GOLDSMITHS, UNIVERSITY OF LONDON

Challenge the Hawk-Eye!

A SOFTWARE STUDIES APPROACH TO DECISION-MAKING TECHNOLOGY IN SPORTS

Juan Pablo de la Vega Castañeda
33370651
London

Centre for Cultural Studies
CU71009A
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Ralph Rugoff: *Is the freedom you are referring to a freedom from having to make decisions?*

Carsten Höller: *Yes, I think this is the ultimate luxury.*

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JUAN PABLO DE LA VEGA CASTAÑEDA
MA in Interactive Media: Critical Theory and Practice
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Introduction

Decisions are being made by everyone all the time whether we want to or not, even failing to make a decision becomes one. It has been generally thought that the more information we can gather on a topic, the better a decision will be made and thus began the reign of big data analysis.

In this dissertation I will briefly describe the perils of excessive reliance on computers for decision making through a historical analysis of thorough scrutiny to the technology behind state-of-the-art computational systems. After a brief description of the things that ought to be kept in mind when using technology to support decision making along with scenarios where it can be useful and how it can help, the analysis will shift to a example drawn form sports: the Hawk-Eye system. This exploration shows how the Hawk-Eye system is presented as an error-free technology that presents the real facts of the match, be it an 'out' call in tennis or a bowl outside the stump area in cricket. Afterwards, the role that sports play in culture construction will be analysed along with what this means for technology in the sense that accepting the decisions made by the system as final and unquestionable can propagate this notion to different fields with unforeseeable consequences. Some examples from these areas are mentioned and briefly described to try to shed some light on the implications that giving machines and algorithms the role of *truth bringers* that presumably have neither bias nor error in their methods could have.

Decision Making Machines

The development of a definition of decision making would be an essay in itself, hence I will borrow form the National Research Council (2014, p.13) who defines it as "a process of evaluating information and reaching an actionable policy or strategy." They also describe a few characteristics of this process, such as the fact that it usually depends on its context and that most of the times it relies on historical and background information in addition to the situation that is being observed or experienced. Although this definition originates from a military point of view and it may seem overly precise, as military definitions usually are, it can be extended to everyday situations without much complication. We might not use this terminology but every morning, for example, we *evaluate* the situations we expect to encounter during the day (people, places, weather...) and then *choose* what to wear, which would fits the *actionable policy or strategy* part of the definition. The fact that we are constantly facing decision-making situations brings as an unsurprising consequence the search for tools that will help in that regard, simplify the process and ease the burden of the responsibility assumed when decisions are made. From oracles to scientists, we usually rely on external sources of information to either make a decision for us or help us reach our own.

Using computers to aid in decision making has been around since the sixties; it is as old as computing itself and the idea existed even before computers did (Buchanan and O'Connell 2006; Power 2007). We have come a long way since and nowadays computers have become ubiquitous; we find them on our mobile phones, on our cars, and even house appliances now come equipped with basic computers and refrigerators can automatically order more milk in case you are running low (Steiner 2012).

During the 1980s, the use of computer systems to aid decision making took the form of knowledge-based systems (KBS). The design philosophy behind knowledge-based systems was to bring expert knowledge and artificial intelligence strategies to create a system that could aid the learning and decision making processes through knowledge provision via specific queries. Knowledge-based systems were never conceived as knowledge black boxes but rather as an attempt to emulate and better understand human cognition processes. As such, KBSs would have to be able to explain their answers by describing the inner workings of their decision process for every suggestion made.(Akerkar and Sajja 2010, p.xvii)

These systems underwent a thorough analysis during the late 1980s by the now extinct

Council for Science and Society. In their report, they recognised the potential usefulness of knowledge-based systems but also pointed out things to be kept in mind while using them. One of the things they pointed out is the definition of intelligence that scientists followed in order to design these systems where "[b]eing academics, they saw intelligence very much in academic terms: the ability to reason, to play games like chess, and to solve problems, rather than to sing, to dance, or to see."(Council for Science and Society 1989, p.3). This can be read as an attempt to bring forth how limited knowledge-based systems can be and to help us understand that their reach can never be all encompassing but is rather restricted to a very narrow area of application.

A second advice is that even in those areas where this kinds of system can be helpful, they should be consider only as tools to be used and never as decision-makers themselves because this would undermine the human authority and responsibility and they indicate that the only way to be able to achieve this is through the understanding of how these systems work(ibid., p.viii).

A third caution provided is the fact that albeit when the way the system works is taken into account and a human has the final verdict in which action should be taken for a particular situation, the speed and complexity of the certain settings make it impossible for a person to evaluate all the information available and becomes obliged to confirm the best suggestion presented by the knowledge-based systems.(ibid., p.36)

Knowledge-based systems never became as widespread as it was expected of them even during the early 1990s. One reason for this could be their high costs them and their tailor-made nature(ibid., p.15), rendering them nearly impossible to generalise. Another reason is the high volume of data that began to be generated during that same decade and which has been growing exponentially since the start of this century and which would require a new set of theoretical and practical tools.

Having to deal with apparently overwhelming amounts of information is not a new thing. Press (2013) places the first awareness of this kind of issue in 1944 when Wesleyan University Librarian Fremont Rider estimates that by 2040 Yale Library would have around 200,000,000 volumes, requiring six thousand miles of shelves along with over six thousand peoples to operate. However, the introduction of the term Big Data came in 1998 by a Silicon Graphics scientist, John Mashey, in a lecture where he warns of the growth in storage and increasing expectation of internet users regarding images, graphics, models, audio and video in an attempt to anticipate the hardware and software requirements needed to withstand the exponentially growing information (Mashey 1998).

Recently Kitchin (2014, p.xv) defined Big Data as "vast quantities of dynamic, varied digital data that are easily conjoined, shared and distributed across ICT [information and communication technology] networks, and analysed by a new generation of data analytics designed to cope with data abundance as opposed to data scarcity." This definition shows how much the field evolved in 16 years. It is now not only a matter of data being generated but data that is also dynamic, distributed and, more importantly, profusely shared; this has been largely enabled by the ubiquity of mobile devices and internet access. Another reason for the success of Big Data is the fact that many scientists believe that more data means more information and insight, and "the data, suitably circumscribed by quantity, correlation, and algorithm, will speak to us,"(Mosco 2014, p.206) but they often forget that correlation does not mean causality but, in fact, "the vast amount of information that can be brought to bear does not guarantee better decisions or a more straightforward decision-making process"(National Research Council 2014, p.5).

Just like with knowledge-based systems, an in-depth investigation towards the limits and limitations of Big Data was recently made, this time by the National Research Council (2013). Their report indicates a similar attitude towards decision-making technology as the one was displayed in 1989 by the Council for Science and Society. They warn of the limits of the tools, specifically of the statistical tools used since "data analysis is based on assumptions, and the assumptions underlying many classical data analysis methods are likely to be broken in massive data sets,"(ibid., p.6) and determine that "the role of human judgment in massive data analysis is essential, and contributions are needed from social scientists and psychologists as well as experts in visualization," and conclude, in a similar fashion to the conclusions of 1989, that "this judgment needs to be based on an understanding of statistics and computation"(ibid., p.5). Despite this analysis and warnings, the fast-paced nature of the developing of these technologies and the increasing specialisation at the core of their development has led some people to conclude that "[w]e are increasingly surrounded by 'black boxes', complex constructs that we do not understand even if they are explained to us." and yet we rely heavily on their performance in our decision-making (Krogerus, Tschäppeler and Piening 2011, p.118).

As more data becomes available, it evidence gathers indicating that the collection and usage of information has been all but naïve. Data is treated as an independent and objective entity which bears only truth and raw information, forgetting that data exist within a socio-temporal space and is influenced by the politics, economics and philosophy that surround it; the technologies and instruments used for their acquisition also influence the data (Kitchin 2014, p.2); data only exists through human intellect and intention, which has certain biases and shortcomings that inevitably will form a part of it (Mosco 2014, p.200).

Algorithms are the second element of Big Data. New ways to analyse massive amounts of information have been (and are still being) developed. In a similar way to data, algorithms are thought to be an abstract identity and not usually understood. However, they are also imbued with an ideological and cultural factor that can present itself through them in ways that cannot always be anticipated but which could be critically relevant (Goffey 2008, p.19). People often do not realise that programs can also have bugs and not work as they are expected. Moreover, according to Kitchin and Dodge (2011, p.86), software plays a fundamental role in the creation of "societies of control" by shifting the agents, motives, and applications through which society, its space and its time are created. It is important to bear these characteristics in mind, since now more than ever, computer systems are being used to assist decision making in relevant situations.

There exists a fundamental difference in the way humans and machines make decisions. For people, emotions, social context, and even structures of authority influence the way in which decisions are taken. These factors, however, are very hard to incorporate into a machine due to sensing restrictions or, even when modelling is possible, excessive complexity of the models would required non-finite time or processing resources, which is impossible to achieve. Another difference is that traditionally, computer scientists have focused their efforts in the intellectual side of decision making, disregarding the role of embodiment in human behaviour and the frequent reliance on intuition rather than rationality (National Research Council 2014, p.5–6,15,23). Rather than an impairment, this could be considered as an advantage in the sense that machinic decision making systems could play a complementary role to humans in situations where the pressure or complexity of a problem can lead them to misjudge a situation and make a wrong decision; the risk, however, is to rely solely on the machines to make decisions crippling both the authority of the people and their ability to make adequate decisions.

In the following sections I will explore the Hawk-Eye technology, widely popularised through cricket and tennis but increasingly used in more sports, to show how the way it is currently being used might result in spreading a culture where technology is presented as an unquestionable black box, that supersedes humans in decision making.

Supporting Sports

Hawk-Eye technology is a system that was first used as a broadcasting aid in Cricket matches in 2001 and has also been a part of tennis transmissions since 2002. The system works by combining multiple two-dimensional video feeds into a three-dimensional model and then uses a series of polynomial interpolations based on the frame by frame position of the ball and compare it to the modelled court (Owens, Harris and Stennett 2003, p.184). At first, this technology used the information recorded form the broadcaster's video feed as its source, which implied that more complex calculations were required to account for pan, tilt and zoom of each of the cameras. At the time, there was no official error measure publicly available and the only paper that describes the system mentions that "[there exists] no quantified assessments but we[they] *believe* that about 90% of requested sequences are of sufficient quality to broadcast"(ibid., p.185, my emphasis), reflecting a lack of clarity is carried to the actual description of the system:

> Tracks are initiated from all unmatched candidates, and are continued using a polynomial fit to predict the ball's location in subsequent images. The polynomial fitting order increases according to a pre-defined program as the track length increases, to allow principally for the effects of perspective projection. Similarly, the radius of the acceptance region for matching varies according to the duration over which matching has failed to occur. (ibid., p.184)

This is very obscure attempt to describe and determine the precision of a system that remains almost as obscure today: a privately owned black box. In 2005, the system was approved by the International Tennis Federation for official use and in 2008 the International Cricket Council included it as part of the Decision Reviewing System. To increase precision, broadcasting feed was replaced by images recorded from six different video cameras carefully placed at a vantage point inside a stadium (Hawk-Eye n.d.[a]). Each one of these cameras produces the required 2D partial trajectory of the tracked element in question (players and balls) which is then combined to build a 'complete' 3D path. To have a better understanding of how this technology is presented, I will focus on its use in tennis and draw some examples from cricket.

A tennis match can be very roughly described as players hitting a rubber ball covered in yellow felt with a racket to try to get it over the net into the other player's side of the court, without exceeding the court's limits. If any part of the ball touches the white lines delimiting the court, the ball is called 'in' and if no part of the ball bounces inside the court or on the white line the ball is 'out' and the player that hit the ball looses the point. Traditionally, line umpires have been responsible for determining whether the ball is in or out and their call could only be overruled by the chair umpire, who had final saying in a point. Tennis does not work like this any more. In 2005 the Hawk-Eye system was introduced along with rules for its use: players are allowed up to three incorrect challenges to the umpire's calls and, if the set goes to a tiebreak, they are given one more.

Decisions called by Hawk-Eye are not presented as a series of statistics but rather as a visual representation. The system itself does not need these visualisations, as Wright (2008, p.79) notes "[v]isualizations are created for people rather than for machines;" they are intended to provide a visual representation of the decision made by the system (see figure 1). It is part of the shift in understanding that Krogerus, Tschäppeler and Piening (2011, p.118) predict, whereby people rely more on images than arguments.

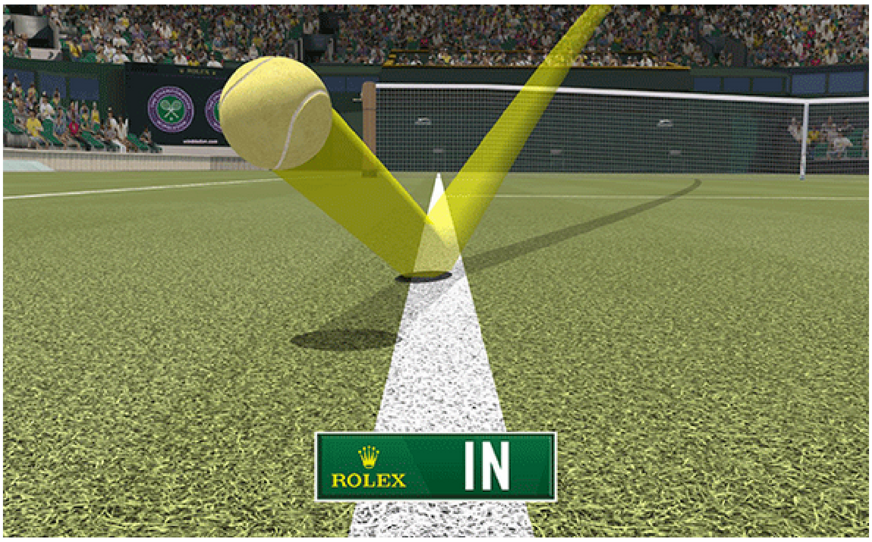


Figure 1: Hawk-Eye visualisation

One problem these visualisations have is that they are presented as a fact, i.e. machinic precision is not questioned but assumed that they presented unaltered "truth" as opposed to the umpire's biased "perception." There is little doubt that these systems are more accurate than the umpires, but the problem lies in that they are presented exempt from error (Fleming 2013) as an unbiased technological presenter of truth in a way in which all of the possible bugs and errors that are always potentially present in the algorithms and even in the logical models themselves (Goffey 2008, p.19) are filtered out of the visualisation. Furthermore, the ability to question the system's decision even for viewers and broadcasters is being further restricted because video repetitions are not longer presented, only the evidence presented by Hawk-Eye is transmitted. (Collins and Evans 2008, p.298) People fail to understand the role of the humans in the development and application of technologies, which can be seen in comments and blog posts on several online platforms, such as the following: "[i]n a post-Hawk-Eye world, elite-level tennis is injected with the purest form of justice: the kind that's unblemished by human error" (Fetters 2012). The "production of credibility" and "ability to persuade" have been key to the success of Hawk-Eye (Kelkar n.d.) but have also had some unintended consequences, altering the way in which the game of tennis is being played.

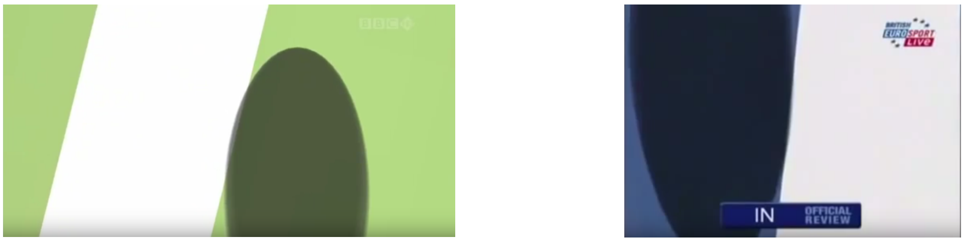
With the introduction of this system, power relationships in tennis have shifted giving technology the upper hand. "In matches where electronic review (commonly called 'hawk eye') is in use, this can over-rule a Line Umpire's and/or Chair Umpire's decision (following a challenge) and cannot be appealed" (International Tennis Federation 2014). Now it is not the line umpires or even the chair umpires that have a final say, but the Hawk-Eye system. In words of Collins (2010, p.136), these technologies "degrade the epistemological privilege of the umpire and referee" and create an imbalanced situation whereby the interpretation of situations and assignment of meaning no longer falls on them(see figure 2). This leads to an unexpected problem: umpires and judges are now more hesitant to make the calls, they pay less attention during the game and increasingly answer "I do not know" when asked for their opinion on where the ball fell (McDermott n.d.). Bourdieu (1990, p.46) issues a warning for this kind of situation: he argues that if you counterpose the perception of a subject to a rational system that is structured around logically sound arguments to produce an "objective truth" then the subject is left no choice but to adhere to that truth or appear "'partial' in both senses."

Another issue is the actual accuracy of the system. As a requirement for its official endorsement, precision of the systems is now officially endorsed and is presented on their website as 2.2 mm for tennis and 10 mm for cricket (Hawk-Eye 2015). Nevertheless, a

Figure 2: In this year's Montreal Rogers Cup, Tennis player Joao Sousa challenged this call and the chair umpire agreed to both him seeing the ball out and the possibility of the Hawk-Eye system being wrong. The call remained Hawk-Eye's

basic understanding of statistics is enough to realise that this are in a way almost as meaningless as the "90%" efficiency quoted above. Usually in statistics, rather than a specific measurement of error, a confidence interval of these is presented. This interval depends on the confidence level and the distribution of the errors. The former is determined by the experimenter and when the dispersion of errors is known, a confidence interval can be associated to them. For example, if a level of 95 percent of confidence is chosen, it would mean that the chance that the error in the experiment is greater than the outer limits indicated by the confidence level is only 5 percent. In the tennis example, rather than giving a crude number such as 2.2 mm, a 95 percent confidence interval could be determined, such as [1.8 mm, 2.6 mm]. What this means is that only 5 percent of the balls would have a measurement error smaller than 1.8 mm or greater than 2.6 mm. If one wishes to increase the confidence of the interval, its size will usually increase accordingly. For example, if a 99 percent confidence interval was sought, its limits could be [1.4 mm, 3.0 mm]. This practice is standard in experimental science and if it were incorporated to Hawk-Eye, it would be easier to understand. Even knowing boundaries, during a match between Roger Federer and Rafael Nadal, Hawk-Eye technology asserted that one millimetre of the ball touched the line without mentioning that this falls well outside their precision claims (see figure 3a), and even closer calls have been made, like the one in a match between Rafael Nadal and Mikhail Youzhny (see figure 3b), which Nadal contested to no avail.

This is a problem because the lack of transparency "could inadvertently cause naïve viewers to overestimate the ability of technological devices to resolve disagreement among humans [when] measurement errors are not made salient"(Collins and Evans 2008, p.283); rather than providing an accurate depiction of how science functions, it presents it as a yes or no tool for decision making (see figure 3), hiding the fact that science is "about probability and probability includes some uncertainty then [if this was made clear when using Hawk-Eye] it could lead to more mature debates about where science plays a central role"(Fleming 2013).



(a) Feder–Nadal

(b) Nadal–Youzhny

Figure 3: Hawk-Eye close calls

Cricket presents the Hawk-Eye technology in a better fashion. In this sport, it was incorporated as part of the decision making process and can help monitor the pitching lines and provide advice for the application of the leg before wicket rule (LBW). The LBW rule can be very confusing but in summary, in order for it to apply, five things must occur during the play (BBC News n.d.):

1. The ball is properly pitched and there has been no *no-ball* call;
2. the ball is pitched inside the area delimited by the stumps;
3. the ball must not hit the bat before the leg pad;
4. the batsman attempts to hit the ball; and more importantly for our analysis
5. the umpire determines that the ball would have hit the stumps if it had not been stopped by the batter.

Hawk-Eye technology provides information on almost all of this regards, being the intention of the batsman the only for which it is not consulted. Again, as in tennis, the system presents a virtual reality simulation of the situation in order for the umpires and the public to visualise the decision it made but, in contrast to tennis, when the calculation of the imaginary trajectory is within the error margin, the system transfers the call to the umpire (see figure 4).

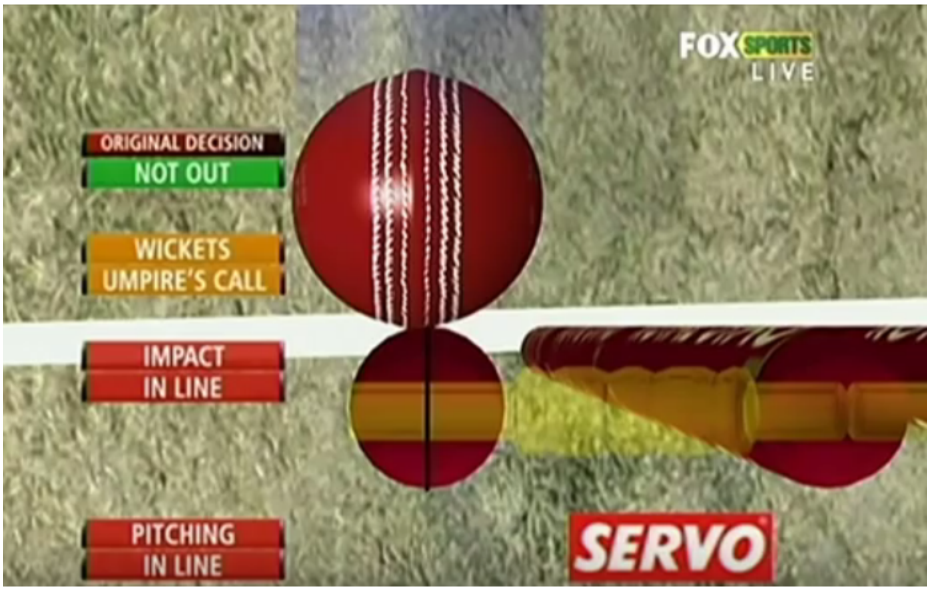


Figure 4: Hawk-Eye visualisation of the LBW play

Although this is a better way to present and use the technology —as an aid in decision making rather than a decision maker in itself— it is a double edged sword. For the call, Hawk-Eye not only assesses the predicted imaginary path of the ball, but also the pitch of the ball, the limits of the stumps and whether it hit the bat or not. In all of this cases, unlike the prediction, there is no questioning of the technology and is presented as a fact, not unlike in or out calls in tennis matches. This may further promote what Collins (2010) has named a "false transparency," which means that technology portrays itself as transparent and self-critical when in fact it only accounts for the errors in the prediction and not the measurements, which inherently carry errors as well.

ESPN blogger Russell Jackson Jackson (2015) heavily criticised Hawk-Eye questioning its performance and the lack of transparency about how the technology works. Hawk-Eye's founder, Paul Hawkins responded to the criticism on a document available on the company's website (Hawk-Eye 2015). As can be expected from a businessman, the answers from Hawkins were no clearer than the information available through their website. The tone of the whole exchange can be described with this exchange:

> *Russell Jackson*: Worse, why upon seeing that projection did every single person in the pub I was in 'ooh' and 'aah' as thought what they were seeing was as definitive and irrefutable as a ball sticking in a fielder's hands, or the literal rattle of ball on stumps? Have we just completely stopped questioning the authority of the technology and the data?
> *Paul Hawkins*: Because Hawk-Eye was right. No harm in questioning things, but keep an open mind until you see some better evidence.

Hawkins never provides an explanation of how the system works or even the algorithms used. In order to justify the accuracy of the system it relies on its "wide acceptance" and the fact that "fans and (most) professional teams now expect Hawk-Eye's verdict on LBW appeals"(Hawk-Eye 2015) and offers no factual evidence.

In this section I have provided insight on how Hawk-Eye technology is presented and used in tennis and cricket. Although not the only technology used in decision making, this one is important because it is now being used in 17 different sports (Hawk-Eye n.d.[b]). In the following section, I will briefly argue that sports play an important role in the production of popular culture and analyse the implications that treating Hawk-Eye technology as an unquestionable producer of truth may have.

A Hawk-Eye Culture

An important part of our culture is sport, and it is increasingly becoming a point of attention in political, social and cultural studies. Beck and Bosshart (n.d., p.27) identifies sport as "the most important non-important issue in contemporary societies" and highlights the role that television has played in its popularisation. Another reason for the extensive reach they now have through mass media and mobile devices through which people can access sports' broadcasts. Sports have become a kind of "social glue"(Biernatzki n.d., p.27) which allow for people to get together through conversations based on this common topic with little danger of conflict in most cases, since people extremely devoted to sports are rare. Nevertheless, the fact that "[s]port does not exist in a value-free, neutral social, cultural or political context but is influenced by all of these contexts"(Jarvie 2006, p.19) must be taken into account to understand the place it holds within society as a producer and keeper of cultural phenomena. In this section, I will briefly give evidence to support the notion that sports can be thought of as a form of popular culture that plays an important part in the naturalisation process described by Fuller (2008, p.4) through which new technologies are often accepted in society and discuss how these technologies are being used in different areas commercially and scientifically.

Habitus is a term often used in the analysis of sport which comes from the French sociologist Pierre Bourdieu. His definition is worth quoting at length since it will be referred to explicitly and implicitly in of much of the analysis that follows.

> The **conditionings** associated with a particular class of conditions of existence produce ***habitus***, systems of durable, transposable dispositions, structured structures predisposed to function as structuring structures, that is, as principles which generate and organize practices and representations that can be objectively adapted to their outcomes without presupposing a conscious aiming at ends or an express mastery of the operations necessary in order to attain them Objectively 'regulated' and 'regular' without being in any way the product of obedience to rules, they can be collectively orchestrated without being the product of the organizing action of a conductor. (Bourdieu 1990, p.53; original emphasis)

If we consider the broad audience of sports, it is not difficult to begin to imagine how sports can play an important role in shaping the *habitus* especially taking into account the fact that they are perceived as having clear rules which are valid regardless of where they are played or watched (Beck and Bosshart n.d., p.25). If technologies are blindly used in sports, this could lead to them being also blindly used in different areas even when people "understand" that they may not be completely accurate, for "habit provides the strongest proofs and those that are most believed" (Bourdieu 1990, p.48), which represents a grave danger since this would mean to relinquish decision making and the production of truth to the machines, provoking with this a shift in power relations probably as profound as the one described by Foucault (2011, p.124) regarding what happened in the 17th and 18th centuries after the introduction of new technical inventions and processes.

Hawk-Eye builds a picture in which sanctions for having an opinion different to that of the technology are present in the form of ridicule and even suspension.[1] Through situations of this kind, Hawk-Eye culture can already be considered to be a part of the

[1] An example of this is the match Open between Serena Williams and Jennifer Capriati at the 2004 U.S. where chair umpire Mariana Alves was suspended after her decisions were different to those broadcasted using Hawk-Eye technology (Repanich 2010). At this time, technology was not part of official reviewing system but only an entertainment tool for television viewers.

habitus, since it shares its characteristic of negatively sanction behaviours that are not in line with "objective conditions" Bourdieu (1990, p.55-6) presented by the technology, i.e. the 'truth'. The truth I am referring to is not a thing *per se*, it is "the ensemble of rules according to which the true and the false are separated and specific effects of power attached to the true" (Foucault 2011, p.132). Historically, the scientific discourse and its institutions have been in charge of giving truth, of defining the types of discourse that are accepted as true statements and to which everything must be compared in order to assign it a value of truth. The fact that truth making is now being transferred to machines modifies the systems of power which truth induces and which extend it (ibid., p.133). This is dangerous because the software used in these machines is not, and cannot, be exempt of spatial, temporal or social consideration. Furthermore, software modifies these spheres as much as it is influenced by them (Kitchin and Dodge 2011, p.66).

During a match this year between Joao Sousa and Bernard Tomic at the Montreal Rogers Cup, after a very close call from the Hawk-Eye system challenge, Sousa approached the chair umpire annoyed about the call, saying that he was certain that the ball had been out. The umpire mentioned that Sousa could in fact be right. During the exchange, the umpire said two important things that bring forth the shift in power relations and accountability in tennis. The first thing he says is "I trust you [referring to Sousa] but you cannot compete with Hawk-Eye" and then, he continues, "it could be wrong, but nothing to do"(Nadal Le Roi 2015). This exchange proves two things: first, that ontological authority in tennis no longer rests in neither the umpires—line or chair— nor the players but is now contained within the Hawk-Eye technology; second, this technology is not questionable even when it is understood that it might be mistaken. From the image of the call (figure 2), given that the sidelines in tennis measure 50 millimetres, it can be determined that the contact point of the ball on the line is less than the average error margin of 2.2 millimetres, which means that it is possible that the ball was out. This is not a certain fact, since this visualisations are a visual approximation of the algorithmic approximation generated by the 3D composition through 2D images, however since no other information is made available, it should provide enough evidence to at least doubt the decision of the system.

The power that comes from this production of truth through algorithms and machines is no longer embodied in an individual who exercises it, it becomes an anonymous machinery impossible to understand and therefore unquestionable (Foucault 2011, p.156). If the trend continues, computer scientists could now wield the power and responsibility previously assigned by Foucault (2011, p.129) to physicists and biologists who could "either benefit or irrevocably destroy life" with their weapons. This time around, even though the power does not come through nuclear or biological bombs it is just as mighty. Computer scientists through black-box algorithms implemented in their programs can decide the fate of even more people than those killed by the atomic bombs. These algorithms live in computer software with applications on a very wide range of fields some of which people are usually aware of, such as finance and advertising, but also medicine, where Big Data algorithms are being used to decide when and which cancer treatment should be given to a patient (Marr 2015) and in mathematics to generate theorems and proofs to further the understanding of certain mathematical fields, sometimes without the aid of human intervention or even supervision (Puzis, Gao and Sutcliffe 2006). Another situation where algorithms are used to simplify or automate decision making is in financial trading, which could have catastrophic consequences as we have seen from the 2010 market crash (MacKenzie 2011), but it is not the only situation in which financial institutions use automated systems, it is also used in determining whether a credits should be granted to applicants. In private conversation with Bernardo Mancera, Solvency Capital Assistant Manager at BBVA Bancomer, Mexico's leading financial institution in the provision of loan facilities, the process was described as consisting of three steps:

1. The algorithm automatically decides whether a credit is approved;
2. this decision is presented to the client, who has the right to challenge the decision made;
3. only if the decision is challenged does a person go over the file and the algorithm to give a final outcome.

Although these seem like a sensible method, the fact that the people who were usually responsible for making this decision now rarely have to intervene thus loosing the sensibility to make this kind of decision and probably unable to assess the situation as well as they used to, since "[p]eople are not good at responding quickly when they have been out of the loop"(National Research Council 2014, p.34).

Conclusion

As we approach the limits of current hardware and are overwhelmed by the massive amount of information generated every day to the point where most of it is no longer stored, Big Data algorithms are starting to become as ubiquitous as information itself. At this point it is wise to take a step back and reflect upon the technologies at hand and the way in which they are being used to understand how they work and what possibilities they can open up. A step that must not be taken is to blindly trust in these technologies and rely heavily on their assessments of problems and the solutions they propose. This reflection, however, is diminishingly present nowadays. In this work, I have presented an overview of how decision making technologies have been analysed and criticised historically by institutions whose goal is to better understand them. They have advised against the over-reliance on automatised systems and the indispensable presence of a human in the decision-making process in order to assess the machine's behaviour and bring personal expertise into the evaluation of situations in a way in which machines are incapable. Nevertheless, this advice does not seem to be currently followed. In trying to understand why people rely so much on machines I have presented an example through the technology used for decision making in sports such as tennis or cricket, namely the Hawk-Eye system. The way this system is used and shown to the audience can provide a false understanding of how technology works and what its limits are. Moreover, because Hawk-Eye has the last saying, it undermines the authority of the umpires and builds a scenario where it is punishable to question technology that permeates and becomes part of the *habitus*. Additionaly, some areas where machine learning algorithms are used to make decisions and 'generate' truth have been presented to better understand the reach and potential implications of unquestionably yielding decision making to computer algorithms in the hope of evince the necessity to change the fact that "[p]eople have become accustomed to computers producing the truth" (Council for Science and Society 1989, p.52).

References

Akerkar, R. and P. Sajja (2010). *Knowledge-Based Systems*. Jones & Bartlett Learning. ISBN: 9781449612948. URL: `https://books.google.co.uk/books?id=mQZnd4zmZsoC`.

BBC News (n.d.). *LBW explained*. URL: `http://news.bbc.co.uk/sport1/hi/cricket/rules_and_equipment/6125026.stm` (visited on 26/08/2015).

Beck, Daniel and Louis Bosshart. 'Sports and Media'. In: pp. 3–27.

Biernatzki, William E. 'Editor's Afterword'. In: pp. 3–27.

Bourdieu, Pierre (1990). *The Logic of Practice*. Stanford University Press.

Buchanan, Leigh and Andrew O'Connell (2006). 'A Brief History of Decision Making'. In: *Harvard Business Review*. URL: `https://hbr.org/2006/01/a-brief-history-of-decision-making` (visited on 29/08/2015).

Collins, Harry (2010). 'The Philosophy of Umpiring and the Introduction of Decision-Aid Technology'. In: *Journal of the Philosophy of Sport* 37, pp. 135–146.

Collins, Harry and Robert Evans (2008). 'You cannot be serious! Public understanding of technology with special reference to "Hawk-Eye"'. In: *Public Understanding of Science* 17.3, pp. 283–308.

Council for Science and Society (1989). *Benefits and Risks of Knowledge-Based Systems*.

Fetters, Ashley (2012). *How Instant Replays Changed Professional Tennis*. URL: `http://www.theatlantic.com/entertainment/archive/2012/09/how-instant-replays-changed-professional-tennis/262060/` (visited on 21/08/2015).

Fleming, Nic (2013). *Interview with Thea Cunningham*. URL: `http://www.nature.com/nature/podcast/v497/n7451/nature-2013-05-30.html` (visited on 25/08/2015).

Foucault, Michel (2011). *Power/Knowledge: Selected Interviews an Other Writings 1972/1977*. Trans. by Colin Gordon et al. MIT Press.

Fuller, Matthew (2008). 'Introduction, the Stuff of Software'. In: *Software Studies A Lexicon*. Leonardo Book. MIT Press, pp. 1–13.

Goffey, Andrew (2008). 'Algorithm'. In: *Software Studies A Lexicon*. Leonardo Book. MIT Press, pp. 15–20.

Hawk-Eye (2015). *Paul Hawkins responds to CricInfo blog*. URL: `http://www.hawkeyeinnovations.co.uk/news/39559` (visited on 26/08/2015).

— (n.d.[a]). *Hawk-Eye in Cricket*. URL: `http://www.hawkeyeinnovations.co.uk/sports/cricket` (visited on 26/08/2015).

Hawk-Eye (n.d.[b]). *Sports*. URL: http://www.hawkeyeinnovations.co.uk/sports (visited on 26/08/2015).

International Tennis Federation (2014). *On Court Officials*. URL: http://www.itftennis.com/officiating/officiating-roles/on-court-officials.aspx (visited on 21/08/2015).

Jackson, Russell (2015). *Why ball-tracking can't be trusted*. URL: http://www.espncricinfo.com/blogs/content/story/855685.html (visited on 25/08/2015).

Jarvie, Grant (2006). *Sport, Culture and Society: An Introduction*. Routledge.

Kelkar, Shreeharsh (n.d.). 'In or Out: The Politics of Hawk-Eye in the Game of Tennis'. URL: http://web.mit.edu/skelkar/www/shreeharsh-kelkar_files/Kelkar-Hawk_Eye_draft.pdf.

Kitchin, Rob (2014). *The Data Revolution: Big Data, Open Data, Data Infrastructures and Their Consequences*. SAGE.

Kitchin, Rob and Martin Dodge (2011). *Code/Space: Software and Everyday Life*. MIT Press.

Krogerus, M., R. Tschäppeler and J. Piening (2011). *The Decision Book: Fifty Models for Strategic Thinking*. Profile Books.

MacKenzie, Donald (2011). 'How to Make Money in Microseconds'. In: *London Review of Books* 33.10. URL: http://www.lrb.co.uk/v33/n10/donald-mackenzie/how-to-make-money-in-microseconds (visited on 29/08/2015).

Marr, Bernard (2015). *How Big Data Is Transforming The Fight Against Cancer*. URL: http://www.forbes.com/sites/bernardmarr/2015/06/28/how-big-data-is-transforming-the-fight-against-cancer/ (visited on 26/08/2015).

Mashey, John R. (1998). *Big Data... and the Next Wave of IntraStress*. URL: http://static.usenix.org/event/usenix99/invited_talks/mashey.pdf (visited on 26/08/2015).

McDermott, James (n.d.). *The Impact of the Hawk-Eye System in Tennis*. URL: https://trainingwithjames.wordpress.com/research-papers/the-impact-of-the-hawk-eye-system-in-tennis/ (visited on 25/08/2015).

Mosco, Vincent (2014). *To the Cloud: Big Data in a Turbulent World*. Paradigm.

Nadal Le Roi (2015). *CLASH : Joao Sousa says the hawkeye is wrong ! (Montreal Rogers Cup 2015 vs Bernard Tomic) [HD] 2015*. URL: https://www.youtube.com/watch?v=3HBzEwe1yMw (visited on 26/08/2015).

National Research Council (2013). *Frontiers in Massive Data Analysis*. National Academies Press.

National Research Council (2014). *Complex Operational Decision Making in Networked Systems of Humans and Machines: A Multidisciplinary Approach*. National Academies Press.

Owens, N., C. Harris and C. Stennett (2003). 'Hawk-eye tennis system'. In: *International Conference on Visual Information Engineering* 14, pp. 182–185.

Power, D.J. (2007). *A Brief History of Decision Support Systems*. URL: http://dssresources.com/history/dsshistory.html (visited on 26/08/2015).

Press, Gil (2013). *A Very Short History of Big Data*. URL: http://www.forbes.com/sites/gilpress/2013/05/09/a-very-short-history-of-big-data/ (visited on 26/08/2015).

Puzis, Yuri, Yi Gao and Geoff Sutcliffe (2006). 'Automated Generation of Interesting Theorems'. In: *American Association For Artificial Intelligence*. URL: https://hbr.org/2006/01/a-brief-history-of-decision-making (visited on 29/08/2015).

Repanich, Jeremy (2010). *Can Cameras and Software Replace Referees?* URL: http://www.popularmechanics.com/adventure/sports/a5772/cameras-fouls-and-referees/ (visited on 26/08/2015).

Software Studies A Lexicon (2008). Leonardo Book. MIT Press.

Steiner, Susie (2012). *Smart fridge? Idiot fridge, more like*. URL: http://www.theguardian.com/lifeandstyle/2012/jan/11/homes-fooddrinks (visited on 26/08/2015).

Wright, Richard (2008). 'Data Visualization'. In: *Software Studies A Lexicon*. Leonardo Book. MIT Press, pp. 78–87.

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