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Articles

‘Making’, ‘taking’ and the material political economy of algorithmic trading

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Abstract

Drawing upon interviews with 72 practitioners of automated, ultrafast high-frequency trading (HFT), this paper identifies the most salient divide within HFT: between algorithms, trading groups and firms that specialize in ‘making’ (in adding bids to buy and offers to sell to exchanges’ electronic order books) and those that specialize in ‘taking’ (in executing against existing bids and offers in those order books). The paper explores how ‘making’ and ‘taking’ algorithms interact, emphasizing the materiality of that inte... ...esting the importan... ...aping of that trad... ...t could be differe...

In many of the world's most important financial markets, most trading is now by algorithms.[1] The trading pits of the nineteenth and twentieth centuries, crowded with human beings, are now almost all closed. Humans still trade with keyboard and mouse, but in many markets most trading is now by computer algorithms, especially ultrafast high-frequency trading (HFT) algorithms. The transformation is still being digested. There is a growing literature in economics on HFT (most recently reviewed by Menkveld, 2016), and a smaller but vigorous sociological literature, the best collection of which is in the May 2016 special issue of this journal, 'Cultures of high-frequency trading' (Lange et al., 2016).

This paper makes four contributions to the sociological literature on HFT. The first is to highlight the diversity of HFT practices. While the special issue and the insightful examination of algorithmic cultures in Seyfert and Roberge (2016) are careful to invoke 'cultures' in the plural, the best existing treatment of diversity (Seyfert, 2016) compares the epistemic regime of high-frequency traders with those of regulators and of market analysts who are critics of HFT, rather than probing differences among the practices of HFT firms. In contrast, this paper discusses the single most important divide within HFT and, simultaneously, examines the two main 'species' of HFT algorithm. The divide is between HFT firms, trading groups and algorithms that specialize in 'making' or 'providing liquidity' (which means entering into exchanges' computer systems bids to buy and offers to sell that cannot immediately be executed) and firms, groups and algorithms that specialize in 'taking liquidity': in entering orders that can be executed straightaway against existing bids and offers.

The divide between 'making' and 'taking' sounds like a narrow technicality, but is actually both fascinating and important: for example, it is felt by some practitioners of automated trading to have an affective, even a moral, aspect. Above all, analysis of the divide helps us understand how HFT algorithms interact, which is – as Borch points out,
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supervise the algorithms, while leaving to others the investigation of the algorithms themselves and of how they interact – even if, as noted below, that investigation involves methodological difficulties. The second contribution of the research reported here is thus its identification of four distinct styles of algorithmic 'taking', each associated with a distinctive form of making/taking interaction. Only one of these forms of interaction – the 'picking-off' of 'stale quotes': see below – has previously been researched in any depth (by Budish et al., 2015).

The paper's third contribution is its empirical investigation of the material nature of making/taking interaction. Although the authors of the May 2016 special issue would all agree that HFT algorithms interact materially, attention to materiality in the existing sociological literature on HFT has been limited. (The researcher on HFT most sensitive to materiality is the anthropologist, publisher and graphic designer Alexandre Laumonier, with his remarkable work documenting the paths followed in Europe by HFT's microwave links.[2]) Because the materiality of HFT is crucial to the success of HFT firms, it is a sensitive topic in interviewing, and building the necessary trust and technical understanding takes time. (For example, it was only after several years that I came to understand the impact of rain on making/taking interaction.) Materialism comes, of course, in many flavours, ranging from Marxism to, for instance, anthropological perspectives (e.g. Miller, 2005) or media theory (e.g. Parikka, 2015). One example, however, of a helpful theorization is the materialism of what one might call 'late actor-network theory' or 'late ANT', from around 2000–2002 onwards (the years of de Laet and Mol's [2000] study of the Zimbabwe bush pump and Mol's The body multiple [2002]). 'Late ANT' materialism makes fully explicit that materiality is not given or fixed, but processual and enacted: 'late ANT' is, to paraphrase Law (2010), a materialism of verbs, not nouns. Of course, the enactment of materiality need not involve human beings at all, but in almost all actor-network studies it does. The materiality on which ANT scholars actually focus is sociomateriality: practices and processe … well as non-human '…

An 'e… paper's fourt… economy' of the inter… y is strongly shaped … and how such a s… d Mol's alternative and equally possible modes of ordering' (Law & Mol, 2008, p. 141).[3] Different possible orderings can have substantially differential effects on 'making' and 'taking' (there are, e.g. a number of influential efforts materially to favour 'making' algorithms). Those orderings can be matters of economic 'life or death' for HFT firms, says one interviewee, and are, as argued in the conclusion, of wider importance too. I use the term 'material political economy' here to refer to this issue: economically consequential material orderings to which there are alternatives.[4] The politics of economic life takes a large variety of forms (monetary, ideological, coercive, legal, regulatory, party-political, social movement, and so on), but among them – perhaps increasingly so – are these material orderings. They remain underexplored, even in the actor-network inspired literature on 'performativity': the latter term's origins in the linguistic philosophy of J.L. Austin (1962) makes it seductively easy to conceive of it as a discursive phenomenon, rather than one involving assemblages that are simultaneously discursive and material.

Precisely because the material practices and systems discussed here are 'political' in the above broad sense – they are consequential; they could be different; disputes can take place about them – it is necessary to emphasize that this paper does not take a position in these disputes. The paper's use of the practitioners' terms 'making' and 'taking' does not imply the preference for the former found in other contexts (e.g. Foroohar, 2016),[5] and the paper seeks simply to illustrate the possibility of alternative material orderings, not to promote any of them. The paper's sections are as follows. After this introduction comes a short account of data sources, a brief overall introduction to HFT, and a section discussing 'making'. Next come brief sections on each of the four styles of making and on the technological systems that shape making/taking interaction. I return to material political economy in the final section, the conclusion.

Data s

As al … s prepared to be … nterviewees, for exam … me: 'even though h … the because he has the money and ability to create legal issues for former employees that speak' (email from interviewee MI, 26 June 2017; X is a founder of the HFT firm for which my interviewee's acquaintance had worked). Gradually, however, I identified, primarily via snowballing, 72 practitioners of HFT – mostly in the world's main centres of the activity: Chicago, New York, London and Amsterdam – who were prepared to be interviewed in varying degrees of technical depth (14 on more than one occasion; seven of them three or more times), along with 29 suppliers of technology or communications links to HFT. Other interviewees included exchange staff, regulators, etc. Interviewees are anonymized in what follows via two-letter labels.

Interviewing has limitations when it comes to understanding HFT algorithms and how they interact. When human beings did deals on trading floors, sociologists could not only quiz traders but also listen and watch, but no-one can in any literal sense see algorithms interacting with each other. We can still interview – and, if access can be negotiated, observe – those who program and supervise those algorithms, but their understanding of the latter's actions can be imperfect (as Lange, 2016, documents). For example, I regularly ask interviewees whether their algorithms often identify arbitrage opportunities (in which, e.g. the same shares can be bought on one exchange more cheaply than they can be sold on another). One interviewee (BU) answered 'not really', then corrected himself: 'The truth is … we wouldn't even know … we'd just be making money'. His algorithm's 'valuation' (essentially, its price prediction) 'will move down for some reason', but he did not usually take the time to investigate why.

Fortunately, however, making/taking interaction has an advantage in this respect. In contrast to a possibly opaque change in an algorithm's price prediction, a transaction between a making and a taking algorithm leaves an immediate trace in the form of an electronic notification (a 'confirm') to both parties. However imperfect interviewees' understanding of their algorithms, they can tell, from these 'confirm' messages, when those al s buy and sell from cal enquiry to be ch mists.

A brief

HFT firm from before

In this article

even an HFT firm with around 50 staff can be a significant player. To my knowledge, only two firms heavily engaged in HFT have more than 1,000 staff, and both also do things other than HFT. Some big banks used to be active in HFT, but their efforts were often less than fully successful: the rapid development of the necessary fast, highly specialized software systems can be difficult in a large, bureaucratic organization. Banks are still active as automated 'market-makers' – see below – in some classes of financial instrument (such as foreign exchange), albeit typically using systems that are slow by HFT standards, but 'taking' strategies in HFT by banks have effectively been ended by the post-crisis constraints on banks' proprietary trading.

The HFT firms I have visited vary widely. Some had offices in bland or even scruffy buildings; others had spectacular views over Lake Michigan, Manhattan or London. Most of their offices could pass for those of a generic dotcom firm, and they usually have something of the relaxed feel of a software start-up. The staff of HFT firms are mostly young and (at least in the roles closest to trading) mostly male. Almost no-one wears a business suit – it is common for me, as the visitor, to be the only person wearing a tie – and the shouting and swearing that used to happen on banks' trading floors is rare. The internal organization of the HFT firms from which my interviewees come varies. Some operate as unified entities, without even the traditional individual 'P&L' (a trader's profit or loss); one firm had a computerized 'signal library' accessible to all its traders and software developers. (What participants call a 'signal' is a pattern of data that informs an algorithm's trading.) Just as Lange (2016) discovered, however, other HFT firms are divided into strictly separate trading teams, with deliberate barriers to communication. One firm, for example, physically separates teams by placing a row of administrative staff between them, and in its main offices even plays white noise between the rows to reduce the chance of members of one team overhearing what is said by members of another. At another compartmentalized firm, said a young trader (interviewee AC), 'you … could get in trouble for being in the next room talking to someone

High-fre … es' comp … st bulk of the w … ading happens … d trading of other fin … place in a further … nited exchanges; a fifth, Interxion's datacentre on London's Brick Lane, is popular with HFT firms because of its central location and proximity to the London Stock Exchange's systems. The most important datacentre for HFT on the Continent is FR2 in Frankfurt am Main. These datacentres are huge warehouses, largely windowless, packed with many thousands of computer servers, powerful cooling systems to extract the heat the servers generate, mile upon mile of cabling, and almost no human beings beyond a few maintenance and security personnel. (Because of tight security, visits to datacentres are hard to arrange, but I have been able to visit two of them.)

Figure 1 The datacentre of the Chicago Mercantile Exchange, the most important in global finance. The microwave dishes via which signals from this datacentre travel to New Jersey and elsewhere, which are currently in a variety of locations close to the datacentre, are being centralized on the pylon under construction on the right of the picture.

Source: courtesy Bird & Renoult. See http://bird-renoult.net/antenna-gods-us-edition-2018/.

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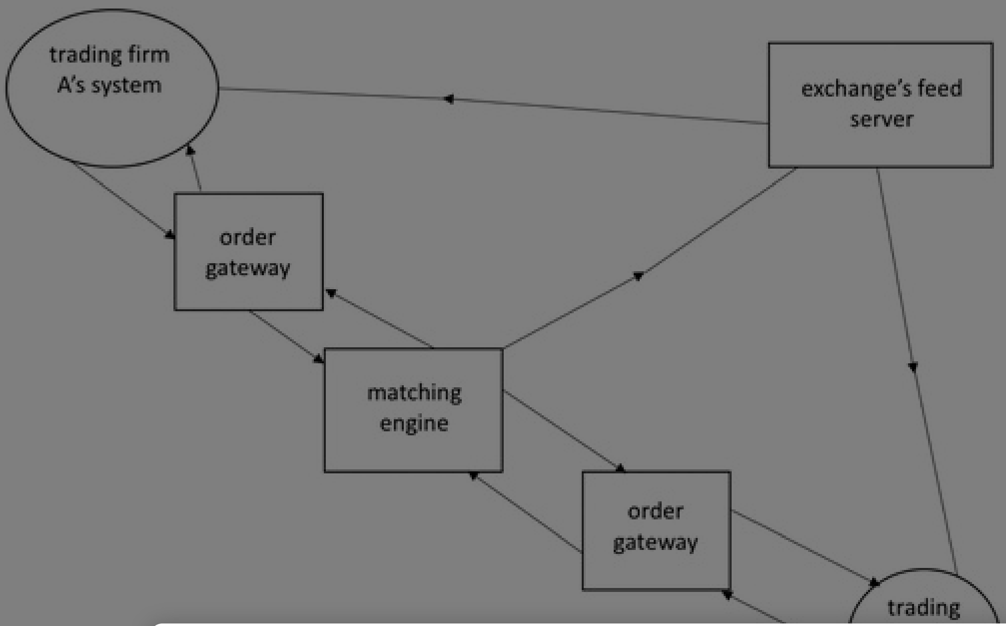
exchange's matching engines. Bids to buy and offers to sell by the algorithms running on HFT firms' servers (and their cancellations of bids and offers) take the form of electronic messages to the exchange's systems, and arrive at the matching engines via exchange computers known as 'order gateways' (see Figure 2). An exchange's 'feed servers' or 'market data publishers' are computers that receive streams of order-book updates – transactions, new orders, cancellations of orders – from the matching engines, and dispatch them in anonymized form as a datafeed, sold to trading firms, that enables them to synthesize their own constantly updated mirrors of the exchange's order books.

Figure 2 Inside a data centre: highly schematic. Arrows indicate the direction in which electronic messages flow. For example, a trading firm's system sends orders (and cancellations of orders) to an 'order gateway', which in turn sends that system a 'confirm' message when, e.g. one of its orders has been executed. For that system to learn as quickly as possible about transactions (and other 'order book' changes) not involving the firm, the latter has to pay the exchange for the datafeed from, and an ultrafast connection to, its feed servers.



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Making

Most of the direct and indirect interaction of trading algorithms is mediated by order books – for exceptions, see MacKenzie (forthcoming) – and what differentiates a ‘making’ from a ‘taking’ order is its price relative to that of the existing orders in the book. Consider the order book in Figure 3. A bid to buy shares at $29.49 would be a ‘making’ order. The matching engine cannot execute it immediately, because there are no offers to sell at that price to match it with. Instead, the matching engine would simply add it to the order book’s queue of bids at $29.49. In most exchanges, that queue is a time-priority list: a new bid to buy at $29.49 will be executed only when all earlier b … d to buy at $29.50 w … htaway (perhaps … price. Doing so remo … taking’.

In an … st ‘taking’ orders a … among trading a … rs being so simple that it is hard to imagine that much pivots on it, and the difference between the prices of a ‘making’ and a ‘taking’ order on a modern electronic exchange is normally very small (the one-cent difference in Figure 3 between a bid that ‘makes’ and a bid that ‘takes’ is 0.03 per cent of the market price, and differences of roughly that size are typical). Yet this simple mechanism and tiny difference are experienced by some participants as having a moral, affective weight. The words chosen by interviewee BQ are unusually strong, but the underlying sentiment is not unique: ‘I tend to want to work at [HFT] companies that are “makers” because I see the inherent evil in the “takers”’.

The ‘moral’ preference for ‘making’ rests on the legitimacy of its most systematic form: ‘market-making’. This involves an algorithm continually keeping both bids to buy and offers to sell in the order book, at or close to the highest bid price and lowest offer price. In the order book in Figure 3, for example, the first-in-the-queue bid to buy 100 shares at $29.49 and the first-in-the-queue offer to sell 100 shares at $29.50 might both have been entered by the same market-making algorithm. Although the goal is economic (to earn the one-cent difference between those two prices, along with any payments the exchange may make to incentivize market-making), algorithmic ‘making’ inherits the legitimacy of a traditional human role: that of the ‘market-maker’, who constantly stood ready both to buy the financial instrument being traded and to sell it (at a somewhat higher price).

Because other market participants’ bids and offers arrive only sporadically, market-makers – whether human or algorithmic – provide a service to market participants who want to transact immediately. Interviewee OH highlights the continuing potency of that source of legitimacy when she recounts an episode in her algorithmic market-making firm at the height of the global financial crisis of 2007–2008. A software developer had left her firm, saying: ‘I couldn’t look my grandmother in the face anymore and say I worked i … g of all its employe … ain to you why you … e market-make … o shift anot … oes the resistanc … “No, no, no”, as i … nst that. But we had t…

Specialists in 'taking' reject this 'moralization' of making (as indeed do some specialists in the latter). They (e.g. interviewees BY and CU) cite taking's central role in what economists call 'price discovery'; its role (via arbitrage, as mentioned above) in keeping prices in different markets aligned; the 'service' (interviewee CU) it provides to those who wish to trade using 'making' orders (which, other things being equal, is cheaper than 'taking'); and the plain fact that without 'taking' an exchange would have no trading. Furthermore, as OG's desire for change indicates, legitimacy – being able to 'look your grandmother in the face' – does not guarantee economically successful market-making. As AG puts it, 'you make a little bit of money', from your algorithm repeatedly selling at a price higher than that at which it buys, but 'you periodically get run over': your market-making algorithm buys when prices are about to fall, or sells when prices are about to rise.

The risk of being run over (which can cancel out a long period of repeated small gains) has two implications. First, a market-making algorithm has to keep its 'inventory' (its aggregate trading position) reasonably small. '[Y]ou have to actively control your inventory', says AE: if inventory starts to rise, a market-making algorithm will 'shade' its bids or offers so as to reduce it. If, for example, too many of its bids have been executed, it will reduce the price of its offers so as to make those more attractive. If that fails, it may begin to 'take': in this example, reducing its inventory by executing against existing bids in the order book. (That occasional need for a market-making algorithm to 'take' is one of the ways in which the divide between 'making' and 'taking' is not absolute).

Second, almost all market-making algorithms make predictions of near-future price movements, and use those predictions to minimize the risk of being 'run over'. As BL says: 'markets move and you need to know when they're going to move because [otherwise] you'll be inventorying at a terrible price'. In all the markets in which HFT is
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kind listed in Table 1. One market-making HFT firm, London-based XTX Markets, even advertises the salience of regression. I assumed its name was one of the quasi-acronyms common in business, but when I read it etched in glass I realized that it was , a pervasive operation in regression analysis (the multiplication of a data matrix by its transpose).

Table 1 The main classes of 'signal' used in HFT in shares

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Nothing in principle stops a market-making algorithm from also 'taking', and my interviews reveal that there are, e.g. algorithms that 'make' if their price prediction is between the highest bid and lowest offer, and 'take' if it is sufficiently far outside them. Blending of this kind is, however, far less common than one might expect. It is more usual to find that algorithms, trading groups and firms specialize either in 'making' or 'taking': 'it's almost like two very different strategies and thought processes' (interviewee BF). For example, those interviewees who headed firms made up of separate trading groups reported that those groups focused either on making or on taking, not both:

> I think there is just something that's so different about having to have an opinion all the time [a market-making algorithm has constantly to be making decisions about its bids and offers] versus occasionally having an opinion [a taking algorithm needs only to identify the intermittent circumstances in which taking will be profitable] … for some reason those two things can't really be married without somehow ruining an aspect of the other one (AG).

The specialization in either making or taking reported by interviewees is confirmed by the litera… …ong firms in the prop… …rences that are broa… …one month, then m… …indeed be 'hard… …ple, reports discover… …ms in a leading '…

> [I]f you're trying to do something different than the system was conceived and built in the first place, you spend an awful lot of time and energy trying to stop it from doing what it wants to do. You get into a position and the first thing it wanted to do was to place an order on the other side [to reduce inventory] … I want to hold [the position] for five minutes. No, you can't do that. It's not that you couldn't, but you'd be trying to rework the code … Very, very, very difficult. (Interviewee CE)

Taking I: 'to gather the world's information in one place' (interviewee CU)

'Taking' is more heterogeneous than 'making' (space constraints prevent discussion of differences in styles of making). All HFT 'taking' strategies involve identifying situations in which it is likely that executing against existing bids and offers in the order book will be profitable, but how that is done varies in important ways, explored in this and the next three sections. One approach is for 'taking' algorithms to process larger amounts of information than is processed by 'making' algorithms, or to process it in ways that are mathematically more sophisticated. If, by doing this, a 'taking' algorithm can improve on 'making' algorithms' price predictions, then there will be profit opportunities. These are not there continuously, but interviewees (e.g. BY) report that when they arise 'taking' algorithms typically buy or sell substantially larger quantities of the financial instrument being traded than 'making' algorithms do.

Interviewee CU gave the example of a 'taking' algorithm trading 10-year US Treasury bond futures in the Chicago Mercantile Exchange's datacentre, shown in Figure 1. The algorithm will take into account the pattern of bids, offers and trades in those futures, and patterns in the trading of the other Treasury bond and interest-rate futures also traded i … ata on the buying a … o datacen … c cable, it will r … d German sove … ment bonds will com … rithm will continu … ures it is

All of this information is also available to the 'making' algorithms of at least the larger market-making firms. The latter's algorithms, though, have to be ultrafast (and therefore not too complex), because of their need to be at or close to the head of the time-priority queue for executions and the danger of their quotes becoming stale and being picked-off (see the next section). As CB, from a very sophisticated market-making firm, puts it: 'we add, subtract, multiply and divide really, really well', in other words very fast indeed. '[W]e're not doing high math and high quant.' There is, in contrast seldom a queue to 'take'. 'Taking' algorithms, which 'aren't fighting for queue position', therefore 'maybe have just a little more time to quantitatively evaluate what the market is really saying', says BY.

That speed can therefore be a less extreme priority in some forms of 'taking' than in 'making' was, to me, a counterintuitive finding from the interviews, but one consistent with the financial-economics literature (Brogaard et al., 2015). Interviewee CU, however, warns that the lessened priority of speed lasts only until another taking firm 'begins competing with you': i.e. discovers and starts to exploit the same predictive pattern. Put more generally, the computationally-complex, quantitatively-sophisticated 'taking' discussed in this section is at one end of a spectrum; at the other end is the 'taking' discussed in the next section.

Taking II: picking-off stale quotes

The web, touched on in the previous section, through which the world's financial information flows is strongly structured: some places – some 'centres of calculation' in the sense of Latour (1987) – are much more important than others; what happens in them has direct, highly predictable, and largely unidirectional effects. I chose the Chicago Mercantile Exchange's (CME's) datacentre for Figure 1 because it is the single most im … 2018) large transact … crucial order books, t … wide, that imm … ate ('stale'). If tha … can simply 'pick off' … etype of this simp … by Budish et

Mercantile Exchange's datacentre – especially the most important such future, the ES, which corresponds to the Standard & Poor's 500 share index – suddenly rises or falls. As discussed in MacKenzie (2018), this is typically followed – less than a hundredth of a second later – by moves in the same direction in the prices of the underlying shares (especially in the prices of the corresponding exchange-traded funds [ETFs], which are composite shares that track the same index). If the algorithms making markets in those shares and ETFs do not cancel their existing bids or offers quickly enough, a 'taking' algorithm will pick them off. Substantial changes in the other simple signals universally understood within HFT to have predictive value (see Table 1) give rise to similar 'picking-off' opportunities.

'Picking-off' creates a speed race between 'making' algorithms, seeking to cancel stale bids or offers, and 'taking' algorithms trying to execute against those stale quotes. In December 2011, one of my first interviewees (AG) estimated the response time needed from an algorithm engaged in this kind of interaction as below 5 microseconds (millionths of a second); a recent interviewee – CR, in April 2018 – says it is now 300 nanoseconds. In some particular contexts a staggeringly brief 120 nanoseconds seems now feasible.[9] (A nanosecond is a billionth of a second, the time it takes the fastest physically possible signal – light in free space – to travel a mere 30 centimetres.) Picking-off is one of the two most important material drivers of what interviewee CR calls 'an endless race' (Budish et al. [2015] call it an 'arms race' in speed); the other driver is the competition among 'making' algorithms to be at the front of queues. Given the current material arrangements of trading, the speed race imposes unavoidable costs on almost all HFT firms. It requires them, for example, to use microwave, millimetre wave or atmospheric laser links – via which signals travel at almost their speed in free space – rather than fibre-optic cable, the material of which slows light to around two-thirds of its free-space speed.

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without being picked-off, and, as Shkilko and Sokolov demonstrate, standard measures of liquidity temporarily improved.

The second phase began after a communications supplier, McKay Brothers, created a new microwave link between Chicago and New Jersey in 2012, using the fastest available technology and choosing a route very close to the geodesic (the geodesic, or great circle, is the shortest path on the earth's surface between two given points). McKay has subsequently kept refining the link to keep it at least as fast as any of the privately-owned links. Since 2012, the McKay link (widely used by market-making firms) has given their algorithms a degree of protection from being picked-off. In this second phase, the effect of rain on the interaction of algorithms seems to have reversed. Now, if it rains sufficiently heavily to interrupt the McKay link, market-making firms cannot know for certain that the private links used by 'taking' algorithms have also failed. So, reports SJ, market-making algorithms have to 'widen spreads', as market participants put it: reduce the prices of their bids and increase the prices of their offers, so lowering the risk of being picked-off (but also reducing one of the standard measures of liquidity).

Note that – in line with late ANT's 'enactment materialism' – the vulnerability of microwave transmission to rain is not a fixed physical effect: it increases as higher frequencies are used. Of the frequencies available in the United States, microwave engineers prefer the most reliable: 6 GHz. Unfortunately, reports SJ, that band is 'crowded' near the Chicago-New Jersey geodesic (microwave signals at the same frequency can interfere with each other), so keeping close to the geodesic requires use of higher frequencies more vulnerable to rain: 11, 18 and sometimes even 23 GHz. The influence of rain on the interaction of algorithms is, furthermore, not found in Europe. The European analogue of the Chicago-New Jersey geodesic is the microwave route from London to Frankfurt's FR2. (Perhaps fortunately for the generally unappealing
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Taking III: market-impact trading

The above two forms of ‘taking’ most likely account for the bulk of the interaction between ‘making’ and ‘taking’ HFT algorithms. There are, however, other forms of ‘taking’ that involve the prediction not just of overall price changes but of the future actions of ‘making’ algorithms. One is ‘market-impact trading’, in which an algorithm reflexively exploits the likely influence of its own actions on other algorithms. One version of this, described by interviewees AC and CR, involves identifying situations in which many of the bids or offers in the order book are from small firms that will ‘cut their losses’ (CR) or ‘puke’ (AC; i.e. liquidate their positions at an unfavourable price) if prices move against them by more than a certain amount. If a well-capitalized firm’s algorithm can detect a ‘weak-hand moment’ of this kind, it can ‘sweep’ or ‘swipe’ (CR) the order book, for example by executing against all the bids at multiple price levels, so driving the market down, forcing ‘weak-hand’ algorithms to liquidate inventories at temporarily low prices, and profiting – often surprisingly modestly, given the scale of the trade – from the difference between those prices and the average price in the ‘swipe’ sales:

> It’s amazing, you see those swipes and they’re huge swipes, millions and millions and millions of dollars underlying value, and if you look at it, the actual profit of one of these trades is $2,000 or something like that. (CR)

Taking IV: cat and mouse

‘Swiping’ is a crude, aggregate way of exploiting predictable behaviour by other algorithms, but ‘taking’ algorithms can also do this far more subtly. Predictability can, for example, arise from ‘making’ algorithms’ pervasive use of linear regression

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corresponding to the Nasdaq-100 share index). A 'taking' algorithm can predict movements in the market for the NQ (for example, by analysis of the balance of bids and offers in the order book for the NQ), and then anticipate how the price predictions of the algorithms making markets in the ES will change in response to those movements. The algorithm can thus sometimes identify a 'coming [order] book imbalance' in the ES, and therefore a predictable shift in price quotations from which it can profit (interviewee CG).

Even more subtle is for a 'taking' algorithm to 'predict what this guy [this specific market-making algorithm] is going to do', and thus profitably play a 'game of cat and mouse' (CG). If, for example, a specific market-making algorithm can be identified, and observed repeatedly, it can be possible to infer when it is approaching an inventory limit and will begin to 'shade' its prices. A sophisticated 'taking' algorithm can then take on a trading position in the anticipation of being able to liquidate it at a profit against those shaded prices. The 'shading', and thus the profitability of the trade, will typically be small (of the order of the minimum price increment: for example, one cent per share, as in Figure 3). If, however, the algorithmic behaviour that has been identified is repetitive and frequent, such small profits can accumulate.

A 'taking' algorithm successfully playing a 'game of cat and mouse' with a specific 'making' algorithm is perhaps the most demanding computationally of all the forms of taking. The volumes of data generated by financial markets are huge (and anonymous), and established statistical techniques such as linear regression are not well suited for identifying the 'signatures' of specific algorithms in these masses of data: more recent machine-learning techniques are needed. Also required is a powerful grid of multiple computers on which to implement these techniques. This grid can run 'offline' (with programs running overnight or at weekends if necessary) when 'signatures' are being searched for; the 'taking' algorithms that are the result of this research have to be simpler t … however, not very … the speed race are … complex comp… he same time…

The gam … lligence – 'one of c … M) – and the that are characteristic of a firm's algorithms (BM). More recently, however, machine learning techniques have, as noted above, started being applied to the 'game'. This is facilitated, reports CG, by technological changes in exchange systems. 'Most people's [computer] systems are very deterministic,' he says. For example, the time taken by an HFT firm's system to respond to an incoming signal (e.g. by sending the exchange a new order) varies between firms, but for each particular firm it tends to be reasonably constant. This creates a potentially identifiable 'signature', but one previously masked by inconsistencies among exchanges in how time is measured and by 'jitter' in exchange systems (random fluctuation in the time taken to process orders). Precise atomic-clock synchronization to the global time standard, UTC, and greater determinism in exchange systems (increasingly programmed in C++, which allows fuller control of the material implementation of computational processes) have, however, removed much of that masking.

Alternative material orderings

As far as I can tell, this 'unmasking' is an inadvertent material effect, not one sought by those who run exchanges. They are, however, by no means always neutral observers of how 'making' and 'taking' algorithms interact. When they intervene it is most usually to encourage 'making'. There is no evidence in my interviews that this is because they regard 'making' as 'more moral' than 'taking'. Their fear, rather, is of 'empty screens' (interviewee GI) – order books devoid of bids and offers – which make an exchange fatally unattractive to traders and institutional investors. Sometimes, exchanges encourage 'making' with economic incentives: for example, small payments (known as 'rebates') to those who place 'making' orders that subsequently are executed against. Sometimes, too, exchanges protect making algorithms from HFT 'takers' by having rules tha … ge, Aquis, has a ru … e told the Financia … quidity', that is …

From … n by exchang … most famous … oys) is a 60-

which all incoming orders to IEX (and all market data from IEX) have to pass, slowing them down by 350 microseconds. The coil is strikingly reminiscent of Latour's famous example of material politics, the traffic-slowing 'sleeping policeman' (Latour, 1999, pp. 187–188), but it is a less than decisive intervention in the interaction between 'making' and 'taking' algorithms, because it slows down both categories equally.[11] That did not, however, prevent the coil sparking fierce controversy among market participants in the United States.

Also deeply controversial, although much less well known, was a 2016 proposal from another small exchange, the Chicago Stock Exchange, to install a software-implemented 'speed bump' that would slow 'taking' orders, while leaving 'making' orders and cancellations (by registered market-makers) unaffected. The staff of the US stock market regulator, the Securities and Exchange Commission, initially approved the proposal, but Republican Commissioner Michael Piwowar opposed that decision, which was then put on hold. In April 2018, the Chicago Exchange – also at the centre of a furore around its possible sale to a group including Chinese investors – was bought by the Intercontinental Exchange, owner of the New York Stock Exchange, and it remains unclear whether the proposed speed bump will be implemented.

As a result, the introduction of material devices and procedures to shape making-taking interaction has mostly been found in foreign exchange trading, in which there is no need to seek regulatory approval and in which banks, with their slow technical systems, are still important market-makers and retain considerable power and influence. The most sophisticated of these devices is a module, described by interviewee GS, that was added to the Thomson Reuters trading system in 2016. The module examines incoming buy and sell orders for each of the currency pairs being traded, classifies them as either 'taking' or 'making', and adds them to the corresponding buffer.[12] The first order to enter an empty buffer starts a 'timer' that runs for three milliseconds (thousandths of a second), ... t contains to the matc... test market-making ... cellations of orders ... tely. This gives ... ves, they have thr... e quotes before th...

Conclusion: material political economy

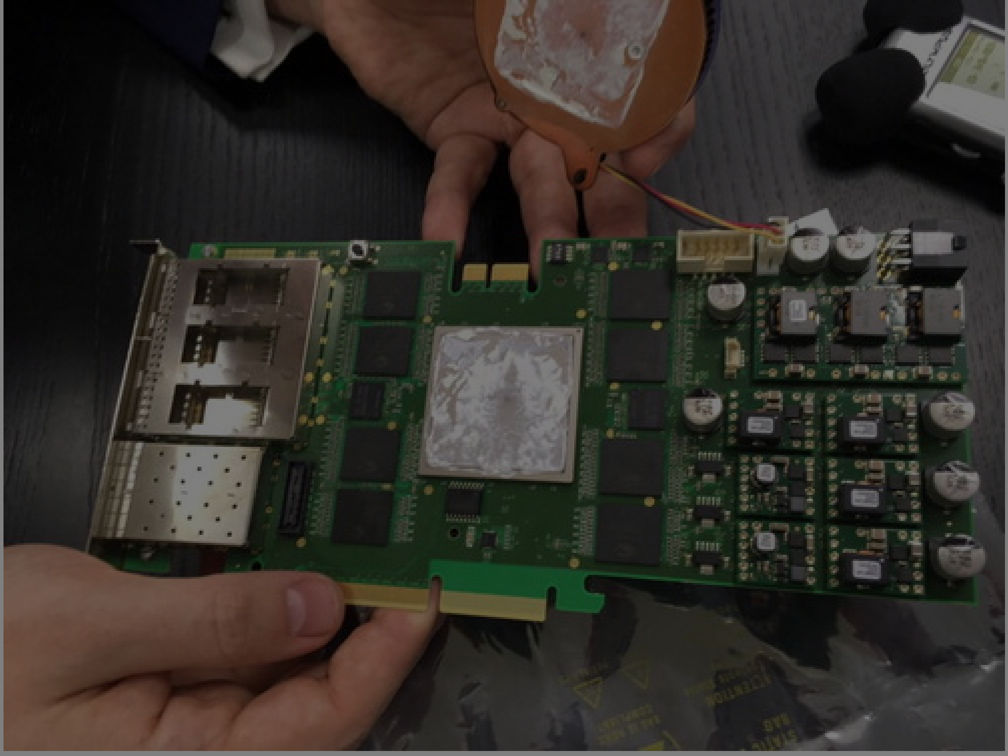
The installation of the Reuters module excited little media interest, but nevertheless exemplifies the phenomenon to which ‘material political economy’ points: the possibility of alternative material orderings that differ in economically consequential ways. In particular, as just noted, the module is designed to alleviate the arms race in speed in algorithmic trading – though it does not solve it: no modification to any one system could; and other proposals exist.[14]

That arms race sometimes disturbs even those whose business it is. Every so often, my interviews are punctuated by an interviewee spontaneously reflecting on it. For example, the need for nanosecond speeds means that many HFT algorithms are no longer implemented in conventional software but directly in hardware: in specialized silicon chips called ‘field-programmable gate arrays’ or FPGAs (see Figure 4).[15] In February 2018, a specialist in the use of FPGAs in HFT broke off telling me how sophisticated rejigging of the patterns of connections within FPGAs could ‘shave 5–10 nanoseconds’ off the time taken to process signals:

> Those engineers that spend day and night on this, it’s ridiculous. It’s quite ridiculous … mind-numbing … a lot of people with extended training … shaving nanoseconds … you could put that brainpower to something else … something different. (Interviewee UC)

Figure 4 A field-programmable gate array (FPGA) in a ‘development kit’ for programming and testing. The FPGA is the large central chip with white paste on it.

Source: Author’s fieldwork photograph.



Display full size

The net present value of the stakes in even the simplest form of interaction between making and taking algorithms (the picking-off of stale quotes, which is, as noted above, one of the two key drivers of the speed race) may be as high as $100 billion (Budish, 2017). Much of that, however, does not crystallize as profit to HFT firms, but takes the form of otherwise unnecessary spending on technology. While faster FPGAs might conceivably have eventual uses in different spheres, that seems unlikely for other speed-race investments such as marginally speeded-up microwave links. What disturbs some insiders seems to be a nagging sense of scarce resources being wasted: either simply their firm's resources, or (as in the case of interviewee UC) social resources.

Just occasionally, too, the material political economy of HFT erupts into the formal political system, at least locally. The geodesic from London to Frankfurt crosses the east Kent coast near the little village of Richborough. In 2016, two communications compani … huge – 10-foot wid … requires a direct 'li …
Richb … Without the latte … nel is narrowe … that is around 1 … n an apparen … y the

managed project fund.[16] Considerable opposition was, however, sparked, involving not just those who live close to the proposed masts but also, e.g. Historic England, guardians of the remains of Richborough Fort, an important Roman administrative/military base. After much local debate, Dover District councillors voted in January 2017 to refuse planning permission for the masts.

In the case of the Richborough masts, the material political economy of algorithmic trading would have been all too visible. Such cases, however, are likely to remain rare. We are going to have to dig beneath the surface of the financial system to unearth that material political economy. One of its effects, for example, is what may become a substantial shift in Europe away from exchanges' anonymous order books, which can be 'seen' (at least in technologically mediated ways) by all human and algorithmic participants, towards other, more private, forms of automated trading involving webs of bilateral relationships among firms that disclose their identities to each other. In order books, as many market-making interviewees point out, their algorithms are vulnerable to being picked-off (despite the partial protection offered by the McKay Brothers' links); they suffer losses when order books are 'swept', etc. Such risks are minimized if market-making algorithms are in direct electronic contact with – for instance, receiving electronic 'requests for quotation' from – a firm known to be simply an institutional investor with no interest in or capacity to pick-off stale quotes. This may bring benefits (there is little need for extreme speed; interviewees who are enthusiasts for the shift said that institutional investors can receive better prices in an ongoing bilateral relationship), but it may leave exchanges' order books – the more 'public' form of price formation – depleted and 'toxic' (i.e. populated by orders that could not be executed bilaterally because the risk involved seemed too high: 'the trades that no-one wants' [interviewee GM]). Yet another – again still subterranean – issue of material political economy is the growing determinism of exchanges' computer systems, referred to above. As random fluctuations in processing time are reduced, the algorithms of HFT firms wit ... Determi ... ms, with the potentia ... of ultra- high ...

The part ... other forms of algori ... e, either because ... aterial phenomenon of the importance of material orderings to economic life is, however, not new: slavery, after all, rested upon guns and whips, manacles and slave ships. Nor, indeed, is material political economy a novelty: volume one of Capital, with its detailed attention to the changing material orderings of production, can be read as in this genre (MacKenzie, 1984). As economic life becomes ever more algorithmic, and takes place to an ever-increasing extent in giant datacentres (let us not forget, for example, the elementary but environmentally important fact that datacentres consume huge amounts of electricity), material political economy is a tradition that urgently needs revivified.

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Notes c

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Donald MacKenzie is a Professor of Sociology at the University of Edinburgh. His most recent book, written jointly with Diane-Laure Arjaliès, Philip Grant, Iain Hardie and Ekaterina Svetlova, is Chains of finance: How investment management is shaped (Oxford University Press, 2017).

Notes

1 The term 'algorithm' is used here to refer not just to a set of instructions sufficiently precise that they can be implemented as a computer program, but to that program running on a physical computer system and having material effects on other systems. For wider research in 'critical algorithm studies', which cannot be reviewed here for reasons of space, see the evolving bibliography at https://socialmediacollective.org/reading-lists/critical-algorithm-studies/.

2 See Laumonier's blog, https://sniperinmahwah.wordpress.com. (Mahwah, NJ, is the location of the New York Stock Exchange's datacentre.)

3 See also, e.g. the Dingpolitik of Latour (2005) or the subtle reflections in Barry (2002) on how 'politics' (in the conventional sense of the word) can have 'anti-political' effects in closing down potential contestation.

4 A different aspect of the 'material political economy' of HFT is explored in MacKenzie (2017): the influence of processes that are in a broad sense 'political' on the 'signals' (patterns of data) that are available for price prediction by HFT algorithms.

5 Practitioners' alternative terms for 'make/take' – e.g. 'add/remove' or
'passive, … erring to
'making … cally has to
be conti…

6 Tra… not wanting
others, … s for strict
compart… ms
imitating … allow one

‘self-trading’ is normally prohibited, because it can be used to create a manipulative ‘false price’.

7 The need to limit this paper’s length means occasional inexact formulations, such as ‘exchange’: not all the trading venues in which HFT is active are registered exchanges, despite having exchange-like roles.

8 See, e.g. Baron et al. (2012); Hagströmer and Nordén (2013); Benos and Sagade (2016). Benos and Sagade, for example, use regulatory data to classify HFT participants in the London Stock Exchange as ‘passive’ (makers), ‘neutral’ or ‘aggressive’ (takers): ‘aggressive HFTs take liquidity 82% of the time, whereas the passive do so only 11% of the time’ (2016, p. 63).

9 These are what in HFT are called ‘wire-to-wire’ or ‘tick-to-trade’ times: the delay between the arrival of a price signal and the dispatch of an order or cancellation.

10 It seems as if the issue was mainly ‘sweeps’ of multiple levels of the order book (interviewee EA), but whether these were ‘market impact trading’ of the kind discussed above is unclear.

11 The main point of the coil is to inhibit a very particular form of ‘taking’. Much trading on IEX is ‘midpoint matching’, in which trades are consummated at the midpoint of the highest bid price and lowest offer price on all the US exchanges. If a ‘taking’ algorithm detected that the midpoint calculated by IEX’s system was out-of-date, it might be able profitably to ‘take’. However, the datafeeds that inform IEX’s calculation of the midpoint do not go through the coil, so the midpoint will be updated before any ‘taking’ order has emerged from the coil.

12 There are separate buffers for ‘making’ orders at different prices.

13 The r … firm are grouped … to an order submitte … etail on the module …

14 In … arms race is contin … uctions.

15 Even … g (around a

conventional computer central processing unit and back again.

16 See http://www.richboroughmast.co.uk/community-benefits/community-benefit-fund, accessed 30 April 2018.

17 For example, the automated advertising auctions triggered by users' Google searches are discrete, single-point-in-time, auctions, in which, e.g. the algorithm that bids first has no advantage. There is an echo here of the material reordering proposed by Budish et al. (2015): see note 14 above.

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