is still lacking. In this paper, we discuss various approaches to action detection and analysis and ultimately propose an outline for a deep learning approach of identification and analysis resulting in a queryable dataset complete with shot evaluations, thus combining multiple contributions into a serviceable tool capable of assisting and automating much of the work currently done by NBA professionals.

KEYWORDS
Predictive Analytics, Machine Learning, Clustering, Action Recognition, NBA Video Analysis, Data Mining, Survey

CCS CONCEPTS
• Information systems → Data mining, Computing methodologies → Machine learning algorithms.

ACM Reference Format:
Dembe Koi Stephanos, Ghaith Husari, Brian T. Bennett, and Emma Stephanos. 2021. Machine Learning Predictive Analytics for Player Movement Prediction in NBA: Applications, Opportunities, and Challenges. In *ACM Southeast Conference (ACMSE 2021)*, April 15-17, 2021, Virtual Event, USA, ACM, New York, NY, USA, 7 pages. <https://doi.org/10.1145/3409334.3452064>

1 INTRODUCTION
An interesting recent application of machine learning is the study of strategies and patterns in major sports. Since 2012, when SportVU first started capturing player location data during National Basketball Association (NBA) games, there have been myriad pursuits to parse this raw data and extract meaningful features about players and the game itself. Professional basketball is a fast-paced, complex system that is continuously evolving, making high-level features challenging to obtain. As a result, most work identifying and analyzing individual plays or actions within a game is still performed by humans watching game tape. Several insightful approaches have been used in attempts to remedy this by using modern machine learning tools like support vector machine (SVM) classifiers, neural networks, and clustering algorithms to automate these time-consuming tasks [10, 12, 14, 19, 21, 23]. Many of these approaches seek to limit the problem by focusing on a particular play or aspect of the game, but a coherent end-to-end system that parses raw data and provides AI-driven recommendations has yet to be fully realized. In this paper, we will examine and critique some of the more effective approaches to pattern mining NBA player movement data, focusing primarily on the most commonly researched play action in literature: the pick-and-roll. We ultimately propose a design for an analytic pipeline capable of play classification, pattern detection, and quality evaluation with actionable recommendations.

Machine Learning Predictive Analytics for Player Movement Prediction in NBA: Applications, Opportunities, and Challenges

D. Stephanos, G. Husari, B. Bennett, E. Stephanos

2 BACKGROUND
Basketball is a team sport in which two teams of five active players compete in timed possessions to amass as many points as possible by scoring, or getting the basketball into their goal, a circular rim positioned 10ft in the air with a glass backboard. Several restrictions are placed on players, who must dribble or bounce the ball when moving and may not leave the bounds of the rectangular court. In the NBA, games involve as many as fifteen players per team, with twenty-four seconds possessions spanned out over four, twelve-minute quarters. Traditionally, a variety of plays, coordinated actions by a team involving multiple passes and player movements, are performed in sequence with the objective of creating valuable scoring opportunities. Recently, these strategies have significantly evolved from long-scripted plays, to read-and-react offenses in which a variety of independent actions are performed by players who then read the defensive response and react accordingly.

2.1 Key Terms
First, we must define key terms pertinent to our discussion. Perhaps most importantly are two key terms we have already used: **play** and **action**. For our purposes, we will define a **play** as a strategic and intentional sequence of actions taken out by cooperating offensive players in an effort to create the space required for a valuable scoring attempt and an **action** as a discrete interaction between 2- offensive players and their corresponding defenders. Both the approach and execution stages may be executed in a number of variants. Since only one player may be in possession of the ball at a given time, many of these plays and actions involve what is called a **screen**, in which an offensive player positions themselves firmly between a defending player and the ball handler, forcing that defending player to navigate around them, subsequently creating space for the non-screening offensive player.

There are many versions of screens, each with several additional variants, but perhaps the most common is the on-ball screen. An on-ball screen occurs when an offensive player sets a screen for the ball handler, and the ball handler then guides their defender into the screen. This can be broken in two stages: the approach

3 DATA
In 2012, the NBA began tracking player movements during games by installing a total of six cameras that capture the location of all ten players on the court, as well as the ball and three referees, twenty-five times per second. This data was publicly available through the

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RESEARCH-ARTICLE

Visual Affordance and Function Understanding: A Survey

Authors: Mohammed Hassanin, Salman Khan, Murat Tahtali [Authors Info & Affiliations](#)

Publication: ACM Computing Surveys • April 2021 • Article No.: 47 • <https://doi.org/10.1145/3446370>

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Visual Affordance and Function Understanding: A Survey

MOHAMMED HASSANIN, University of New South Wales Canberra, Australia
SALMAN KHAN, Inception Institute of Artificial Intelligence, IAT, UAE
MURAT TAHTALI, University of New South Wales Canberra, Australia

Nowadays, robots are dominating the manufacturing, entertainment, and healthcare industries. Robot vision aims to equip robots with the capabilities to discover information, understand it, and interact with the environment, which require an agent to effectively understand object affordances and functions in complex visual domains. In this literature survey, first, “visual affordances” are focused on and current state-of-the-art approaches for solving relevant problems as well as open problems and research gaps are summarized. Then, sub-problems, such as affordance detection, categorization, segmentation, and high-level affordance reasoning, are specifically discussed. Furthermore, functional scene understanding and its prevalent descriptors used in the literature are covered. This survey also provides the necessary background to the problem, sheds light on its significance, and highlights the existing challenges for affordance and functionality learning.

CCS Concepts: • Computing methodologies → Vision for robotics;

Additional Key Words and Phrases: Affordance prediction, functional scene understanding, deep learning, visual reasoning

ACM Reference format:
Mohammed Hassanin, Salman Khan, and Murat Tahtali. 2021. Visual Affordance and Function Understanding: A Survey. *ACM Comput. Surv.* 54, 3, Article 47 (April 2021), 35 pages.
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1 INTRODUCTION

Affordance understanding is concerned with the possible set of actions an environment allows, an area of study that aims to answer the question of how an object can be used by an agent. Ecological psychologist James Gibson was the first to introduce the concept of affordances in 1966 [37]. Since then, this theory has been extensively used in the design of better and more robust robotic systems capable of operating in complex and dynamic environments [53]. In contrast to affordances, which are directly dependent on an actor, functionality understanding relates to identifying the possible set of tasks that can be performed with an object. Therefore, an object’s function is a permanent property of it independent of the characteristics of its user. Affordance and functional understanding not only enable humans or Artificial Intelligence (AI) agents to better interact with the world but also provide valuable feedback to product designers who need to consider potential

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ACM Computing Surveys, Vol. 54, No. 3, Article 47. Publication date: April 2021.

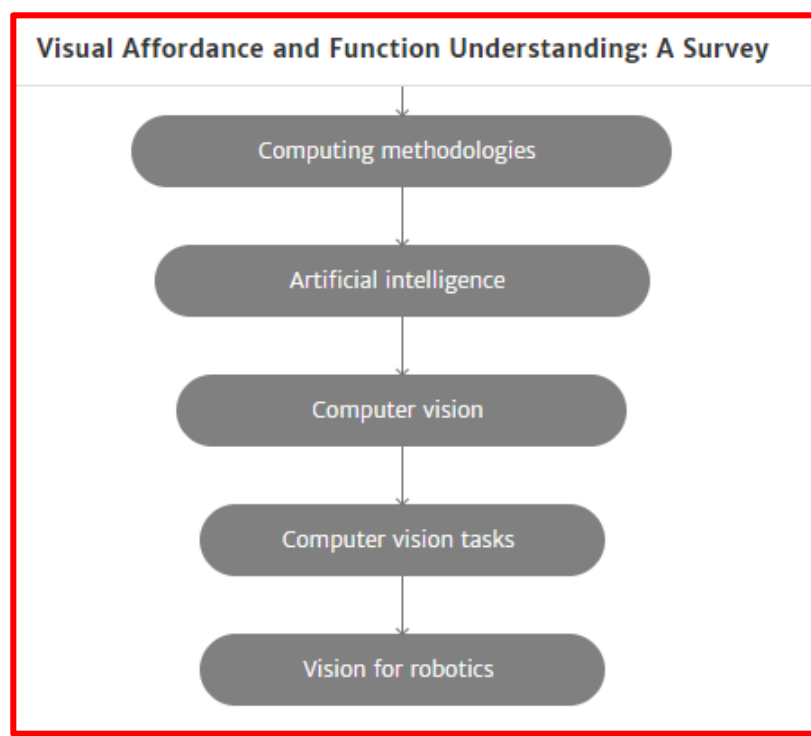
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Abstract

Nowadays, robots are dominating the manufacturing, entertainment, and healthcare industries. Robot vision aims to equip robots with the capabilities to discover information, understand it, and interact with the environment, which require an agent to effectively understand object affordances and functions in complex visual domains. In this literature survey, first, “visual affordances” are focused on and current state-of-the-art approaches for solving relevant problems as well as open problems and research gaps are summarized. Then, sub-problems, such as affordance detection, categorization, segmentation, and high-level affordance reasoning, are specifically discussed. Furthermore, functional scene understanding and its prevalent descriptors used in the literature are covered. This survey also provides the necessary background to the problem, sheds light on its significance, and highlights the existing challenges for affordance and functionality learning.

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Marta Kwiatkowska

December 2020, pp 1–3 • <https://doi.org/10.1145/3324884.3418901>

Computing systems are becoming ever more complex, with decisions increasingly often based on deep learning components. A wide variety of applications are being developed, many of them safety-critical, such as self-driving cars and medical diagnosis. ...

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2020 35th IEEE/ACM International Conference on Automated Software Engineering (ASE)

Safety and Robustness for Deep Learning with Provable Guarantees

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ABSTRACT
Computing systems are becoming ever more complex, with decisions increasingly often based on deep learning components. A wide variety of applications are being developed, many of them safety-critical, such as self-driving cars and medical diagnosis. These deep learning models are often developed using deep learning frameworks that are not designed to be provably safe. This paper introduces a new approach to deep learning model development, which uses deep learning frameworks that are designed to be provably safe. This paper introduces a new approach to deep learning model development, which uses deep learning frameworks that are designed to be provably safe. This paper introduces a new approach to deep learning model development, which uses deep learning frameworks that are designed to be provably safe.

1 INTRODUCTION
Much of the recent success of Artificial Intelligence (AI) derives from deep learning [1]. Deep neural networks (DNNs) have been developed for a variety of tasks, including computer vision, face recognition, autonomous driving, machine translation, speech recognition, text analysis and medical diagnosis. Unfortunately, neural networks are susceptible to adversarial perturbations [2, 3]. An adversarial example is an input which, though nearly indistinguishable to a human observer, causes the network to misclassify. As an illustrative example, Figure 1 shows an image of a truck (left) correctly classified by a conventional neural network, which is then misclassified after changing only a few pixels. This is an example of an adversarial example (AE), typically achieved by small, non-random perturbations of the original input. These perturbations are tiny, which a human observer would not classify correctly. Another important class of adversarial examples are mutation-based, which preserve the network's operations while making semantic changes, but are not necessarily close to the original input with respect to the distance function. Adversarial examples have now been demonstrated for virtually all applications of deep learning, and the ease with which they can be obtained highlights the need for appropriate safety mechanisms to use during deployment, as well as software development frameworks to ensure the safety and robustness of neural networks, as argued in this paper.

CCS CONCEPTS
Theory of computation → Logic and verification; Computing methodologies → Neural networks.

KEYWORDS
Neural networks, robustness, formal verification, Bayesian neural networks.

ACM Reference Format
Kwiatkowska, M. Safety and Robustness for Deep Learning with Provable Guarantees. In 35th IEEE/ACM International Conference on Automated Software Engineering (ASE '20), September 14–18, 2020, Virtual Event, Australia. ACM, New York, NY, USA, 3 pages. <https://doi.org/10.1145/3324884.3418901>

1 This paper is derived from the Technical Report TR2020-01, available at <https://arxiv.org/abs/2008.01191>.
2 This paper is derived from the Technical Report TR2020-01, available at <https://arxiv.org/abs/2008.01191>.

2 ROBUSTNESS ASSURANCE FOR NEURAL NETWORKS
This research is supported by the EPSRC grant EP/S010336/1 (EPIC) and the EPSRC grant EP/S010336/2 (EPIC).

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INVITED-TALK Machine Learning @ Amazon
Rajeev Rastogi
CODS-IKDD '15: Proceedings of the 2nd IKDD Conference on Data Sciences • March 2015, Article No.: 2, pp 1 • <https://doi.org/10.1145/2778865.2778867>
In this talk, I will first provide an overview of the key Machine Learning (ML) applications we are developing at Amazon. I will then describe a matrix factorization model that we have developed for making product recommendations

ABSTRACT Security engineering for machine learning (keynote)
Gary McGraw
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