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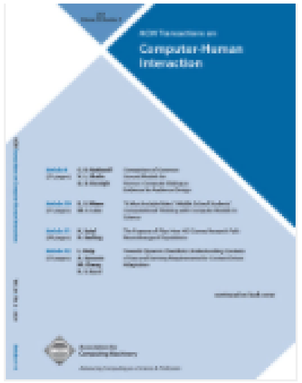

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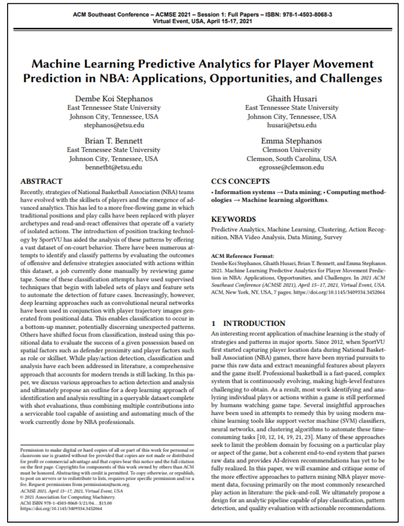

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Machine Learning Predictive Analytics for Player Movement Prediction in NBA: Applications, Opportunities, and Challenges

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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 offensives that operate off a variety of isolated actions. The introduction of position tracking technology by SportVU has aided 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.

CCS CONCEPTS

• **Information systems** → **Data mining**; • **Computing methodologies** → **Machine learning algorithms**.

KEYWORDS

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

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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 domain 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.

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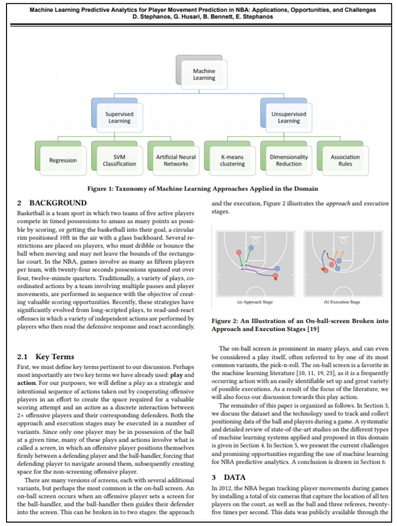

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D. Stephanos, G. Husari, B. Bennett, E. Stephanos

Figure 1: Taxonomy of Machine Learning Approaches Applied in the Domain

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 to two stages: the approach and the execution, Figure 2 illustrates the *approach* and *execution* stages.

Figure 2: An Illustration of an On-ball-screen Broken into Approach and Execution Stages [19]

The on-ball screen is prominent in many plays, and can even be considered a play itself, often referred to by one of its most common variants, the pick-n-roll. The on-ball screen is a favorite in the machine learning literature [10, 11, 19, 23], as it is a frequently occurring action with an easily identifiable set up and great variety of possible executions. As a result of the focus of the literature, we will also focus our discussion towards this play action.

The remainder of this paper is organized as follows. In Section 3, we discuss the dataset and the technology used to track and collect positioning data of the ball and players during a game. A systematic and detailed review of state-of-the-art studies on the different types of machine learning systems applied and proposed in this domain is given in Section 4. In Section 5, we present the current challenges and promising opportunities regarding the use of machine learning for NBA predictive analytics. A conclusion is drawn in Section 6.

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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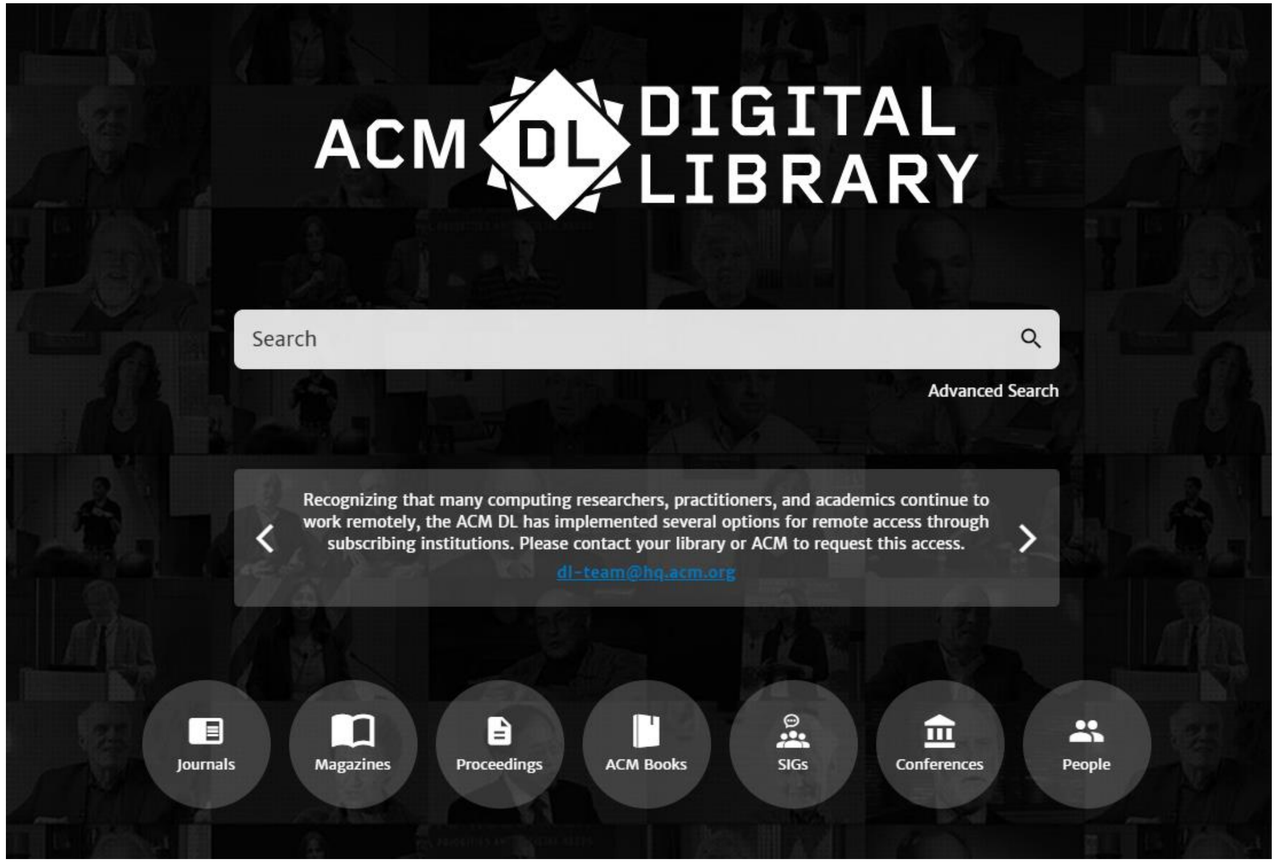

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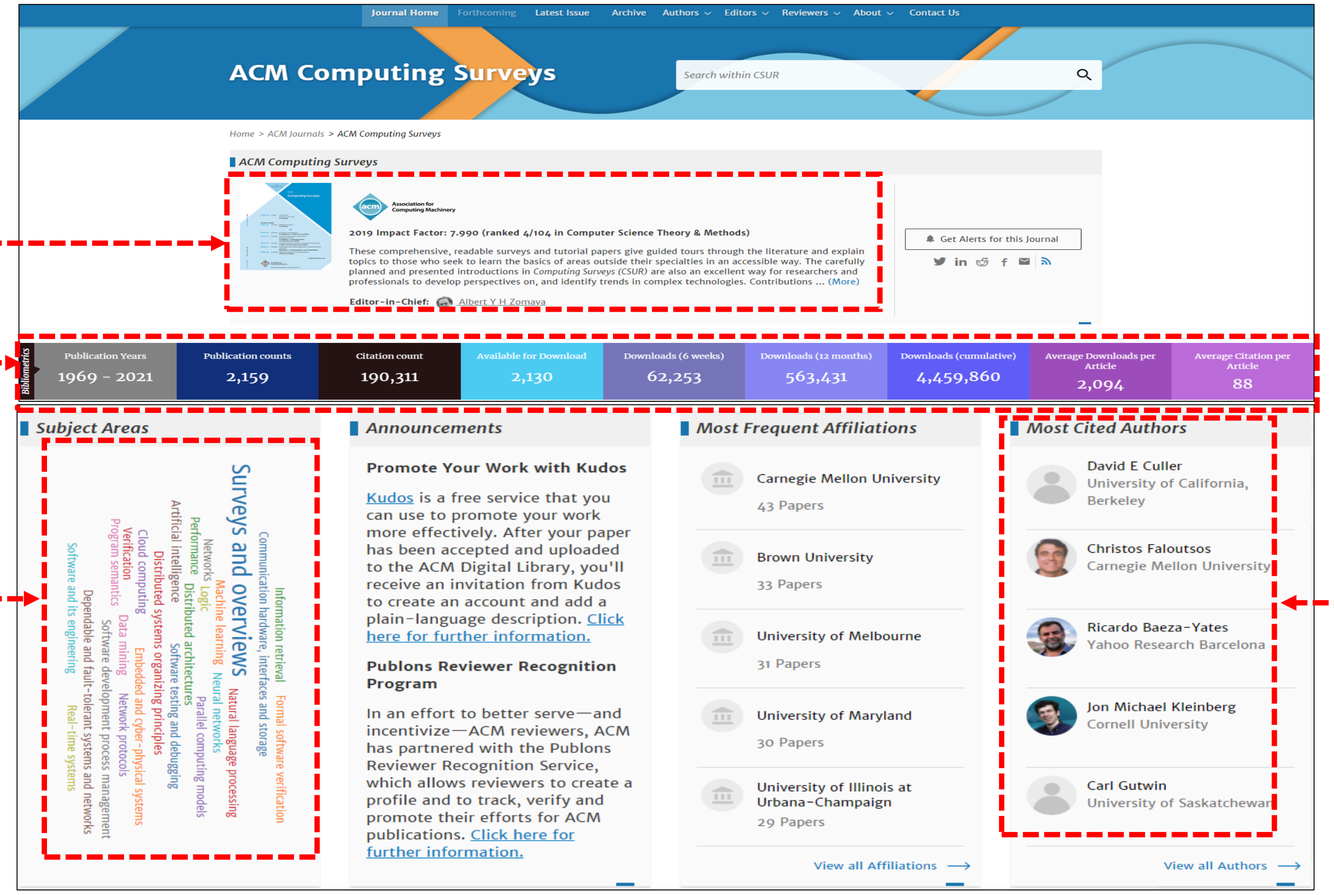

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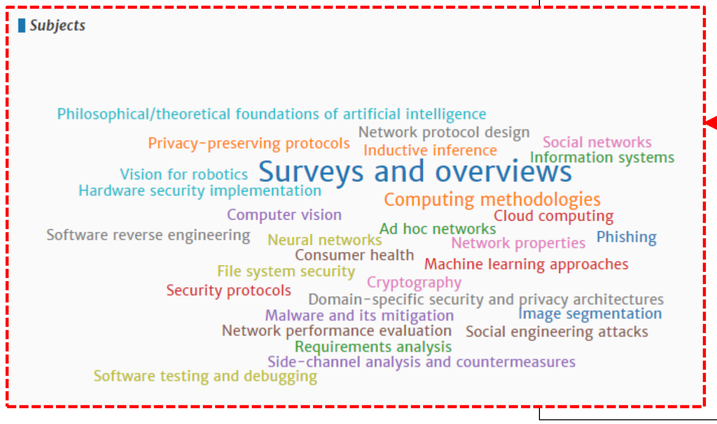

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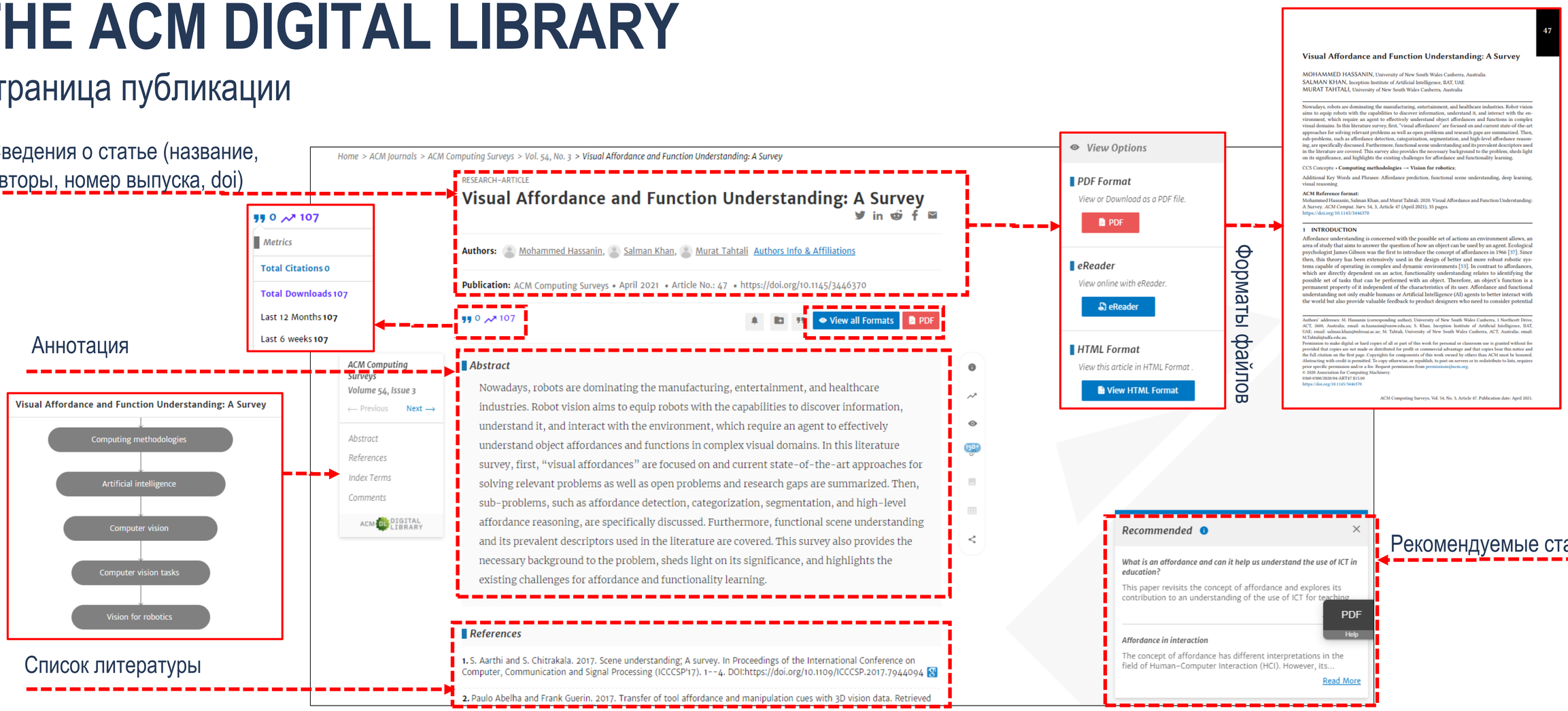

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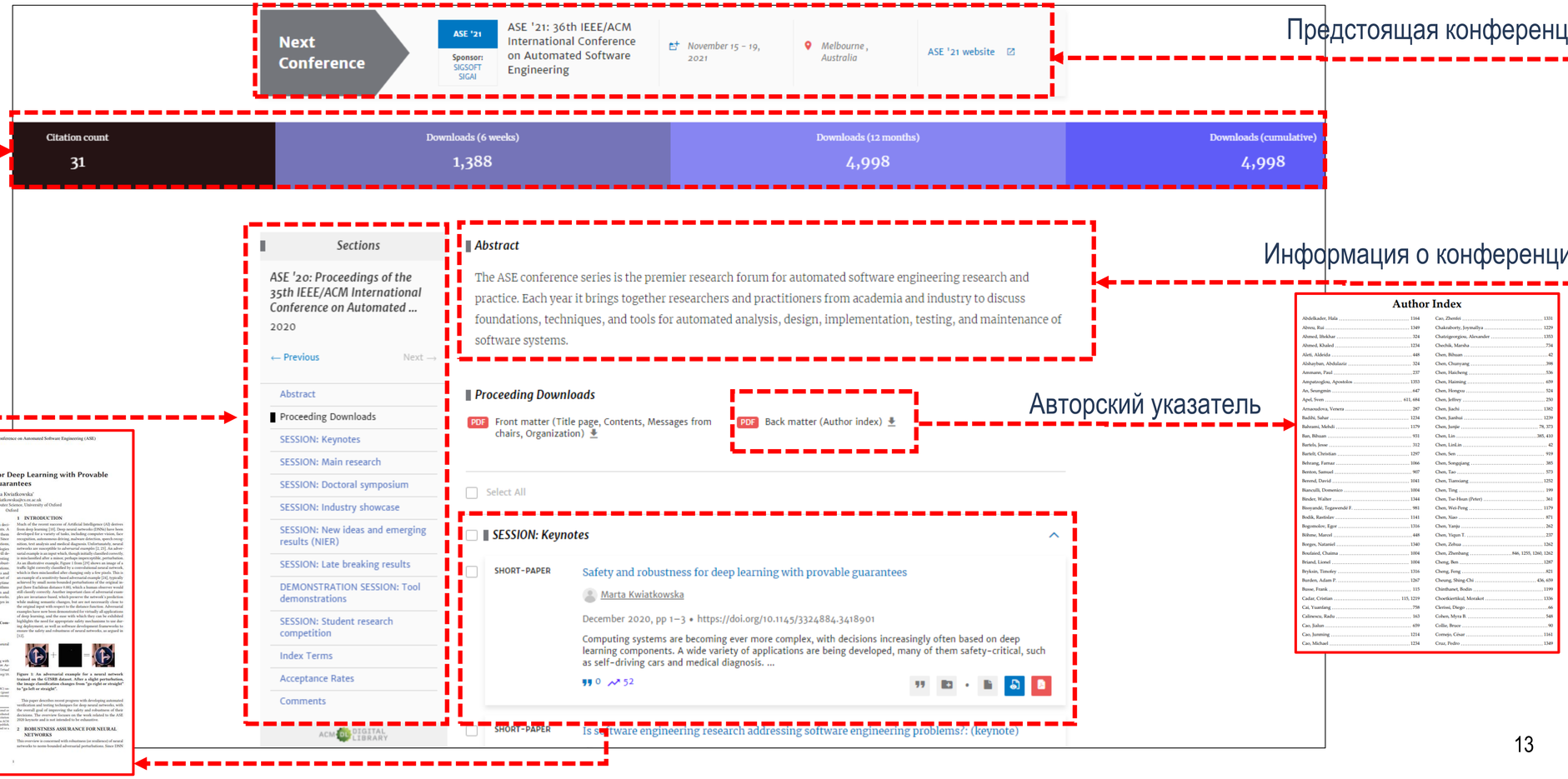

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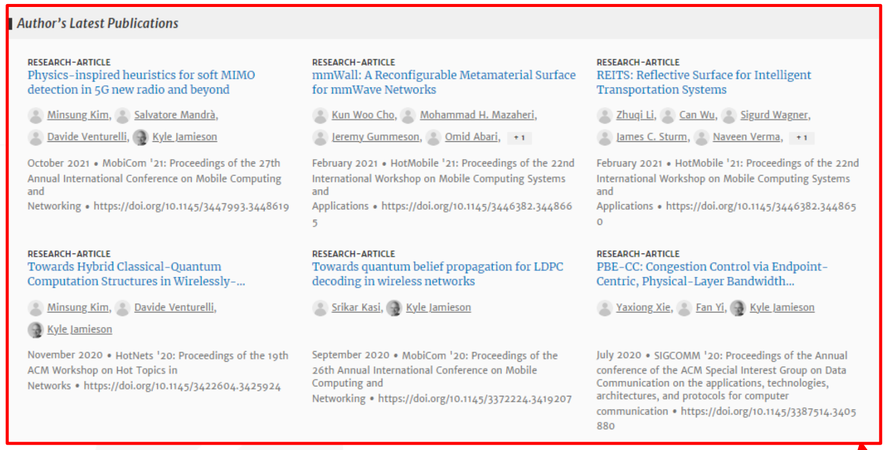

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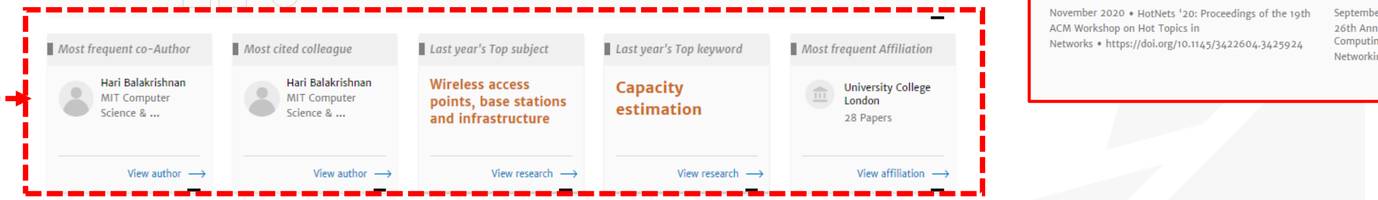

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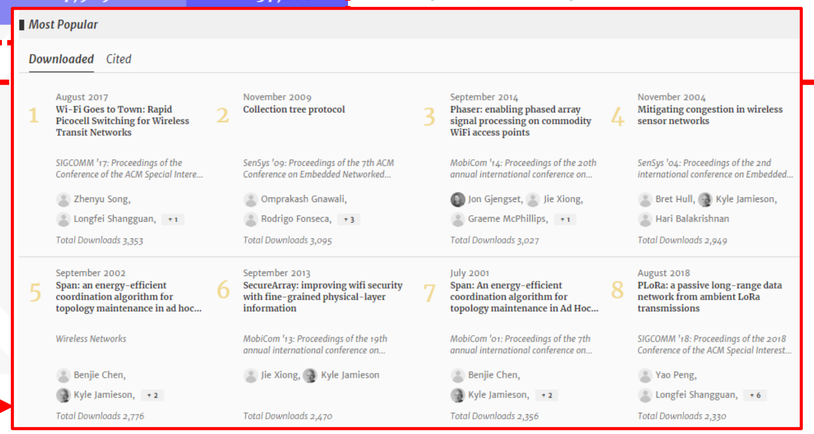

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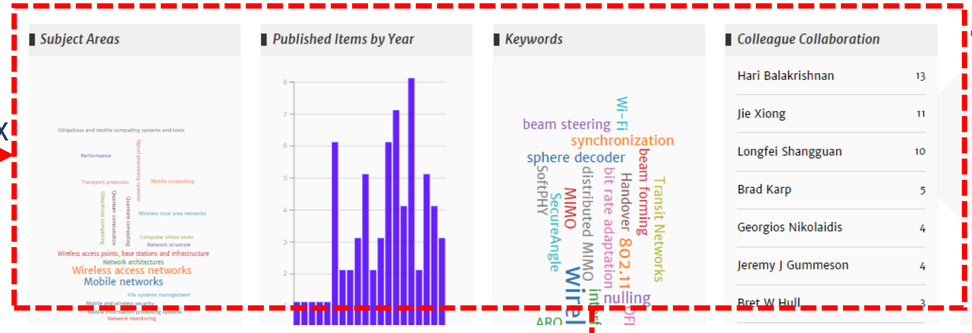

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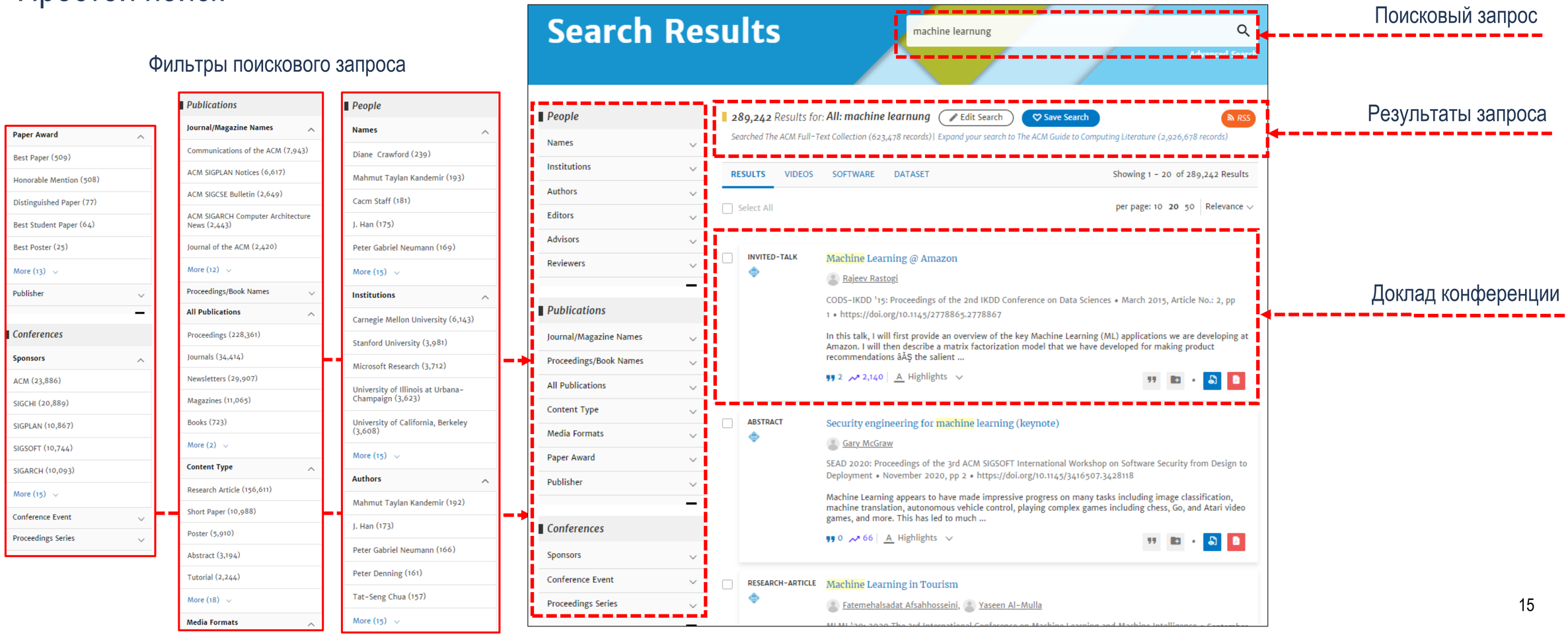

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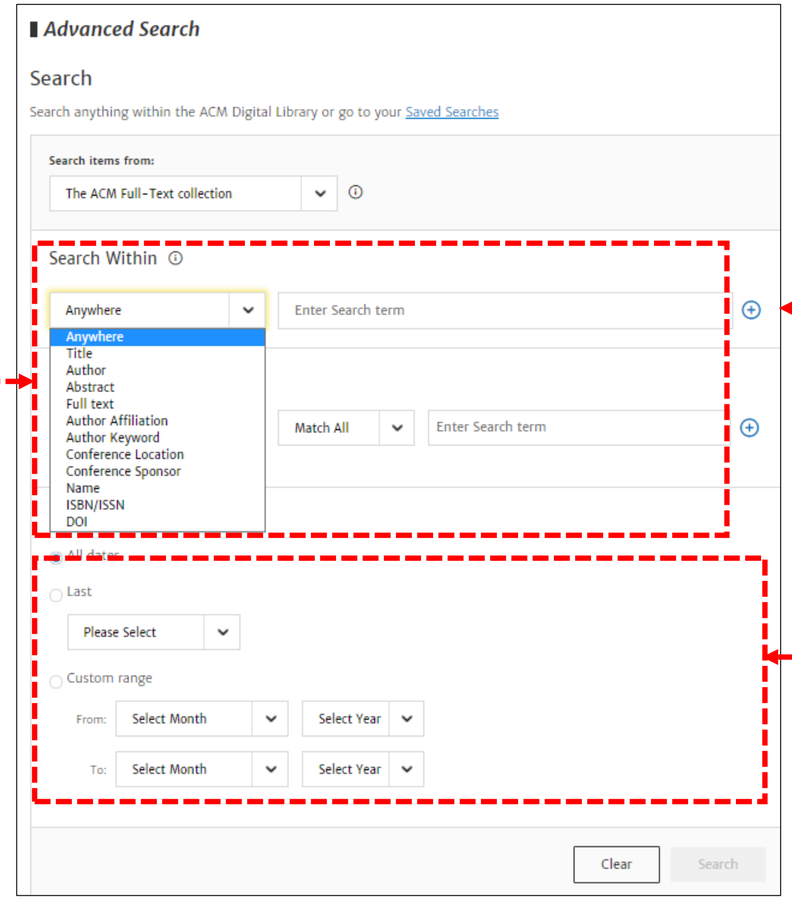

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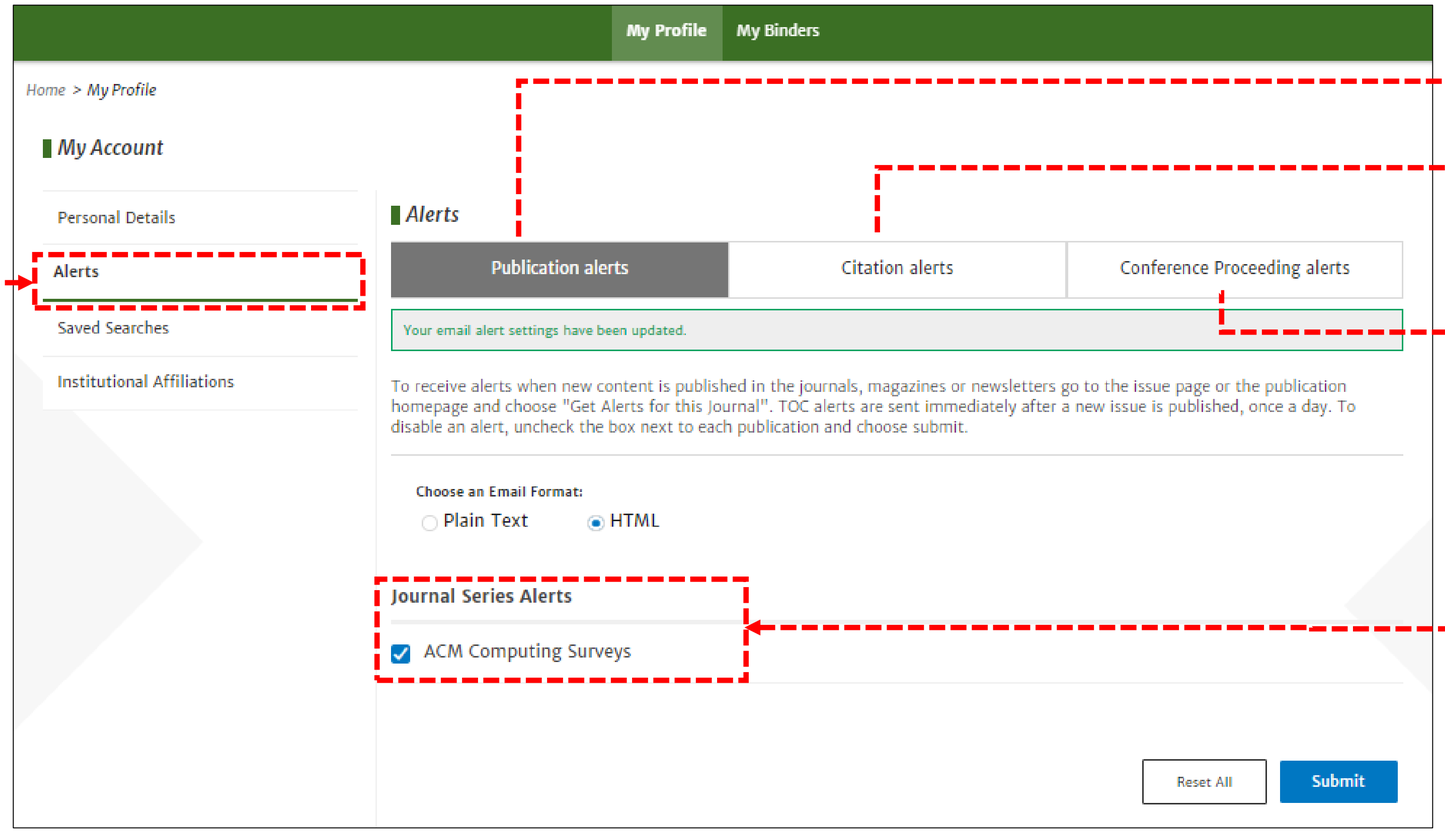

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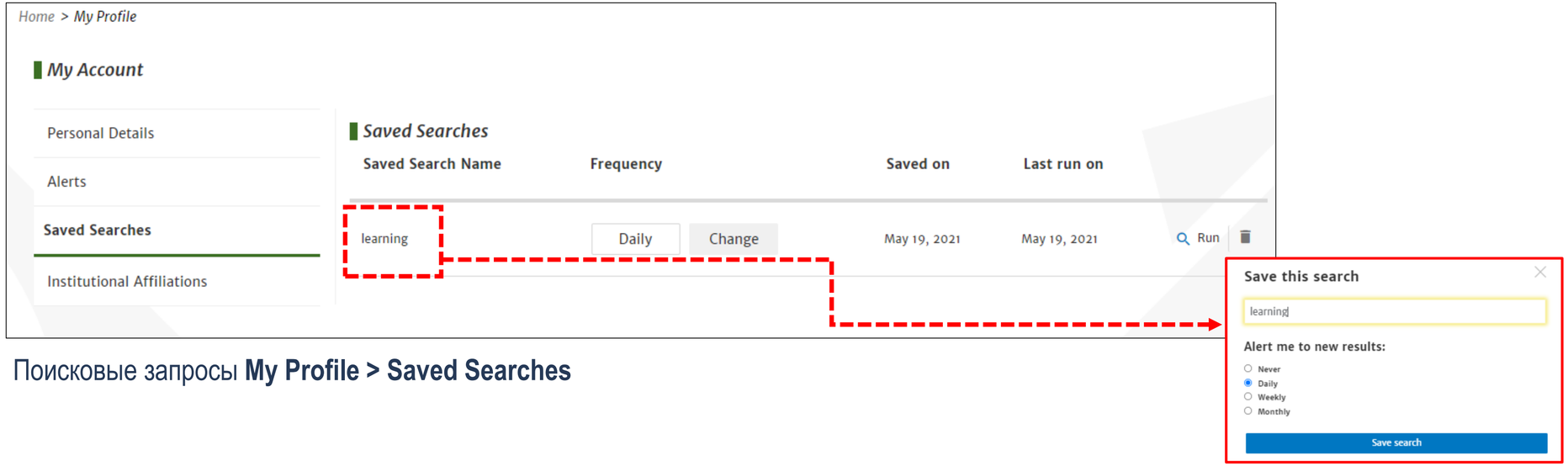

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