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Master's Thesis

Technology and Materiality in Financial Markets

Analyzing Algorithmic and High Frequency Trading in Terms of Social Studies of Finance

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Abstract

The present work analyzes Algorithmic and High Frequency Trading in terms of the *Social Studies of Finance*. The underlying notion of this approach - to a large extent deriving from Actor-Network-Theory - is that human and nonhuman entities produce agency in socio-technical networks that also make up markets. Drawing on a detailed review of theory and expert interviews, these socio-technical networks are revealed and it is thereby shown that technology and materiality do play a pivotal role in realizing Algorithmic and High Frequency Trading. Time and space are compressed due to the manifold delegations of tasks to machines which allows for the enormous acceleration of trading. The resulting consequences for the shape of calculative agency, transparency, the distribution of power, the creation of algorithms and accountability are concretely described and interpreted with reference to theory.

Im disziplinären Rahmen der *Social Studies of Finance* wird der algorithmische und hochfrequente Handel an Finanzmärkten untersucht. Grundlegende Idee dieses hauptsächlich von der Akteur-Netzwerk-Theorie inspirierten Ansatzes ist, dass Handlungsmacht (englisch: Agency) sowohl von Menschen als auch Objekten in sozio-technischen Netzwerken ausgeübt wird, auch in Märkten. Durch einen Rückgriff auf Theorie und Experteninterviews werden diese Netzwerke offengelegt und dadurch gezeigt, dass Technologie und Materialität eine entscheidende Rolle spielen. Das Delegieren zahlreicher Tätigkeiten an Maschinen komprimiert Raum und Zeit, so dass die Beschleunigung moderner Finanzmärkte realisiert werden kann. Die daraus resultierenden Konsequenzen für kalkulatorische Handlungsmacht, Transparenz, Machtverteilung, Kreation von Algorithmen und Zurechenbarkeit von Verantwortung werden unter Rückgriff auf die zuvor erarbeitete Theorie beschrieben und interpretiert.

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List of Abbreviations

AT	=	Algorithmic Trading
ANT	=	Actor-Network-Theory
CME	=	Chicago Mercantile Exchange
CFTC	=	Commodity Futures Trading Commission
DAX	=	Deutscher Aktien Index
ETF	=	Exchange-Traded Fund
HFT	=	High Frequency Trading
NASDAQ	=	National Association of Securities Dealers Automated Quotations
NYSE	=	New York Stock Exchange
SEC	=	Securities and Exchange Commission
SSF	=	Social Studies of Finance

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1. Introduction

The present work sociologically analyzes the pervasive technological transformations that are currently changing the shape and practices of modern financial markets. The ever increasing capacities of computer power and the proliferation of accelerating information and communication technologies have brought forth novel types of trading, namely *Algorithmic Trading (AT)* and its offspring *High Frequency Trading (HFT)*. Both types require complex configurations of technological infrastructure, especially HFT since it builds on exploiting informational edges deriving from speed advantages. The automation and electrification of market structures has consequences for traders, stock exchanges, business models and trading strategies (Lenglet, 2011, p.45 ff.). Although there are no consistent and clear-cut figures stating the current relevance, the following numbers give a hint to the essential role AT and HFT play for contemporary financial markets. E.g. in the U.S. equity market, roughly 50% of all orders are estimated to have been generated by algorithms and at least 30% of the whole equity trading volume (1,2 - 2,5 trillion shares p.a.) are assessed to be realized algorithmically (Avellaneda, 2011, p.1). At *Eurex*[1] for example, 80% of all orders have been executed via electronic direct market access without any human intervention (Eurex, 2013). At *CME Globex*[2], 50-70% of the trading volume are covered by AT and it is also responsible for 70-80% of the circulating messages, depending on the actual market (CME, 2011, p.2). Similarly, HFT strategies have overtaken a tremendous share of trading. In 2009, while only making up 2% of roughly 20.000 trading companies in the U.S., HFT firms presumably account for up to 73% of all equity trading (Iati, 2009). These figures decrease according to TABB Group[3] estimations which state that 56% of the U.S equity trade-volume are realized by HFT. For Europe, they assess 38% of the trading volume to be referable to HFT (Grant, 2010). These figures document that the

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[1] Eurex (European Exchange) is one of the biggest exchanges for financial derivatives, situated in Eschborn, Germany.

[2] Globex belongs to the CME Group and is one of the biggest exchanges for futures and options, situated in Chicago, USA.

[3] TABB Group is an U.S. research and advisory company for the financial services industry.

automation of trading and HFT crucially reconfigure financial markets and reveals the enormous impact of technology: „Technology has revolutionized the way financial markets function and the way financial assets are traded.“ (Hendershott & Riordan, 2009, p1.) Electrifying and automating initially started in the late 1970s when the *New York Stock Exchange* established the designated order turnaround (DOT), a first electronic execution system. This was accompanied by more sophisticated ways of market data distribution which now rendered computers possible to assess quotes and trades. In 1983, *NASDAQ* introduced a computer-assisted execution system for their broker dealers. In spite of these initial developments, AT did not gain further momentum until the 1990s. In 1992, the CME launched *Globex*, its first fully automated trading platform. (Aldridge, 2010, p.7 ff.; Leinweber, 2007, p.46). *Deutsche Börse* likewise introduced *IBIS (Integriertes Börsenhandels- und Informationssystem)* in 1991 which was replaced by *Xetra* in 1997, a fully automated trading system (Deutsche Börse, 2010, p.10). Eventually, with entering the 2000s, electronic trading capabilities have heavily been increasing and now reached contemporary levels.

An important event that generated enormous attention for AT and HFT, and also conveyed it to the public and political sphere, was the so called "Flash Crash" on May 6, 2010, which inspired severe criticism towards these technologies as they were accused of being responsible for heavy market fluctuations. Throughout this work, the author will repeatedly refer to the Flash Crash which is therefore expounded in the following. So, what happened on May 6, 2010? At *CME Globex*, overall U.S. share prices and index futures rapidly declined and rebounded almost completely in a time frame of a few minutes. Equity securities and Exchange-Traded Funds (ETFs)[4] dropped and rebounded up to 15 % of their values. 20.000 trades were realized at prices up to 60% away from the values they had briefly before, some of those at prices around $0,01 while others almost reached $100.000 before readjusting to normal figures. On this day,

[4] ETFs are funds that are linked to certain indexes. In contrast to conventional funds they can be traded on exchanges like normal stock throughout the whole day and not just once a day (NYT, 2008).

volatility in the markets has already been high and the buy-side liquidity for the E-Mini S&P 500[5] had already fallen about 55%. Against these conditions, a huge sell-order of 75.000 E-Mini contracts (valued at roughly $4.1 billion) was pushed into the system via an automated execution algorithm that should take care of the order's realization for a trader (SEC/CFTC, 2010, p.1 ff.; MacKenzie, 2013, p.40 ff.). The chosen algorithm was programmed "to feed orders into the June 2010 E-Mini market to target an execution rate set to 9% of the trading volume calculated over the previous minute, but without regard to price or time." (SEC/CFTC, 2010, p.2) So, without considering price or time, the algorithm sold 75.000 contracts in 20 minutes which shocked the already stressed markets (SEC/CFTC, 2010, p.2). Finally, other market participants - including HFT - were able to absorb the sell pressure induced by this execution which then allowed for the quick rebound (SEC/CFTC, 2010, p.3). But, simultaneously, those market participants passed on the irritations to other markets since they were active in cross-market and derivatives trading (SEC/CFTC, 2010, p.6). This event and the resulting discussions concerning the regulations of HFT triggered contemplations about altering them. The SEC and CFTC for example worked out a detailed report called *Findings Regarding the Market Events of May 6, 2010* (2010), which builds the basis for further regulations such as interruption mechanisms that pause trading if certain thresholds of volatility are exceeded (Handelsblatt, 2010). Equally reacting to these events, the German government also passed the *Gesetz zur Vermeidung von Gefahren und Missbräuchen im Hochfrequenzhandel,* aiming at regulating and decelerating HFT (Handelsblatt, 2013) These events and endeavors display that there is a necessity for a deeper understanding of AT and HFT.

Thus, investigating these technology-depended forms of trading has also reached the scientific community. Naturally, the field of economics is interested in examining AT's and HFT's potential impact on markets and its dynamics (Chaboud et al., 2011, p.1). Mostly, the respective studies focus on formally and

[5] The E-Mini S&P 500 ("E-Mini") is a future contract introduced by the CME in 1997. It is exclusively traded on CME Globex, 24 hours a day. Its notional value is $50 times the S&P 500 Index (SEC/CFTC, 2010, p.10).

empirically inquiring into the influence AT and HFT have on market liquidity and volatility. Most available studies support the hypothesis that liquidity improves, especially in periods of market stress, and volatility is at least unaffected (Gomber et al., 2011, p.57 ff.; Hasbrouck & Saar, 2011, p.35 ff.; Brogaard, 2010, p.64; Chaboud, Chiquoine, Hjalmarsson, & Vega, 2009, p.25 ff.; Hendershott & Riordan, 2009, p.22; CME, 2010, p.6). Contradictory, other studies indicate that HFT is fostering price volatility (Zhang, 2010, p.33 ff.; Boehmer, Fong & Wu, 2012, p.27). The other academic field that is concerned with inquiring into financial markets is the so called *Social Studies of Science (SSF),* a rather new area that provides the academic frame to which the present work belongs. Roughly speaking, this field is a subset of economic sociology and tries to sociologically analyze how markets are constructed, especially with respect to the incorporation of material devices. With regards to financial markets, those studies rely on qualitative data and try to explore and describe the heterogenous networks which are necessary to realize complex entities like AT and HFT. The idea guiding these endeavors is to open the black-box(es) that contain modern finance by analyzing the elements and relations constructing it (MacKenzie, 2013; MacKenzie & Pardo-Guerra, 2013; MacKenzie, Beunza, Millo & Pardo-Guerra, 2012; Preda, 2012; Pardo-Guerra, 2010; Hardie & MacKenzie, 2007). Furthermore, Lenglet's (2011) *Conflicting Codes and Codings: How Algorithmic Trading Is Reshaping Financial Regulation* represents one of the most relevant approaches to unpacking the Black Box of AT and therefore represents a crucial source for this work. The intention to retrace the networks constructing AT and HFT reveals the heritage of SSF in the Social Studies of Science and Technology and one of its major theoretical paradigms, namely Actor-Network-Theory (ANT) as it is famously established by Bruno Latour (2008 [1991], 2007, 1992), John Law (1992, 1989) and Michel Callon (2005, 1989, 1986). Its unconventional basic idea is that nonhuman entities can also enact agency since they are interwoven with human beings in socio-technical networks that jointly originate agency. And, as technology occupies such a pivotal position in AT and HFT, it is a logical deduction to follow that premise in this study. Accordingly, the overarching purpose of the present work is to trace the associations making up the actor-network that brings off the agency of AT and HFT. Subsequently, the ques-

tion is how AT and HFT are realized? How do human and nonhuman actors mutually construct what we witness as AT and HFT, and what are the consequences in terms of agency? Taking this purpose and the unconventional theoretical groundwork into consideration, this paper follows another rationale than usual studies. It does not articulate concrete hypotheses and does not try to proof or falsify them. The present study rather needs to be understood as a highly explorative approach that tries to achieve two relevant goals (see chapter 6 for more details on the methodology). First, it tries to compile a comprehensive theoretical framework that provides useful concepts for analyzing technology, particularly in market contexts. Second, it tries to discover the hybrid network of humans and material devices that configure AT and HFT using the tools developed for achieving the first goal.

Most of the mentioned SSF studies pay attention to these theoretical thoughts and analyze AT and HFT by illuminating relevant actors, technologies and histories. But, they do not systematically apply notions and concepts deriving from the rich theoretical body of ANT and SSF. Therefore, this paper shall add new insights to this rather undiscovered field by elaborating on a comprehensive theoretical frame and by applying this to the phenomena of AT and HFT. Qualitative expert interviews with professionals of the financial industry serve as the main source of data that will be analyzed and interpreted with reference to theory. Accordingly, the present work will adhere to the following outline: First, the phenomena AT and HFT will be described briefly, so that the reader can familiarize oneself with the central subject of this thesis (Chapter 2). Afterwards, there will be an introduction to thoughts of economic sociology that explains why it makes sense to approach economic phenomena in terms of social theory (Chapter 3). The following two sections will present a very essential part since they elaborate on the basic notions and concepts of ANT and SSF (Chapter 4 and 5). This procedure has the purpose of rooting the work profoundly in the respective social theoretical paradigm and to develop a basic set of concepts that will enable and structure the actual analysis. The following part is concerned with explaining the methodology and shows how the interview sample and interpretation procedures have been designed (Chapter 6). Afterwards,

Chapter 7 draws on presenting the obtained results and their theory related interpretations. Eventually, there will be some concluding remarks briefly summarizing the analysis, pointing at limitations of the present work and suggesting further research (Chapter 8).

2. Electrification and Automation

This part presents the main object of study, namely Algorithmic Trading (AT) and High Frequency Trading (HFT) that demonstrate the current technological peak of an ever proliferating automation of trading in financial markets. The definitions of AT and HFT serve as first explanations of what is dealt with in this paper and should not be confused with the actual analysis of those phenomena. The interview and literature based investigation of the socio-technical implications of AT and HFT will be presented in chapter 7. This will contain a concrete analysis of relevant actors, technologies, theories and other entities that contribute to the realization of AT and HFT. Nevertheless, this part marks the point of departure, setting stage and vindicating the author‘s decision to examine AT and HFT from the social theoretical perspective of Social Studies of Finance.

This digitization of financial markets generally manifests in three ways: First, sophisticated software instruments (e.g. algorithms) have been developed and are utilized on large scale. Second, the possibility of decentralized access and interconnected flows has fostered a global market integration. Third, the networks establishing markets have become more complex since transactions have multiplied and become more sophisticated what implicates longer chains of involvement (Sassen, 2005, p.19). The overall term capturing this and establishing the broad frame AT and HFT derive from, may best be covered by applying the term Electronic Trading (ET) that simply describes that orders can be managed by utilizing electronic devices that also work over distance (Chlistalla, 2011, p.2; Jain, 2005, p.2955 ff.). This development reached a significant point in the late 1980‘s and early 1990‘s when market participants were provided with

the ability to access electronic public limit-order books[6] (MacKenzie et al., 2012, p.5; Chlistalla, 2011, p.2; Chaboud et al., 2011, p.1). This does not mean that trading is exclusively handled by machines since orders are still placed by human beings utilizing devices like computer keyboards or telephones in combination with their own physique as these actions acquire rapidity, accuracy and coordination (MacKenzie et al., 2012, p.7; Preda 2009, p.684 ff.; Zaloom, 2006, p.10 ff.). The mechanization of trading has displaced the classical form of trading that took place in the trading pit, an octagonal or circular venue where trading communication was executed through open outcry by human traders (MacKenzie, 2012, p.6 ff.; MacKenzie et al., 2012, p.6 ff.; Zaloom, 2006). An analysis of how displacing the pit with algorithm running machines affects the socio-technical reality of trading is given in chapter 7.

2.1. What is Algorithmic Trading?

AT is an "umbrella term" capturing the explicit usage of algorithms for electronic trading. Yet, there are varying understandings of how this usage is put into shape (Chlistalla, 2011, p.2 ff.; Gomolka, 2011, p.4; Gomber et al., 2011, p.13). Some focus on the usage of algorithms in the automated execution of orders and their optimal fractionation of submitted slices to reduce the order's market impact (Domowitz & Yegerman, 2005, p.1; Gomber & Gsell, 2006, p.7). Others also include that the creation of orders, the analysis of market data and the subsequent taking of actions, is also part of AT that then can "commonly [be] defined as the use of computer algorithms to automatically make trading decisions, submit orders, and manage those orders after submission." (Hendershott & Riordan, 2009, p.2) Accordingly, algorithms are involved in supporting or taking the trading decision by getting and analyzing market data as well as by executing the resulting transaction (Gomolka, 2011, p.7; Aldridge, 2010, p.16 ff.). For the purpose of this paper it is useful to orientate oneself towards this

[6] "(A ‚limit order' is an order to buy at or below a given price, or alternatively an order to sell at or above a given price.) Market participants can place orders in the book directly, and the book is public in the sense that it is visible to all market participants (but not normally to the general public)." (MacKenzie et al., 2012, p.5)

broader definition of AT since an investigation of the socio-technical construction of financial markets incorporates the execution as well as the calculation that both make up an integral part of the whole AT phenomenon. It is important to state that these algorithms are a form of "electronic trading whose parameters are determined by strict adherence to a predetermined set of rules aimed at delivering specific execution outcomes." (Chlistalla, 2011, p.2 ff.)

In general, one can state that algorithms are used in two main camps of AT. First, there are execution algorithms, usually used to split and time large orders to reduce market impact which is particularly interesting for large institutional investors. Usually, brokers utilize algorithms to process their clients' orders. Nowadays, these orders are also forwarded to the broker electronically and can be processes directly, so that the broker does not have to transform the orders anymore. Furthermore, some clients are directly interacting with the market's order-books without intermediating brokers (DMA - Direct market access) (Avellaneda, 2011, p.7 ff.). Second, there are proprietary traders, firms trying to use algorithms to successfully trade on their behalf. The second branch can be subdivided into roughly five strategies: (1) electronic market making which is actually the same as normal market making but automated, (2) arbitrage between markets which is the exploitation of price differences between different markets or between a derivative and its underlying, (3) statistical arbitrage which tries to profit from the recognition of patterns, (4) order anticipation strategies which try to detect execution algorithms in action benefit from that, (5) momentum ignition which is illegal and refers to a practice of faking the placement of a large order to profit form the price movements resulting from it. Some of these strategies require HFT which is described in the following part (MacKenzie, et al., 2012, p.8 ff.). This shall serve as an overview showing the main ways of utilizing algorithms in trading.

2.2. What is High Frequency Trading?

HFT can be defined as being a particular sort of AT since both rely on the utilization of machines and automated calculation. The crucial difference distinguishing HFT as a peculiar subset of AT is its acceleration and fast pace which can be witnessed in terms of low latencies and short times of position holdings. This results in fast reallocations and turnovers of capital (Chlistalla, 2011, p.3; Aldridge, 2010, p.16 ff., p.24 ff.; MacKenzie et al., 2012, p.9; see also Figure 1).

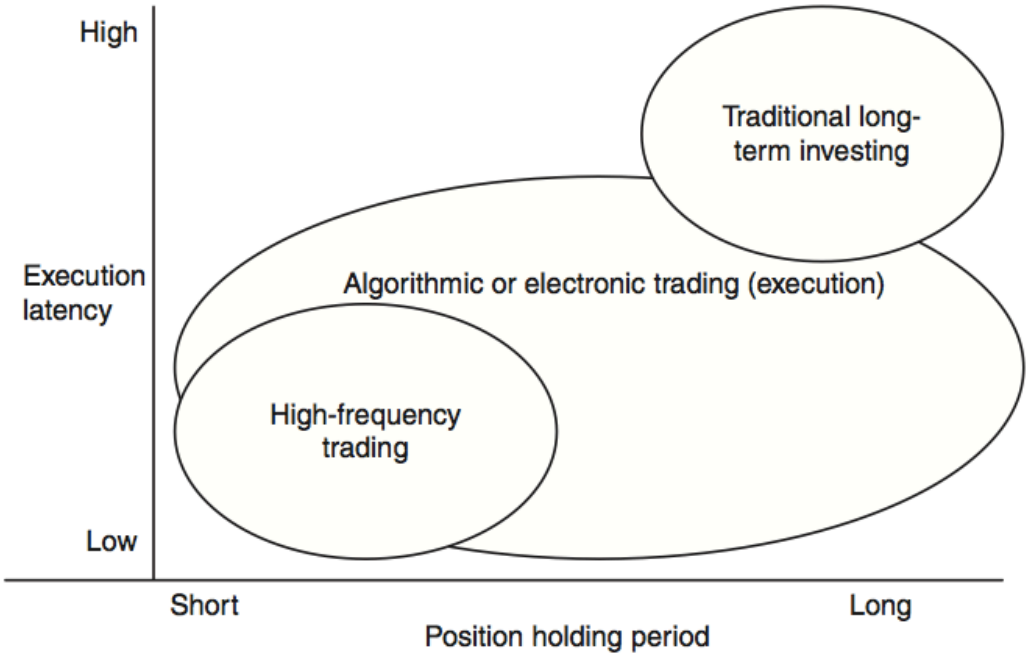

Figure 1: HFT vs. AT and traditional long-term investing (Aldridge, 2010, p.17)

Brogaard (2010, p.5) describes the similarities and essential differences between both trading forms this way:

> "Algorithmic and HFT are similar in that they both use automatic computer generated decision making technology. However, they differ in that algorithmic trading may have holding periods that are minutes, days, weeks, or longer, whereas HFT by definition hold their position for a very short horizon and try and to close the trading day in a neutral position. Thus, HFT must be a type of algorithmic trading, but algorithmic trading need not be HFT."

The aspired neutral closing of a trading day (flat position) is also emphasized by Gomber et al. (2011, p.15) and Aldridge (2010, p.2), who maintains that this way HFT circumvents the risks generated by holding positions overnight. Concerning the time horizons, there is no common understanding of what is to be defined as short position holdings signifying HFT. Chlistalla (2011, p.3) points out that High Frequency Traders usually hold a position for a few seconds. Brogaard (2010, p.4) narrows this down to milliseconds while Aldridge (2010, p.4) states that HFT can happen in a time frame ranging from seconds to even a day, depending on the HFT strategy applied. Accordingly, one can conclude that HFT is generally characterized by very short holding periods that in special cases might expand (Zubulake & Lee, 2011, p.5 ff.). Besides, HFT usually exploits rather small price differences but generates considerable profits due to high rates of repetition and accordingly due to high trading volumes (Gomber et al., 2011, p.15; Chlistalla, 2011, p.3).

The distinction between AT and HFT is of interest since the difference has technological and material implications for the social construction of those phenomena themselves. The given explanations of AT and HFT already reveal the significant role technology plays. How technological devices are deployed exactly and how this affects the whole construction of AT and HFT will be explained in chapter 7 with reference to social theoretical consideration that will be expounded in the following sections.

3. Economic Action as Social Action

The issue dealt with in this paper is situated in the economic system and usually examined by the discipline of economics and its derivatives. But those disciplines seem to lack explanatory power for some attributes of economic life as we can see when we take a look at Robbin‘s commonly known definition of Economics (1945 [1932], p.16): „Economics is the science which studies human behavior as the relationship between ends and scarce means which have alternative uses.“ This basic definition represents a formal and individualistic notion

of economic behavior that neglects the social peculiarities of its execution (Ganssmann, 2010, p.64 ff.). Thus, this section will provide arguments vindicating why it makes sense to apply a different perspective, namely an approach inspired by sociology and social theory. This shall not be understood as an attempt to establish a counter perspective questioning the general legitimacy of classical economics.[7] This work shall rather contribute to analyzing economic action by expanding the scope of perspective. A pivotal and influential hint concerning the sociality of economic action is given by Granovetter‘s notion of „Embeddedness“ (1985) in which he maintains that economic action is interwoven with social structures that subsequently need to be regarded in its analyses. This approach mainly focuses on how social relationships structurally influence economic behavior or institutions and has become one of the most fruitful and pursued notions in the field of economic sociology (Beckert & Deutschmann, 2010, p.8). The economy was already research subject to those thinkers, who brought forth sociology in the late 19th and the early 20th century which is demonstrated by Durkheim‘s *The Divison of Labor in Society* (1992 [1893]), Simmel‘s *Philosophy of Money* (1989 [1900]) and Weber‘s *Economy and Society* (2010 [1921]) (Swedberg, 2003, p.5 ff.). But, output and recognition of economic sociologists has been increasing for the last decades after Granovetter‘s work (1985) set the point of demarcation for a new economic sociology. The reason for this success can presumably be attributed to the prominent neoliberal regimes which have mainly been established by Reagan and Thatcher in the early 1980s (Swedberg, 2003, p.32 ff.). Accordingly, the ever increasing dissemination of the economy to other subsystems results in a growing need for describing and understanding economic processes. Hence, it seems like explanations provided by the disciplines belonging to economics - usually in the guise of neoclassics, game theory and behavioral economics - are insufficient and therefore support the uprising of economic sociology. Notions of

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[7] In this respect Michel Callon states the following (interviewed by Barry & Slater, 2002, p.301): "There are two positions we have to abandon. The first is the idea of critique of hard economists, which is intended to show them that they are wrong. And the second position is to describe markets just to say that they are more complicated than economists or political decision makers believe.... Let us stop criticizing the economists. We recognize the right of economists to contribute to performing markets, but at the same ti*me we claim our own right to do the same but from a different perspective*." (own emphasis)

equilibrium and unbound rationality as well as the methodological individualism have not kept their promise of delivering comprehensive explanations for all economic phenomena (Beckert & Deutschmann, 2010, p.10 ff.; Swedberg, 2003, p.32 ff.). Approaches inspired by the new economic sociology can contribute by adding network theory, organization theory and cultural sociology to the instruments for analyzing economy (Swedberg, 2003, p.37 ff., 2007, p.12).[8] Throughout the paper (especially chapter 4 and 5), the author will argue and show that Actor-Network-Theory serves as an additional theoretical framework that especially fits for capturing economy in terms of modern financial markets and helps to understand by expanding the perspective to the materiality of social (economic) action.

Furthermore, one could argue that economic action is not only embedded in social relations that somehow shape economic outcomes. It is a legitimate and logical claim to assume that economic action is itself deeply social. Niklas Luhmann (1988) captures this thought simply by speaking of the „Economy of Society“ (German: "Die Wirtschaft der Gesellschaft") and not of the economy and society. According to the systems theoretical paradigm that guides Luhmann‘s work, one can simply state that economic action is actually economic communication and therefore a part of society since communication represents the operation making up society: „Alles wirtschaftliche Handeln ist soziales, daher ist alle Wirtschaft immer auch Vollzug von Gesellschaft.“ (Luhmann, 1988, p.8) In the functional subsystem of economy the specific sort of communication is concerned with communicating scarcity that is simultaneously produced and organized by the economic system (Beacker, 2006, p.12 ff.). Based on the social theoretical idea that social action (as communication) is always accompanied by the mutual creation and synchronization of meaning, Svetlova (2008) argues that economic action is first and foremost endowing life with meaning. Subsequently, she maintains that a fertile analysis of economy needs to inquire into those processes of meaning creation through economic interaction. As a con-

[8] Beckert & Besedovsky (2010, p.25) add even more social theoretical sets that might fit for explaining economic phenomena: rational-choice-theories, interactionism, phenomenology, interactionism, Marxist theories, systems theory and modernization theory.

sequence, economic sociologists should not only search for explanations that account for the social relations economic behavior is embedded in, but confidently utilize basic social theoretical notions to describe and capture economic action as social action (Baecker, 2006, p.36 ff.; Beckert, 2007, p.61).

This crucially social aspect of economic action is aptly demonstrated by the constitution of markets, which build a central subject of inquiry for economic sociologists, besides other groups of phenomena like organizations, labor, elites, money, economic macro-structures or ideologies and attitudes in and towards economic life (Beckert & Besedovsky, 2010, p. 25). Usually, markets can be depicted as areas in which exchange (which already implies mutually oriented and therefore social behavior) is executed and subsequently as a mechanism for allocating resources. This perspective has been subject to severe abstraction because neoclassical market theory shifted the focal point. Markets were drafted as price mechanisms determined through the pure meeting of supply and demand, regardless of social realities like jurisdiction, the state, humans or social relationships, a „flaw“ to which economic theory reacted in terms of new institutional economics (Swedberg, 2007, p.15 ff.). In „The Great Transformation“, a skeptical Karl Polanyi (1978 [1944], p.71 ff.) emphasizes that markets are one way to organize the economy besides mechanisms of reciprocity, redistribution and autarkic housekeeping (which all can co-exist). He points out that markets are the peculiar institution enabling the exchanging and trading of goods that dominates our society.[9] Taking this into consideration, the essential point for this paper is that markets shall not only be understood as abstract price mechanisms of exchange. In markets, members of society interact, also by using material devices which is why it os of interest to examine how these interactions happen, in the present case especially with respect to the role of technology. This evidently reveals the sociality of economic action since exchange implies the mutual synchronization of individuals. Accordingly, Ganss-

[9] Polanyi‘s skepticism towards market societies and capitalism is illustrated nicely in this quotation: „Die Marktform hingegen, die mit einer eigenen, spezifischen Zielsetzung verbunden ist, nämlich Austausch, Tauschhandel, ist imstande, eine spezifische Institution hervorzubringen: den Markt. Dies ist letztlich der Grund, warum die Beherrschung des Wirtschaftssystems durch den Markt von ungeheurer Bedeutung ist: sie bedeutet nicht weniger als die Behandlung der Gesellschaft als Anhängsel des Marktes.“ (Polanyi, 1978, p.88)

man (2007, p.66) asks: „Wo wenn nicht bei der Tauschanalyse, müssten sich Ökonomen also Gedanken über die soziale Dimension wirtschaftlichen Handelns machen?“ Besides their mere relevance by representing the basal self-organized coordination mechanism of our economy, it is a peculiarity that pushes markets to the center of sociological attention. By drawing on social networks, norms, cognitive structure and formal institutions, markets reduce the contingency that inherently accompanies social interaction. Due to these reductions market participants partake in the actually hazardous market interaction that producees compromises between exchange partners (Beckert, 2007, p.49). Economic interaction therefore represents a way of coping with contingencies that emerge due to the uncertainties involved in social associations. Reacting to these circumstances, economic theory developed game theory that takes this social interplay into account by analyzing it in terms of strategy (Ganssmann, 2007, p.71 ff.). Markets serve as social coordination mechanisms and a market sociologist needs to inquire into how these intra-individual synchronization problems are solved (Beckert, 2007, p.61). Hence and with regards to the present issue of AT and HFT, we need to ask how technological means are utilized and incorporated into solving social coordination problems in modern financial markets.

4. Actor-Network-Theory: Sociology of Associations

It has been shown that sociological accounts can or must be part of an adequate and comprehensive analysis of economic behavior, especially of markets. Since this paper is concretely concerned with the socio-technical characteristics of AT and HFT, Actor-Network-Theory[10] (ANT) will provide the crucial social theoretical framework because it represents an unique approach that deliberately incorporates material entities into its conception of society. Therefore, this

[10] I will stick to calling it Actor-Network-Theory with a relating hyphen between the actor and the network as I think that it symbolizes the idea of combining both aptly and because Latour himself advocates for the hyphen in a more recent work (2007, p.9) although he objected it in earlier work because it reminded the reader of an overcome agency/structure cliché (2005 [1999], p.16 ff.).

section will elaborately illuminate the concepts and notions of ANT, mainly put forward by Bruno Latour (2008 [1991], 2007, 1992), Johnson (1988)[11], John Law (1992, 1989) and Michel Callon (2005, 1989, 1986), who will play an important role later on since he was one of the first to transfer ANT to the economy and markets. In order to comprehend the purpose of this thesis it is essential to develop an understanding of this rather unconventional theoretical branch.

The first point worthwhile mentioning is that ANT tries to fundamentally rethink what sociology is and what its research subjects are. It critiques the common and usual approach of trying to find, explain, describe and analyze „the social" as an already existing and limited sphere or attribute of phenomena which is why Latour calls this tradition - that in his view needs to be overcome - „sociology of the social". In contrast to that, ANT is a performative approach in the sense that it claims that the subject of research is constituted through tracing and identifying associations of elements during the process of researching itself which is why Latour advocates for the name „sociology of associations". This also illustrates that ANT understands phenomena as being dynamically and constantly changing, an ex ante definition of what is social and therefore subject to sociology would pre-exclude possible insights in what is needed to keep these „social" formations stable (Latour, 2007, p.1 ff, p.34 f.; Callon, 1989, p.93; Law, 2005, p.4 ff.). Latour emphasizes this by claiming that there are no groups, but only group formations resulting from tracing of associations:

> „The problem with any ostensive definition of the social is that no extra effort seems necessary to maintain the groups in existence, while the influence of the analyst seems to count for nothing - [...]. The great benefit of a performative definition, [...], on the hand, is just the opposite: it draws attention to the means necessary to ceaselessly upkeep the groups and the key contributions made by the analysts' own resources." (Latour, 2007, p.35)

The analyst's influence on the way groups are formed is even more emphasized when we take into consideration that Latour supports the epistemological idea

[11] This text has officially been published under the name of Jim Johnson which is actually an alias of Bruno Latour, who is the real author of this paper.

„that the whole is always smaller than its parts“ which he postulates in reference to the work of the French Sociologist Gabriel Tarde (Latour, 2012, p.1 ff.).[12] Drawing on Tarde‘s concept of monads[13], Latour claims that the common distinction of the individual (micro perspective) and society (macro perspective) is an analytical contrivance of sociological forefathers like Durkheim, who had to deal with a lack of data that would have given them the possibility to analyze society as a constant stream of sociation processes. Accordingly, society needs be understood as the continuously ongoing interplay of networked associations and the researcher can use the monad - as an analytical anchor of tackling a point in these networked flow of associations - to discover more and more peculiarities and connections the deeper he examines the monad. An attempt that seemingly becomes better feasible due to the availability of digital network data nowadays (Latour, 2012, p.2 ff., 2011, 2010, 2001). Therefore, Latour and Tarde say that the whole is smaller than its parts because it (the whole) symbolizes a homogenous generalizing that disregards the importance of differences causing differences in a bottom-up manner:

> „Wenn wir einmal die soziale Welt betrachten, und somit die einzige, welche wir von innen kennen, so sehen wir Akteure, Menschen, die viel differenzierter, viel individueller charakterisiert, viel reicher an beständiger Veränderung sind als der Regierungsapparat, die Glaubens- und Rechtssysteme, selbst als die Wörterbücher und Grammatiken, welche aus ihrem Wettbewerb hervorgehen. Ein historisches Ereignis ist viel einfacher, viel klarer, als der Geisteszustand ihrer Handlungsträger je gewesen ist.“ (Tarde, 2009 [1893], p.67 ff.)

This fits to the performative idea of the sociology of associations because the tracing of linkages and the resulting group formations mirrors the idea that soci-

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[12] This claim evidently contradicts the idea of systems theory that there are emergent properties which was introduced to systems theory by von Bertalanffy (1969, p.55): „[...], the whole is more than the sum of parts' is simply the constitutive characteristics are note explainable from the characteristics of isolated parts. The characteristics of the complex [...] appear as ‚new‘ or ‚emergent‘.“

[13] Tarde‘s monads are just a way of dealing with the idea that it is the small unit which is of interest, no matter if we are dealing with sociology or other disciplines: „Alles entsteht im unendlich Kleinen und kehrt dorthin zurück.“ (Tarde, 2009 [1893], p.25) Contradictory to Leibniz‘s monads, Tarde‘s monads do not incorporate a godly and harmonizing stability. They are a way to analyze how „small“ entities associate to certain phenomena without relying on „higher-level“ explanations and universal laws (Tarde, 2009 [1893], p.47 ff.; Latour, 2001, p.14 ff.)

ety is a dynamic entity and its phenomena are made tangible by detecting its traces. Concerning the agenda of this paper we will try to identify and format the group and technologies formations which are hidden in the broad concepts of AT and HFT that will build the monads that are going to be examined concretely in the progress of this paper.

After explaining this crucial self-conception of ANT above, the following parts will elaborate on some significant specifics and concepts that provide the reader with the analytical toolkit to investigate AT and HFT.

4.1. Agency I: Action is Overtaken

First and foremost it is necessary to deal with the category of *agency* that plays an important and unique role for sociologists of associations. Agency can be defined as the capacity to act and to give meaning to action (Callon, 2005, p.4 ff.). The crucial argument here is that agency is not the result of an individual‘s doing which again contradicts usual notions of economics‘ methodological individualism or rational-choice paradigms (Callon, 2007, p.345 ff.). By traditionally focusing on individuals as originators of actions and the resulting effects, the social sciences narrow the perspective which especially precludes certain explanations in terms of what or who caused the observed action. Applying the term agency avoids this by analyzing what kind of networks enable and realize actions, an individual must not be confused with individual agency (Callon, 2008, p.33 ff., p.41). According to ANT, acting is executed in a network of agents and things which is the reason why Latour states that „action is overtaken“ (Latour, 2007, p.43). Cognitive science and psychology contribute to this notion in a pivotal way since representers of these disciplines like Hutchins (1995, 2000), Minsky (1988) or Salomon (2001 [1993]) cultivate the notion of distributed cognition. They argue that executing complex cognitive tasks is not realized by singular individuals, but constituted through networks of people and devices. Hutchins (1995) for example illustrates this by examining how the task of navigation is distributed between people and calculative devices on a military

vessel. Salomon (2001 [1993], p.111 ff.) states that distribution means that no single locus of action or cognition can be identified since aspects like authority, language or cultural heritage affect it, too. Pea sums this up and puts emphasize on the fact that networking our cognition actually makes human intelligence potent (2001 [1993], p.81): „When we look at actual human practices, we see that human cognition aspires to efficiency in distributing intelligence - across individuals, environment, external symbolic representations, tools, and artifacts - as a means of coping with the complexity of activities we often call ‚mental'."

This notion of cognitive distribution actually builds the bridge leading to ANT's name: actors are made to act in an actor-network. This idea stems from the Social Studies of Science and Technology that represents the disciplinary heritage of ANT. It emphasizes that knowledge production in the scientific system is not the simple outcome of individuals trying to discover the truth, but rather a product of heterogenous networks, including other researchers, equipments, laboratories, papers and so on (Latour & Woolgar, 1986 [1979], p.236 ff.; Law, 1992, p.2). Thus, a common understanding of a distinct actor and a distinct network is replaced by one actor-network because they represent „two sides of the same coin" (Callon, 1998, p.8). It is important here to emphasize that this shall not lead to a crude social deterministic approach:

> „For the social sciences to regain their initial energy, it's crucial not to conflate all the agencies overtaking the action into some kind of agency - ‚society', ‚culture', ‚structure', ‚fields', ‚individuals', or whatever name they are given - that would itself be social. Action should remain a surprise, a mediation, an event." (Latour, 2007, p.45)

For the present work, the first question concerning distributed agencies concerns the different agents involved in AT and HFT. What kind of organizations are necessarily involved in building the prices, synchronizing buy- and sell-sides and realizing the trades in AT and HFT?

4.2. Agency II: Action is Overtaken by Nonhumans

This leads to the next essential and especially unaccustomed claim put forward by ANT‘s advocates, namely that *agency can also be attributed to nonhumans,* which contradicts common ideas in terms of epistemology, ontology and ethics (Latour, 2007, p.63 ff., 1992; Johnson, 1988; Law, 1992, p.3 ff., 1989, p.113 ff.; Callon, 2008, p.37 ff.). The already applied term of a heterogenous network points in this peculiar direction: material objects also need to be incorporated into our idea of society that then is composed of socio-technical actor-networks: "The question is how a cockpit, rather than a pilot, remembers its speeds." (Hardie & MacKenzie, 2007a, p.391) This analytical symmetry of objects and humans opens up a new perspective on network elements because now it is possible to account for effects of every element involved in an agency forming a heterogenous network (Law, 1989, p.114): "[...] from the standpoint of the network those elements that are human or social do not necessarily differ in kind from those that are natural or technological.“ It is this mixture of applying relational network ideas and including materiality that inspired John Law to speak of *relational materialism* (Law, 1992, p.7; Law, 2005, p.4 ff.).[14] Thus, ANT builds a hybrid approach that is neither to be located in the realm of technological determinism nor in the realm of social constructivism, is neither social realism nor natural realism (Callon & Latour, 1992, p.345 ff.; Callon, 1985, p.34).[15] Latour even claims that this intermediate position is providing the social sciences with the necessary toolkit to answer the question "Where are the missing masses?"

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[14] Mirowski and Nik-Khah (2008, p.95) fundamentally criticize that this is a notion originally developed by the proponents of ANT. They rather argue that "Operations Research" - a discipline developed after World War II to enhance military performance - already introduced and applied ideas that are now put forward by ANT's advocates. Unfortunately, this claim cannot be investigated and analyzed throughout this paper.

[15] In *We have never been modern* (2008 [1992]), Latour shows that this understanding is fundamentally questioning the human self-conception of modernity since the distinction of nature and culture as two different spheres needing totally separate styles of science (the natural sciences and the social sciences) cannot be maintained. This is also the aspect where ANT is subject to fundamental critique. Yearley (2006, p.62 ff.) for example questions the symmetry that ANT applies towards natural and social entities by using the same argument conversely, namely that this distinction is exactly what makes modern science fruitful while blurring this division leads to arbitrary relativism. Furthermore, he states that a scholar that wants to explain agency of technical, biological or chemical material needs to understand their inherent logic and therefore needs to be a biologist, chemist or engineer.

(1992) which assumedly are to be found in material objects that contribute to society‘s existence as some kind of (black) matter that had been disregarded for a long time. Evidently, agency is not consciously exercised by nonhumans. Yet, this is what makes their agency even more strict, there is no escape, no hope for weakness and mercy because „*no human is as relentlessly moral as a machine*“ (Latour, 1992, p.232, own emphasis). Imagine you are entering your car and it is reminding you of fastening your seat belt with a loud and annoying alarm that only stops if you comply with the reminder, without exception or consideration. Transferring this to the paper‘s topic the most relevant question is how the automation of trading affects agency. If decisions are increasingly made by machines, how is the agency distributed and how does it affect the shape of financial markets? How are economists, stock exchanges, infrastructure providers, engineers, coders and bankers involved in the processes of AT and HFT and how do they contribute to the distributed execution of trading, what is the composition of the actor-network that realizes AT and HFT? Economists like Chaboud et al. (2011) for example analyze differences between trades initiated by humans and those initiated by nonhumans. With regards to ANT we would dissolve this distinction and analyze how what kind of actors contribute to the distributed agency that realizes AT and HFT. Accordingly, elaborating on how shifting technological and material circumstances influence the composition of agency in financial markets is a promising intend of ANT related and sociologically motivated research (Preda, 2012, p.31).

4.3. Delegation and Translation

Having clarified that agency is enacted by actor-networks that can also involve material entities, it is now necessary to elaborate on another ANT principle, namely that of delegation and translation. As described above, machines are merciless in executing their given tasks which explains why humans are inventing and utilizing them. This is exemplified by the technology used by European hotels to keep their customers from forgetting to give back their room keys when exiting the house. Instead of reminding them via verbal notes and signs

(which might be unheard, unread or misunderstood), they delegate this task to a material reminder which is simply a big and heavy weight attached to the key. So, the message "please do not forget to give the keys" is translated by this weight. Now, guests want to get rid of this inconvenient object causing unease in their pants (Latour, 1991, p.103 ff.). This pattern is also illustrated in Johnson‘s *Mixing Humans and Nonhumans Together: The Sociology of a Door-Closer* (1988)[16] in which he multifariously and a bit ironically describes how a door and an automatic door-closer (a so called groom) affect social order.[17] First of all he points out that doors are useful inventions since otherwise we would always need to hammer new holes in the walls to get into a building and close them afterwards to keep the cold, the foreign and the unwanted outside, all efforts that are solved by a simple hinge pin. Established once, doors fulfill the task of continuously regulating in- and outflows. All the work that would be necessary to fulfill the same function now is transferred to the hinge pin. This process is what Latour calls delegation or translation: „I will say that we have delegated (or translated or displaced or shifted out) to the hinge the work of reversibly solving the hole-wall dilemma.“ (Johnson, 1988, p.299). As a consequence, time is compressed since all the delegated work is delegated to one nonhuman that repeatedly accomplishes the task for which otherwise humans would need to be disciplined for again and again. *The technological artifact folds times and spaces* because it is not only the time that is compressed into the material object, is is also the places where the object has been brought into existence and that it refers to that are condensed in itself (Latour & Venn, 2002, p.249 ff.; Latour, 1992, p.231 ff.). Thus, to assess the impact of a nonhuman in an actor-network one can always think of all the tasks that humans would need to perform if the nonhuman was not there. The question for AT and HFT is then what

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[16] Remember, it is actually Bruno Latour using a pseudonym.

[17] This again is a point where possible critique docks: „It is clear that the interpretative method is unusable, since doors have no social life in which we could participate [...] What method is left? It ought to be science, but Latour is not an expert in any of the fields of science that would help him understand doors [...] How then does he convince us of the agency of doors?.“ (Collins & Yearley, 1992, p.318) Furthermore Collins & Yearley (1992) claim that Callon‘s and Latour‘s ANT approach leads back to techno-determinism and natural realism and is not adequate for sociological understanding of the power of science, technology and knowledge. Callon & Latour (1992) react to this by accusing Collins and Yearley of sticking to the traditional nature/social distinction and simply not understanding what ANT aims at.

kind of tasks are delegated to algorithms and technological devices that otherwise would have to be done by humans and how this delegation contributes to the spatial and temporal compression of trading.

4.4. Inscription, Description, Prescription, Subscription

A crucial aspect of technology engineering, design and creation is the so called *inscription* that is based on the notion to understand technological devices as scripts. Those creating the technological artifacts have certain ideas of the world their technology will be utilized in. They envision realities, users and usages that will be inscribed into the technology created (Latour, 1992, p.236 ff.).

> „Designers thus define actors with specific tastes, competences, motives, aspirations, political prejudices, and the rest, and they assume that morality, technology, science and economy will evolve in particular ways. A large part of the work of innovators is that of ‚inscribing' this vision of (or prediction about) the world in the technical content of the new object." (Akrich, 1992, p.208)

The complementary part of the inscription process is the so called *description*. The ideas of the engineer inscribed into the technological device do not necessarily fit to the reality it is eventually used in. Users describe the technology according to their own notions, environments and necessities. To learn about technology means inquiring into this area of tension between inscription and description that represents a negotiation process between engineers and potential users (Akrich, 1992, p.208 ff.). In terms of this paper's issue the question subsequently is: How is the inscription process distributed amongst what kind of agents? Moreover, it is necessary to look for the descriptions of these technologies and for the discrepancies between inscription and description and how they are dealt with.

Prescription can be defined as the behavior nonhumans expect from humans, a way of acting necessary to successfully perform a certain task. Imagine a door

with a groom that closes the door automatically, fast and vigorously. The user then is expected to pass the door rapidly and not to follow a person ahead too closely (Johnson, 1988, p.301 ff.; Akrich & Latour, 1992, p.261). This innocent example of prescribing sheds light upon another significant facet of technology: its ethics, morals and politics (Latour, 1992, p.232). Winner (1980) points out that material artifacts have politics by referring to the example of bridges over parkways on Long Island that had been built from the 1920s onwards by the famous urban planner Robert Moses. The interesting fact concerning these bridges is that they are very low (about nine feet), too low to let public buses pass which where about twelve feet tall. Presuming racial and social prejudices, Winner (1980, p.124 ff.) argues these chosen heights had the intention to keep buses off the parkways since they were mainly used by Blacks and poor people who were not supposed to disturb the recreation areas of Long Island that should exclusively be accessible to white upper and middle class citizens.[18] Without debating whether this depiction is right or wrong, it nevertheless illustrates the point that certain (discriminating) behaviors can be prescribed to potential users by inscribing them into technological artifacts. This leads to the notion of *subscription* that describes the degree to which the actual description of the technology fits to the behavior prescribed by it. If users adhere to the prescription they subscribe to it and follow the given implications (Akrich & Latour, 1992, p.261). Therefore, we have to ask whether and what kind of politics are prescribed by AT and HFT related technologies and how users subscribe to those prescriptions. Is there room for deviant behavior or is the heavy automation connected to a high level of subscription that expands the agency of machines and algorithms while human agency is diminished?

[18] Joerges (1999) fundamentally questions this interpretation of Moses‘s bridges by showing that other factors influenced the bridge design and by shedding light on Moses‘s intentions.

4.5. Intermediaries Transport, Mediators Translate

Another crucial distinction that is worthwhile mentioning in terms of ANT is the difference between an intermediary and a mediator. This distinction reminds of von Foerster‘s (2008, p.122 ff.) definition of trivial and non-trivial machines. Trivial machines repeatedly produce predictable outputs to certain inputs while non-trivial machines produce varying unforeseeable outputs. Accordingly, intermediaries represent elements in actor-networks that transfer meaning without transforming it, knowing what goes in suffices to define what goes out, they are like black-boxes with a stable value of one, whereas mediators can have alternating values which makes it difficult to conclude the outputs in regards of knowing the inputs. Mediators transform and alter what they are supposed to process in a complex and unpredictable way. Therefore, it is necessary to examine how the elements are realized, crafted, implemented into actor-networks, to see how their manifold attributes contribute to the construction of society - and this is exactly what is done in this paper with regards to automated financial markets (Latour, 2007, p.39 ff.). Fitting to other ANT premises, what is an intermediary or a mediator is not set in stone, the roles can change rapidly. So for AT and HFT, the question is whether we can depict the technologies and the algorithms as intermediaries or mediators. Are they intermediaries that transform economic action to really rational processes that handle inputs predictably and therefore contribute to the construction of financial markets as black boxes counting as one or are they mediators transforming economic actions according to their own unknown attributes? As an intermediary modern trading technology would simply transport other factors like economic needs or economic theory, and it would suffice to look at these factors to explain the outcome of financial markets. As a mediator the technology translates and it becomes necessary to analyze the technology itself which is what is done in this paper (Latour, 2007, p.105 ff., 202).

4.6. Punctualization, De-Black-Boxing and Responsibility

A major aim of applying an ANT-related perspective is to discover relations and associations that are usually *black-boxed or respectively punctualized*. Usually we do not notice all the connections necessary to use and establish a certain technology. We do not consider all the technicians, designers, resources, journalists, entertainers or program directors necessary to build the TV and fill it with content until it breaks down and we have to regard relevant associations to get it back going. All complex network ramifications disappear since the actor-network establishing the technology is black-boxed and works as a closed entity. This functions as a fundamental way of reducing complexity. Imagine the amount of efforts individuals would have to expand if they continuously had to deal with the complexity involved in utilizing and engineering technologies, even if they were simply watching TV. Hence, punctualized networks function as resources, reliable entities (as routines, agents, devices, organizational relations, standards etc.) that are applicable easily and do not require additional reflection (Law, 1992, p.4 ff.). These packages of relations that are bundled in taken for granted black-boxes re-appear in cases of malfunction as the Flash Crash again illustrates nicely for the financial markets (for more see p.73).This also counts for the ascription of *responsibility*. A pilot for example is usually hold accountable for the directions taken by an airplane. Usually and mostly, responsibility is attributed to certain individuals (here the pilot) that represent the agency since they combine the actions and sequences eventually projecting the entity of flying an airplane. But in case of an accident or crisis there is an investigation analyzing the actor-network involved in making an airplane fly: was it engine failure, a mistake of flight control or human error? (Callon, 2008, p.36 ff.).

Accordingly, the ANT researcher de-black-boxes these packages and traces the relations and elements involved to understand socio-technical phenomena which is the purpose of this exploratory paper with regards to financial markets. What linkages can be found in the black box of AT and HFT in general and how do agents and objects involved deal with punctualized resources provided by the network?

5. Social Studies of Finance (SSF)

The academic field that heavily builds up on ANT is the so called *Social Studies of Finance (SSF).* This branch is relatively young and its contributors work on analyzing markets from an ANT perspective for roughly 15 to 20 years by now (Preda, 2012, p.23 ff.; MacKenzie et al., 2012, p.3). Donald MacKenzie is one of its main representers and he heavily underlines the ANT heritage of SSF (2009, p.179): "[...] the social studies of finance is a material sociology of markets, one that emphasizes their physicality, their corporeality, and their technicality." Richard Swedberg (2008, p.57 ff.) acknowledges that it is that *materiality* that makes SSF valuable since economic sociology and especially economic theory are underdeveloped in assessing and analyzing the role of material objects and devices.[19] Yet, most analyses of markets in terms of SSF appear rather disconnected since they try to account for phenomena with different perspectives, some follow a micro approach while others deploy a macro lens. The overall contribution to a sociological understanding of markets is that markets are more than mere exchange relations: "The market, in this sense, involves not only relationships of exchange [...] but also entails creating symbolic, material, and cognitive supports that enable economic life-forms to emerge." (Pardo-Guerra, 2010, p.235) Moreover, one might assume that the increasing usage of algorithms in the whole process of electrifying might disembed the markets from their social realities. As a result, markets would fit to the notion of an abstract place of pure supply and demand provided by participants that have access to instantaneous information, and where geographical location does not have an impact on market success. In a nutshell, markets would approximate the idealistic notions from economic theory (Sassen, 2005, p.18). By referring to the already stated theoretical considerations, the present work tries to question this presumption by showing that the applied technology is itself social and socially relevant. First, the codes, devices and strategies implemented electronically are

[19] Swedberg states that the severe abstractions established by modern economic thought cannot account for the material sphere of economic actions. He claims that ancient thinkers who are more or less disregarded in modern economic thought, like Xenophon or Aristotle, put the necessary emphasis on material objects, e.g. in terms of agriculture or household (Swedberg, 2008, p. 60).

themselves created in socio-technical networks. Second, their outcomes are located in actor-networks that perform financial markets in the guise of AT and HFT. Thus, rejecting the notion of embeddedness is not acceptable. It rather needs to be adapted to incorporating technology.

5.1. Calculative Agencies, Market Devices & Agencements

One of the first to move in this „new“ disciplinary area of SSF is Michel Callon who tries to apply ANT to economic markets because markets nicely display that humans *and* nonhumans beget action and „It [sic] would be worrying if ANT had nothing to say about the market when it was all along designed specifically to describe and analyse [sic] those imbroglios in which humans and non-humans alike are involved.“ (Callon, 2005, p.182) The relevance of markets for sociological considerations has already been stated, but an ANT driven analysis adds a practical perspective with regards to the socio-technical practices (Beunza & Stark, 2004, p.370).

A crucial notion exceeding the definition of markets as places of exchange is that markets have *calculative agencies* that bring together sources of calculativeness (Callon, 1998, p.3 ff.). According to what has been said about overtaken agency and distributed cognition in the chapters before, calculative agency is not born in the individual‘s rationality, it is accomplished in heterogenous networks. It is crucial here to stress that materials are not simply used as instruments since this simple understanding of technologies as tools disregards the transformative power provided by those utensils that go far beyond fulfilling a simple function. Latour & Venn (2002, p.250) illustrate that having a hammer does not simply allow for driving a nail into the wall, it opens up a new flow of possibilities that becomes imaginable in the moment the hammer is taken in

hand.[20] Used for calculative agency, they actively contribute to it and shape it by making economic entities formalizable and tradeable, or put simply: equipment matters (Callon, 1998, p.3 ff.; Callon & Muniesa, 2005, p.1236; Preda, 2009, p.675; MacKenzie et al., 2012, p.3). The objects involved in enabling calculative agencies and therefore markets are so called *market devices* which appear in manifold fashions ranging from „analytical techniques to pricing models, from purchase settings to merchandising tools, from trading protocols to aggregate indicators [...].“ (Muniesa et al, 2007, p.2) Actors might need information that come from other persons or devices like news tickers and they might need a pencil and a piece of paper and a calculator; all circumstances that are associating an actor-network that is necessary to bring off calculative agency. In financial markets these agencies are particularly striking. The invention of the ticker for example imposed new types of actions since the new equipment enabled new ways of estimating decisions. Moreover, trading rooms of investment banks also provide different devices allowing different calculative agencies (algorithms, telephones, pricing tools, etc.) (Callon & Muniesa, 2005, p.1237). This shows that markets are not simply represented by the utilized tools and formulas. *The networked calculative devices build up agency that performs the market* (Beunza & Stark, 2004, p.371 ff.). An example that shows how the technological conditions contribute to the performing of the market is given by the case of *Island*, a new trading venue that had emerged in 1995 in the U.S. Until then, share prices were usually denominated in 1/8ths of a dollar. On *Island* this changed and prices were denominated in 1/256ths of a dollar. This altered the way in which calculative agency could be exercised on this venue because traders were able to make much finer price adjustments and therefore outcompete NASDAQ broker-dealers (MacKenzie & Pardo-Guerra, 2013, p.19).

SSF researches have coined a particular term to describe the socio-technical networks realizing markets, namely *agencements* (Callon, 2008, p.37 ff.; Callon,

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[20] Latour & Venn (2002, p.250) refer to Stanley Kubrick's film *2001* that depicts this transformation through technology in an impressive manner: The ape takes the bone and realizes the possibilities that result of using it as a (in this case murderous) technology, he throws it into the air and the famous match-cut to the space station reveals the transformative power of technology. If the scene is unknown, you can find it here: http://www.youtube.com/watch?v=qtbOmpTnyOc

2007, p.320 ff.; Callon, 2005, p.4; Muniesa et al., 2007; Hardie & MacKenzie, 2007, p.74; MacKenzie, 2009, p.19 ff.).[21, 22, 23] The term is deliberately chosen since it inherits a world-play: First, agencement indicates an assemblage or configuration. Second, it contains the crucial term agency (MacKenzie, 2009, p. 20 ff.; Hardie & MacKenzie, 2007, p.58; Callon, 2008, p.38). The challenge resulting from this is to identify these devices serving as sources of calculativeness through their relations in agencements. According to Lenglet (2011, p.50 ff.), following this intention is a fitting and necessary endeavor with regards to AT. This leads to a core question of this paper: *„Who (or what) actually calculates (and how) when we say that ‚the market' calculates?"* (Callon & Muniesa, 2005, p.1229; own emphasis) Or, as anthropologist Zaloom (2006, p.11) puts it in her ethnographic field study of trading: "What were the places, people, and technologies that generated the flow? "

To start answering this question one should initially point out what calculation means in the context of this work. Calculation does not merely mean the act of mathematical and numerical operations, it rather is the ability to distinguish between entities and to evaluate what will happen with those demarcated entities in the future. This can be captured by a three step process: First, the entities of interest are detached and moved into a space of calculation (which can literally be a physical place like a piece of paper, a factory, a trading room or a clearing house). Second, the separated entities are subject to manipulation, transforma-

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[21] The term agencement is actually introduced by Deleuze and Guitarri (1997). Authors like Callon (e.g. 2007, p.320) or MacKenzie (e.g. 2009, p.18 ff.) transferred it to SSF. Deleuze and Guitarri develop this idea by elaborating on the notion of the rhizome which fits actor-network ideas put forward in the present volume (1997, p.41): "[...] das Rhizom ist Allianz, einzig und allein Allianz. Der Baum braucht das Verb 'sein', doch das Rhizom findet seinen Zusammenhalt in der Konjunktion 'und... und... und... '."

[22] For Callon (2008, p.30 ff.), the idea of agencements also allows for conceptualizing a new type of homo economicus that does neither reject individuals' self-interest nor disregards that it hinges on networks. This *homo economicus 2.0* as he coins it accounts for the embeddedness of economically acting individuals by emphasizing that they are associated in networks that function as resources (financial, social, cultural, emotional etc.) which are necessary to accomplish the goals the traditional homo economicus would have to fulfill individually.

[23] Hardie & MacKenzie (2007, p.74) point out the problem of utilizing such a term that is basically broadening the scope might be dangerous because it could become an empty phrase capturing banal descriptions. This fits to a general critique which states that ANT is only creating a complex jargon for describing rather than explaining phenomena (Giddens, 2009, p.812 ff.).

tion and association. Third, a result needs to be produced that is the outcome of the steps accomplished before and that is able to be processed outside of the agencement. Moreover, it is worthwhile to distinguish between qualitative and quantitative calculation. The quantitative side represents a way of enabling algorithmic formulation while the qualitative part is considered with intuition of judgement (Callon & Muniesa, 2005, p.1231 ff.). Interesting in this respect is that calculative agencies differ in the kind of power they are able to provide. They are more powerful when they are able to create long lists of distinguished entities, allow manifold relations and reclassifications among them and be able to develop formulas and algorithmic patterns that deal with the created hierarchies and reclassify them (Callon & Muniesa, 2005, p.1238). Evidently, these tasks heavily depend on technological infrastructure: "As this calculative power depends on the equipments that agencies can rely upon, we can easily understand why it is unevenly distributed among them." (Callon & Muniesa, 2005, p.1238). In case of automated financial markets it is relevant that different algorithmic configurations have different implications for the distribution of power. E.g. power relations are inherently different with regards to the architecture of the market. An open outcry system for example establishes other power relations than a fully electrified market place that we can witness in terms of AT and HFT (Callon & Muniesa, 2005, p.1241).

5.2. Framing

According to Callon and Muniesa (2005, 2005; also Callon, 1998, p.16 ff.), the most important process enabling calculation is *framing* which they understand as the ability to identify distinct entities (be it persons, groups, objects or goods) that can clearly be demarcated as being of interest for a transaction. It literally is the ability to clarify what needs to be taken *into account* and what not. It is close to the idea of punctualization mentioned above. If a buyer-consumer is to purchase a car of a producer-seller then he will frame the car as the good, himself as the consumer and the sell side as the producer (Callon, 1998, p.18). All the other complexities distinguishing these entities are reduced and blanked out,

they are disentangled from other ramifications to be traded on a market. To put it differently: the good is simultaneously objectified and singularized. Objectifying refers to the process that builds the good in the sense that it is processable on the market while singularizing refers to the attribute that it can be disentangled from the associations necessary to objectify it, so that it can be incorporated (re-entangled) into the buyer‘s world. Being disentangled is the precondition for market circulation (Callon & Muniesa, 2005, p.1234; Callon, 2007, p.343; Callon, 2005, p.5). Without disentanglement, calculation is not possible and the hypothetical car could not change its owner. Objects and persons are transformed in the sense that they are now able to function on a market, the good is black-boxed and able to be traded while the buyer and seller appear as a buyer and as a seller, they are also black-boxed in the sense that all their other relations are cut off for the moment of the market transaction (Callon, 1998, p.16 ff.). But, framing cannot occur exclusively. It is not possible to separate entities entirely for the sake of transaction, there is always something overflowing: „Something passes from the seller to the buyer: the car, which conveys with it the know-how and technology of the producer. All the property right of the world cannot prevent this overflowing, except by eliminating the transaction itself.“ (Callon, 1998, p.18)[24] The question for financial markets operating with AT and HFT subsequently is: Have processes of framing changed with the advent and proliferation of new technological means?

5.3. Performativity of Economics

The notion of performativity - also prominently disseminated by Michel Callon - describes the idea that economic theory actually plays a significant part in the realization and shaping of markets. Accordingly, economics, understood as a broad discipline including subcategories like Marketing etc., does not only observe how economy functions, it rather produces the markets itself through the

[24] Accordingly, one could criticize Callon for sticking to the idea of framing that is as artificial as economic theory that also relies on hypothetic rules that enable clearcut framing (Holm, 2007, 229 ff.). At this place, it shall just be reminded that such a discussion exists but will not be intensified here.

models and concepts it creates (Callon, 1998, p.2; 2002, p.285 ff.). In the introduction to the aptly titled volume *Do Economists Make Markets?,* MacKenzie, Muniesa and Siu state that "economics is not just about 'knowing' the world, accurately or not. It is also about producing it. It is not (only) about economics being 'right' or 'wrong' but [...] about it being 'able' or 'unable' to transform the world." (2007, p.2) Wondering about performativity with regards to markets is more than asking for the effect of economics. According to the already outlined ideas, investigating performativity is also concerned with following the people, skills, datasets, techniques, tools, and ideas deriving from economics and being performed in "reality". These spillovers of economics can happen through several channels. Economists might directly interfere by consulting to firms or governments, they also might contribute via the providing of pricing formulas or models and of course via exercised policies. Somehow, the scientifically produced economic knowledge is incorporated in actual market practices of economy (Callon, 1998, p.30; MacKenzie et al., 2009, p.30 ff.; MacKenzie, 2006, p.15 ff.; MacKenzie et al., 2007, p.5 ff.;). Sociotechnical agencements provide configurations that might either support manifesting ideas that have been deducted from economics or not. But they perform them, more or less successfully (Callon, 2007, p.330). Concerning AT and HFT the question is, if there are any hints suggesting that AT and HFT actually perform ideas deriving from economics?

6. Methodology

The given theoretical explanations shall serve as the basis for the upcoming analysis and provide the essential notions and concepts to conduct a fruitful investigation of AT and HFT in the paradigm of ANT and respectively SSF. To achieve this, the study will make use of expert interviews, combined and enhanced with an additional literature and document review. Accordingly, the main instrument used to gain empirical data belongs to the realm of qualitative social research which aims at reconstructing the processes making up social realities (Lamnek, 2010, p.30). This methodological approach is chosen deliberately and

with regards to the subject and goal of this study, which does not follow the usual idea of disconfirming hypotheses that attempt to state certain causal relationships between different variables. As it has been pointed out in chapters 4 and 5, the ANT researcher tries to de-black-box entities like AT and HFT by tracing the relevant associations and by understanding how particular elements are incorporated in the agencements that are of interest. The aim and promise of ANT and especially of SSF therefore is „to investigate how various types of agencies are configured as accountable and recognizable as such in action. Another challenge is to investigate how robotic agencies are produced and put to use collaboratively by various groups in finance.“ (Preda, 2012, p.31) Following this highly explorative approach, it seems to be a rather logical consequence to employ qualitative instruments for exploring AT and HFT since those tools inherit the flexibility and reflexivity that is necessary to examine such phenomena in the way this study-outline indicates (Lamnek, 2010, p.23 ff., 36). The goal of this paper therefore is to identify the agencements of AT and HFT and to explain how their elements are related to each other by analyzing them with the theoretical concepts of ANT and SSF. Subsequently, this analysis also shows how the theoretical concepts are suitable for describing these entities in an appropriate way and how they function as classifying and integrating constructs (Mayring, 2010, p.24). Most SSF papers (see e.g. Hardie & Mackenzie, 2007; MacKenzie & Pardo-Guerra, 2013; MacKenzie et al., 2012; MacKenzie & Millo, 2003; Pardo-Guerra, 2010) are not using those theoretical notions in the systematic way as the present paper attempts to do. The systematic usage of theoretical notions shall help to develop a reliable toolkit for analyzing technology in general, and economy related entities like AT and HFT in particular.

The methodology guiding the applied proceeding is to ask participants of AT and HFT how certain kinds of agents, organizations or devices are involved in their construction. Accordingly, we deal with experts in the field of AT and HFT because they provide the access to the peculiar knowledge that is of interest for the research project (Gläser & Laudel, 2010, p.11 ff.). Moreover, the choice to conduct expert interviews is vindicated by most relevant SSF-studies examining trading in terms of technology. They are mainly based on qualitative data and

document analysis, and especially on qualitative interviews (Hardie & Mackenzie, 2007; MacKenzie & Pardo-Guerra, 2013; MacKenzie et al., 2012; MacKenzie & Millo, 2003; Pardo-Guerra, 2010). As a consequence, seven interviews have been conducted to retrieve the required data since "interviews are particularly well-suited for providing detailed accounts of the microcosm of everyday life, of personal relations, of organisational [sic] and familiar interactions, and, precisely due to their situated character, of subjective and personal meanings and lived experiences (however much ex post they may be)." (Pardo-Guerra, 2010, p.17)

The expert interviews for this thesis have been conducted as non-standardized , guideline-based interviews which each lasted between 30 to 60 minutes. The guideline issues have been deducted from theory and have been adjusted with respect to the actual interviewee's profession and organization (For the guidelines see Appendix 2). These adaptations are supposed to enable the best possible extraction of rich data in every particular interview situation (Gläser & Laudel, 2010, p.150). The interviews have mainly been conducted via Skype due to economical and temporal restrictions. Though, one interview (Interview D) has been conducted personally. The interviews have been conducted between March 25 and April 29 2013.

To make the research process as transparent as possible, the following three sections will elaborate on three important aspects characterizing the process itself. First, the sample of this study will be described and explained in detail. Second, the procedure utilized for evaluating the gathered data will be expounded. Third, different criteria for the quality of qualitative research will be explained and reflected with regards to the present research.

6.1. Sample

In this qualitative approach the decisive attribute of the sampling method cannot be statistical representativity like in quantitative inquiries. According to Lamnek

(2010, p.172), qualitative research rather aims at achieving contentual representation through appropriate sampling. To achieve this, the strategy applied here can be ascribed as belonging to the idea of theoretical sampling since theory governs that "[...] you select individuals, groups, and so on according to their (expected) level of new insights [...]." (Flick, 2009, p.118). The utilized sampling strategy is theory guided in so far that it follows the ideas of distributed agencies and agencements. Accordingly, the crucial idea for the sampling is that it incorporates participants belonging to varying relevant organizations associated in the actor-networks performing AT and HFT and who are supposed to give typical insights into the shape of those distributed processes. This results in a selective sampling that drafts participants with respect to features characterizing them as promising sources (Lamnek, 2010, p.171 ff.). In the present case, the relevant attribute for selection is the subject's profession. The professional involvement in AT and HFT supposedly qualifies them as sources of the desired expert knowledge. Hence, the presented sample is composed of persons working at exchanges, banks, trading companies, data infrastructure providers and associations. The actual selection of interview partners was then additionally influenced by availability and accessibility (Gläser & Laudel, 2010, p.98). Relevant institutions and persons (if contacts have been available) have been researched, contacted and asked to participate in the desired interviews. Yet, in a lot of involved organizations, especially banks, proprietary traders and hedge funds, one is confronted with a "culture of secrecy" (Gomolka, 2011, p.1 ff.) due to the delicate information which are supposed to demarcate their particular competitive advantages. Thus, the actual sample has been influenced by the scarcity of positive responses.

Overall, seven interviews have been conducted. Three of them have been with individuals working at exchanges, one with a person working at a bank, one with the representative of an association, one with an employee of an infrastructure provider and one with an executive of a proprietary trader. In the following, you can find more detailed descriptions:

Interview A (Person A / Exchange A):
Interview A has been conducted with the management assistant of a big German stock exchange that is focusing on retail investors. It has been conducted in German and via Skype.

Interview B (Person B / Exchange B) :
Interview B has been conducted with the Vice President and Head of Media Relations of a big German stock exchange. It has been conducted in German and via Skype.

Interview C (Person C / Exchange C):
Interview C has been conducted with the Head of Monitoring of a big German exchange for derivatives. Person C is especially responsible for the design of the exchange's trading system with regards to HFT. It has been conducted in English and via Skype.

Interview D (Person D / Bank D):
Interview D has been conducted in German and personally at the department for electronic execution and algorithmic trading of a globally operating bank, located in Zürich. Person D is responsible for the algorithmic sales desk of Bank D in Germany, Austria, Switzerland and Turkey.

Interview E (Person E / Association E):
Interview E has been conducted with the Vice Chairman of Association E that is politically representing the interests of principal traders in Brussels. It has been conducted in English and via Skype.

Interview F (Person F / Infrastructure Provider F):
Interview F has been conducted with the EMEA Director of Financial Services of the world's largest data center provider, situated in London. It has been conducted in English and via Skype.

Interview G (Person G / Trader G):
Interview G has been conducted with the executive of a proprietary High Frequency Trader, located in cologne. It has been conducted in English and via Skype.

6.2. Evaluation Procedure

Initially, all interviews have been recorded as audio files which have then be entranscribed word-for-word.[25] Possible dialects and linguistic idiosyncracies have been smoothened for the sake of readability. Due to the fact that the analysis is concerned with extracting content, laughing and other irrelevant utterances have not been transcribed (Gläser & Laudel, 2010, p.193). To ensure anonymity, all information that could allow for a conclusion about the interviewee's identity have been removed. To allow for the actual analysis, the transcripts subsequently have been imported into a QDA (qualitative data analysis)[26] software that is used to code the transcript. Those codes split the texts into units of evaluation, depending on the content, which then provide the needed structure for further content analysis (Mayring, 2010, p.94). Evidently, those codes are applied by an interpreting subject (the individual author) and can thus not claim to be "objective" (Gläser & Laudel, 2010, p.201). The choice and creation of codes is not arbitrary, but a result of the theoretical pre-considerations above. This theory-driven code generation is supposed to enable a compatible contribution to the scientific community (in this case especially ANT and SSF) and the knowledge produced by it (Mayring, 2010, p.50 ff.; Mayring, 2002, p.100; Gläser & Laudel, 2010, p.31, 199 ff.). Moreover, the code system has also been handled openly, so that insights deriving from the actual interviews could be incorporated into the design of the code system itself. Designing the code system dynamically allows for capturing more perspectives and avoids a narrowing preselection of relevant information. This proceeding accounts for openness which is another attribute fundamentally associated with qualitative research (Lamnek, 2010, p.20; Gläser & Laudel, 2010, p.201). Figure 2 displays a visualization of the codes, segregated with respect to those which have been theory/literature induced and those which have been interview induced. Presenting the considerations that have lead to the eventually utilized codes, accounts for the claim of

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[25] This has been done by using the transcribing software *f5*. For more information see: http://www.audiotranskription.de/f5.htm

[26] In concrete, the software used is called *MAXQDA 11*. For more information see: http://www.maxqda.de/produkte

explication which states that qualitative research processes need to be transparent and traceable so that others can intersubjectively comprehend it (Lamnek, 2010, p.23; Gläser & Laudel, 2009, p.31; Mayring, 2010, p.49).

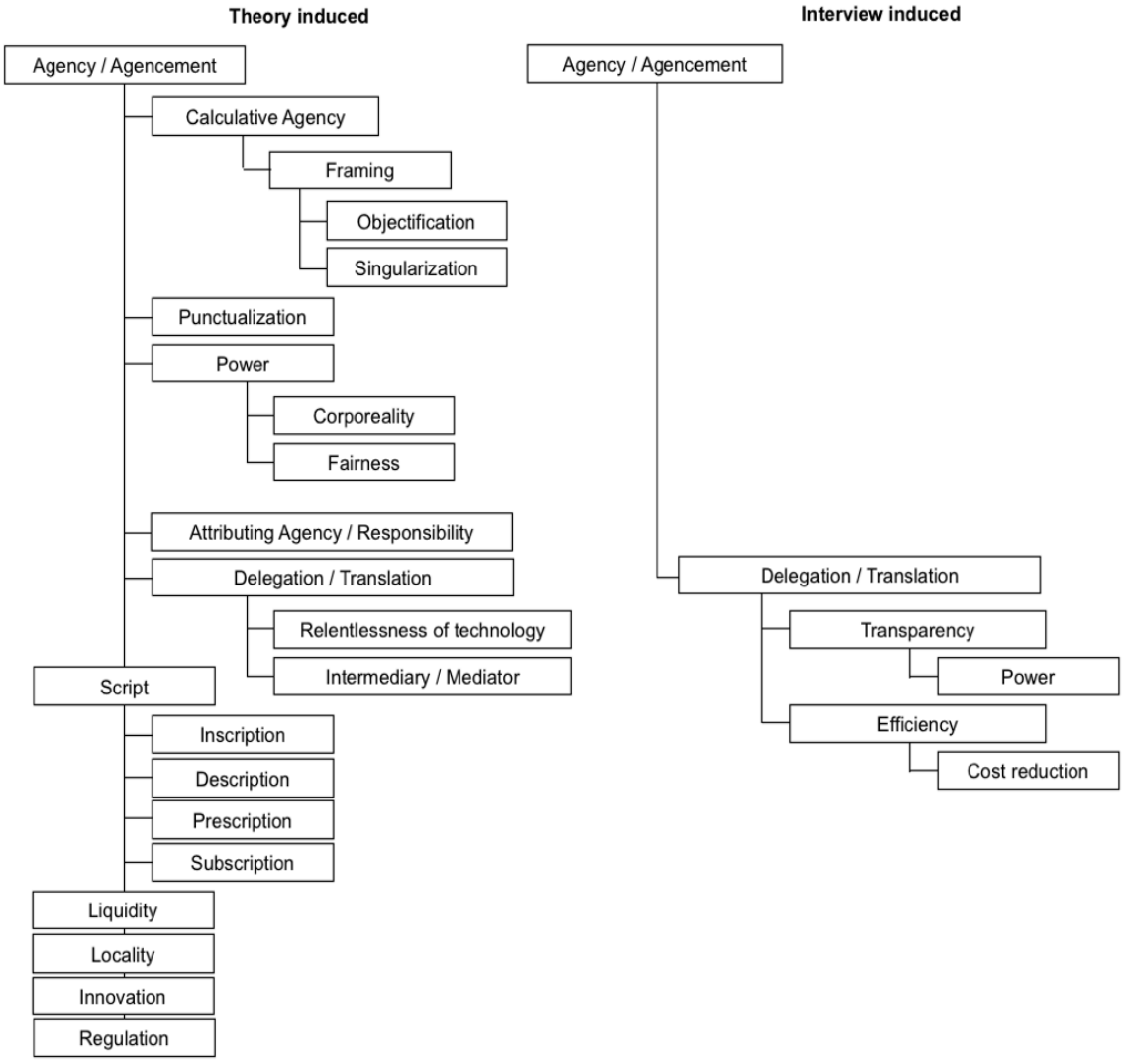

Figure 2: Visualized code system (own work)

6.3. Quality Criteria of Qualitative Research

Qualitative approaches and quantitative proceedings differ in the quality criteria usually attributed to it. The traditional criteria for scientific work, normally counting for quantitative inquiries, are validity, reliability and objectivity. Those are not equally obtainable for qualitative research that therefore requires new and specific indicators of scientific quality (Mayring, 2002, p.140 ff.; Flick, 2009, p.384 ff.). According to Mayring (2002, p.144 ff.) these particular criteria can be: (1) Documentation of procedure, (2) argumentative backup of interpretations, (3) adherence to rules, (4) proximity to the subject, (5) communicative validation, (6) triangulation.

In the present work, the (1) documentation of procedure is achieved in three ways. First, a comprehensive theoretical account is presented that provides the reader with the essential concepts necessary to understand the paper's theoretical rooting. Second, these concepts are the resource for deducting the categories and issues utilized in the empirical inquiry which makes the interview process and the analysis transparent and traceable. Third, the methodological procedure is explained and vindicated in detail. (2) The argumentative backup of interpretations is achieved by analyzing the data with reference to the theoretical concepts and with inner consistency. (3) Adherence to rules is guaranteed by the systematic procedure of analysis that has been explained above. (4) The proximity to the subject can only be ensured partially as most of the interviews have been conducted via Skype which does not allow for a deep penetration of the subject's lifeworld. (5) Communicative validation is understood as re-discussing the results of the interviews with the subjects. This could not be performed in this study due to research economical and temporal limits. (6) Triangulation can also not be achieved in this paper since the analysis is exclusively based on ideas deriving from ANT and there is no comparison of qualitative and quantitative data.

7. Analysis: Results and Interpretations

The following sections present the results and their interpretations. To account for the systemic approach that has been maintained above and to ensure contentual consistency, this part will *mainly* be structured according to the concepts that have been explicated in the theoretical parts 4 and 5 and which have already served as the main source for the interview guidelines and the code system. Hence, the theoretical concepts provide the interpretative frame for the obtained data. Yet and according to the openness of the research process itself, some aspects will deviate from this structure since the gathered data generated new categories or suggested arranging the results and their interpretations differently.

7.1. Agencements and Calculative Agency of AT and HFT

This part will elaborate on the agency - or more particular the agencements - that configure AT and HFT. Thus it will consist of broad depictions of associated organizations and technologies (as whole entities) that together enable their calculative agency. More concrete explanations of how these associations are realized follow afterwards.

The evidence suggests that a few crucial players are necessary to operate AT or HFT as a whole entity. First of all, there are electronically operating exchanges that allow electronic access and thus function as "incubators" of the development (Interview C, p.17). Then of course, since it is about markets, you need a buy-side and a sell-side willing to take part in the respective electronic exchange. This is the basic set. Yet, this configuration may change and extent depending on who is trading how. A proprietary trader for example is trading on its own behalf, responsible for its own money (Interview E, p.1, Interview G, p.1 ff.) while banks may also function as brokers and therefore have to mediate for others who then also contribute (Interview D, p.1 ff.). Thus, in the latter case the set would branch out. Although, it is legitimate to say that electronically organ-

ized exchanges (or trading venues) and electronically operating buy- and sell-sides build the basic network. Yet, especially essential for HFT, there is a very important player involved that guarantees the needed transaction speed for the participants by enabling physical nearness in terms of co-location. These players are infrastructure providers that either supply fast fibre optic cable connects (Interview D, p.23) or, even more important, provide data centers that are located in proximity (co-located) to the exchanges or even house the exchange's matching engines as well as the participants' servers (see section 7.6. for a more detailed discussion of locality). *Infrastructure Provider F* sells participation with those data centers to financial services companies. The interviewees state on the one hand that the infrastructure provider is a mere means to an end, they take it as a punctualized resource facilitating trading (Interview C, p.7; Interview F, p.6; Interview G, p.10) On the other hand, evidence also suggests that they do play a crucial role in shaping AT and HFT (Interview B, p.7; Interview C, p.8 ff.; Interview G, p.10). These providers do not only deliver a kind of highway the business rolls on, they occupy an essential place in the agencement of AT and HFT which is aptly illustrated by the following example: When MF Global[27] faced severe problems concerning their liquidity, customers tried to get to other brokers because they feared that MF Global could not support their trading anymore. The moment MF Global and its clients faced dysfunction, MF Global as a punctualized trading entity needed to be de-black-boxed, so that concerned partners could analyze the respective actor-network to find solutions for their misery. In that situation, *Infrastructure Provider F* quickly cross-connected these customers inside their data centers and thus ensured the appropriate access to other brokers and this way enabled further trading. Hence, it kept up calculative agency by altering an essential part of its configuration at that moment and re-punctualizing it (Interview F, p.8). Another fact that vividly grasps that the agency of AT and HFT is distributed in agencements, is that the co-location services of *Infrastructure Provider F* that are put up for sale are

[27] MF Global was a large derivatives broker that went bankrupt in late 2011 (Bunge, 2011).

branded as "financial ecosystems"[28] which is a term that exactly expresses the idea of distributed agency in actor-networks:

> "So what is an ecosystem? [...] Well it consists of a stock exchange or a trading venue as center. It then consists of sell-side companies, brokers and dealers, who connect to that exchange and provide trading services, electronic co-location services, many services looking after the customers of sell-side servers on behalf of them." (Interview F, p.4)

Those players contribute to the current overall shape of AT and HFT. Accordingly it is not only one agent identifying and using market opportunities by exploiting technology or speed advantages. It may have started with big electronic market makers who recognized that investing in technological means bares possible profits what then triggers other competitors like banks to follow. And subsequently, exchanges follow to be able to supply the demanded technological interfaces which brings in the infrastructure providers that offer solutions for these needs (Interview F, p.14). Like the ape's stick in Kubrick's *2001* did the emerging technology trigger possibilities and new agencement configurations that attempt to put them into action (Interview B, p.13, p.23; Interview E, p.10; Pardo-Guerra, 2010, p.265 ff.). *Person E* therefore describes fittingly: "[...] technology has really given us the opportunity to do this. Prop trading shops and exchanges have seen that light soon after. There was certainly a collaboration between them *because you cannot do this all by yourself. So it is a combination*." (Interview E, p.10, own emphasis) Similar to Hutchins's (1995) military vessel (see p.18), it is the distribution of agency that enables the thriving of AT and HFT. *Person A* from *Exchange A* confirms this mutual interplay but points out that data and information providers like Bloomberg or Thomson Reuters are also essential since they feed the decision making processes (Interview A, p.17; also Interview B, p.22 ff.). For *Person D* who algorithmically brokers for institutional customers - who with their decisions also contribute to the actor-network - do these information providers play an important role because they also organ-

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[28] According to Townsend et al. (2009, p.9), ecosystem is a term that describes the interactions and energy flows between enlivened and lifeless elements as a whole.

ize the customers' market accesses. Via a Bloomberg trading terminal for example, the customer can enter his order and choose which broker and successively which of the offered algorithmic strategies to use (Interview D, p.3). So, all this already shows that in general, technology builds an essential part of the AT's and HFT's calculative agency which is affirmed in all interviews. *Person G* trenchantly summarizes this development (Interview G, p.2, own emphasis):

> "*In total or in general I could say that I do not consider ourselves any longer as a financial services company, it is more like an IT company. 50 percent IT company, 50 percent financial services company. Because of the amount of technology that is needed for this business*."

This view also holds for exchanges because "Börse ist natürlich heutzutage ein Technologieunternehmen" (Interview A, p.7; also see Interview C, p.4 ff.) or banks (Interview D, p.4 ff.). The transformation can maybe best be observed when taking a closer look at the educational backgrounds of the professionals involved. While individuals trained in business administration or economics are still active as traders, sales traders or marketing sales, there is a significant group of persons trained in mathematics, physics, statistics, engineering, information technology, programming and the like who are needed to account for the required thinking in and application of highly formalized and mathematical models (Interview A., p.7; Interview C, p.1 ff.; Interview D, p.4 ff.; Interview F, p.7; Interview G, p.4 ff.). The technological transformation of calculative agency is therefore traceable with regards to the participants' education which *Person E* depicts congruously: "*We now deal with engineers, mathematicians, econometrics, science folks. Those are the traders from today.*" (Interview E, p.6, own emphasis) This proximity to highly formal scientific disciplines actually supports the idea of performativity stated above in chapter 5. Concerning the question who or what actually calculates when we say "the market calculates" (see p.29), we have to acknowledge that it is this whole configuration that calculates. One interviewee does not speak of calculation but of information processing as the the pivotal purpose of centrally organized markets (Interview B, p.11). The point being here is that this information processing of the "the market" then is also a

product of the explicated agencement. MacKenzie (2013, p.4 ff.) notes that AT and HFT have transformed, from being "content" to building "context". In former times, they made up a small niche of trading, operating in the shadows of the agencements of pit-trading. But since their proliferation, the technological context has changed and other agents of the relevant agencement adapt to it and therefore change their configurations.

7.2. Delegations and Translations in AT and HFT

A very fruitful way of understanding the application of particular technologies is to analyze them in terms of delegations and translations. Therefore it is necessary to examine what tasks are shifted out to the technology and how this folds time and space (see chapter 4.3.). So, the first and most obvious fact that has been delegated to algorithm-running machines is the necessity for actual human and physical presence in the pit. In the open outcry system, the market began and ended with the actual space of the pit which in vital times could be filled with up to 2.000 people performing trade in certain pits (MacKenzie, 2013, p.7). In this place the whole communication process, and therefore the actual trading, was vitalized via hand signals, talking and shouting (Interview A, p. 3 ff.; Interview E, p.2, Zaloom, 2006, p.56 ff.; MacKenzie, 2013, p.7). Delegating this to algorithms and machines has consequences in terms of temporal and spatial compression. The need to actually be present at a room in a building restricted access possibilities:

> "Yeah, basically first of all, you had to show up in the pit, it was the only place where you could trade. You always had to reserve a spot. Before that, you had to buy or lease a seat, those were limit, those had limited numbers. Obviously, the space was limited, so limited people could actually stand in that pit. [...] So today's world is, and this is exactly where we are in co-location, where there is absolutely unlimited space to put your computers in." (Interview E, p.2 ff.)

This case aptly reflects how technology compresses space since after delegating the open outcry communication processes to machines rather than interacting humans, it is now possible to basically operate on a global scale in one co-location data center without any human presence necessary: "*Wer vor Ort sind, das sind Plastik- und Metallteile, Rechnerplatinen, eben ein, das ist ein Rechner, der vor Ort ist.*" (*Person B* in *Interview B,* p.10, see also Interview C, p.10) Aptly, *Deutsche Börse* itself comments the introduction of *Xetra* as a process of opening up the exclusivity of the pit: "Seit dem ersten Betriebstag ist die Börse nun überall dort, wo die Bildschirme stehen." (Deutsche Börse, 2010, p.11). As a consequence of this spatial compression, markets are also closer to each other (not in an actual geographical sense) because its participants can now quickly react on worldwide events which results in one price being valid at the exact current time and not at one time or another (Interview B, p.11 ff.). The market is translated, from the pits and the traders' bodies, to data centers and servers, it has become an "entity without location" (that locality in fact does play a role will be discussed in chapter 7.6.). This changes calculative agency in the sense that traders no longer are the market, but observe and analyze it (Zaloom, 2006, p.5, p.141). [29]

To examine delegation processes it has ben pointed out that it is useful to take a look at the actual tasks which have been translated from humans to nonhumans. Without algorithmic and electronic trading, after there was a communicative agreement concerning the trade, the trader needed to write a ticket, timestamp it and it then had to be matched with the counterparty's ticket. A chain of tasks that roughly took about 30 minutes (Interview E, p.3; Interview D., p.16, Zaloom, p.8 ff.). When the whole process takes about 30 minutes it respectively means that there are 30 minutes of uncertainty, of "being in Limbo" (Interview E, p.3). An even slower variation of this was that all buy- and sell-tickets were only matched at an auction once a day. And the actual transaction of traded certificates was then even realized via bicycle couriers (Interview B, p.4). The same holds for the messaging speed between exchanges. In the 19th century, wiring

[29] See Appendix 3 for a picture showing a crowded pit in Chicago.

an order from New York to Philadelphia took 30 minutes each way which opened up huge windows of risk. After delegating this whole process to computers, algorithms, fibre cables and data centers, these processes are temporally compressed (Interview B, p.1; Interview E, p.3, p.5 ff.). This affects the calculative agency because the computers enabled continuously happening price determinations which could not be done by human beings (Interview B, p. 4ff.). Enabling this continuation and processual pace alters calculative agency severely because perceiving and managing risk has drastically been translated as *Person E* explains (Interview E, p.5): "These days we have minimized that to microseconds and we now know virtually every part of the day what our risk is. And the beauty of that is that we calculate risk as costs." The amount of uncertainty resulting from long time-lags diminished because "within a split-second you know if a trade has been done or not." (Interview G., p.3)

The transformative effect of this time folding also affects another aspect of AT, namely brokerage for clients. In times without automation, clients forwarded their orders via telephone, the broker itself then also called its own market maker in the pit who then looked for possible prices. He then called back with the actual offers and the broker successively re-called the client. And if they started by ordering the market price it could already have moved during the order procedure time. (Interview C, p.6; Interview D, p.2). Zaloom (2006, p.60 ff.) gives a detailed account of this chain of human actors at the Chicago Board of Trade: The client deciding to order, the desk manager receiving the order per phone, the "clerk" forwarding it to the pit and checking the prices, the "clerk" writing down the order, giving it a time-stamp and handing it to a "runner" that acts as a courier and gives it to a broker's clerk who then processes it to the broker executing it. Obviously, this process involved much more tasks which were directly exercised by humans and therefore cost time. Translating these tasks to computers significantly reduced time lags because you do not need to discipline all these involved human beings again and again. Only a clients' telephone order sometimes took up to 20 minutes, now it is reduced to a tenth of a millisecond (Interview D, p.7 ff.). As a consequence, the immediacy of price building and order processing changed risk management. *Person A* states that

due to its focus on retail investors, *Exchange A* still has so called "Quality Liquidity Providers", human intermediaries that interfere when the respective market is illiquid. The moment those humans interfere, time is de-folded and uncertainty re-occurs: "Das heißt, wir sind dann im Risiko und müssen uns dann glattstellen, möglichst über den Handelstag." (Interview A, p.3). In contrast to that, one can observe this whole process without any human intervention at *Exchange C* that is fully automated (Interview C, p.10 ff.):

> "So let's start where a machine, so one of our client's machines, receives market data. The market data, which contains an interesting event, would trigger one of their algorithms. For instance there is a big trade in one of the two liquid futures, then they put together an order. So, they specify the size, the price and the type of order they want to send, put that on the wire to us. They have a dedicated line to us and that order is received by one of our gateways. The gateway makes sure that the matcher which is behind the gateway is not flooded with messages if a machine for instance would start sending thousands of orders. It is a buffer between the clients and us. The gateway then forwards the message to our matcher. The matcher then checks if the order is executable or not. If it is executable it creates a trade. If it is not executable it is added to the book or rejected. After that, the matcher will send back an acknowledgement that the order was received back to the gateway and the gateway then forwards it back to the client. And, of course, there is a second path as well. There mostly is some public information as well. So, if the order is added to the book or if there is a trade, then the whole market needs to be updated. So, the matcher then creates some market data and then forwards that back to all clients."

7.3. Relentlessness of AT and HFT

Another important aspect of these delegations is that applying technology in the calculative agency of AT and HFT brings strict and unyielding relentlessness (see p.20). Algorithms, as nonhumans, do not make mistakes, they function according to their programs which does not mean that the programming cannot be defective. But they adhere to the prescribed rules, without exception. Respectively, more human intermediation means more error-proneness, which stan-

dardization through automation circumvents. Humans send faulty faxes, confuse figures for prices and quantities, give wrong information on the telephone, have problems in communicating, e.g. due to speaking different languages or having incongruences of meaning (Interview B, p.4; Interview C, p.11 ff. Interview D, p.2; Interview G, p.12). In general, using algorithms simply reduces ambiguities that inevitably occur in processes of human communication and social interaction. This way they contribute to a central feature of markets, namely dealing with contingencies (see p.14). *Person D* illustrates the misunderstandings in a humanly managed order-process: "'Ich möchte gerne 10.000 Apple-Aktie bestmöglich kaufen.' Dann ist natürlich 'bestmöglich' immer eine Definierung, wo ein Händler sagt: 'Ah, bestmöglich heißt im Schlusskurs.' Ein anderer sagt: 'Bestmöglich heißt möglichst gleichverteilt über den Tag.'" (Interview D, p.1) Using electronic processes avoids these contingencies of meaning since a certain algo-strategy follows exactly the imposed steps of action according to the fed parameters (Lenglet, 2011, p.62). Hence, operating mercilessly disables deviance, which is why *Person D* states that this relentlessness partially kills the fun of brokerage. For example, in traditional trading, participants could negotiate and a broker could claim for a better commission since a certain trade was especially hard to realize (Interview D, p.10). Similarly, *Person G* maintains that traditional pits provided the opportunity to sell large positions like 10.000 or 20.000 shares at a certain price. Now, technology forces you to slice the positions and successively reach the volume by going through the order-book step-by-step with different prices (Interview G, p.2 ff.).

In times of crises and heavy irritations it is this relentlessness that might cause problems since their is no intuition or felt responsibility for keeping up the markets. If data and inputs evoke a crash, it is processed without contemplation at an enormous pace as the Flash Crash illustrates again. In an open outcry system someone in the pit would have had the time and the space to pause and demand caution (Interview G, p.11 ff.; Zaloom, 2006, p.53). Thus, the data suggest that it is not algorithms causing fluctuations, but the time compression and their relentlessness that contributes to the acceleration of critical states (Interview F, p.13; Lenglet, 2011, p.61 ff.; MacKenzie, 2013, p.40 ff.). This is again

shown by the Flash Crash of May 6. On behalf of a trader, the wrongly chosen algorithm relentlessly executed the huge order although market conditions contradicted it. But, algorithms as technologies do what they have been disciplined for. Lenglet (2011, p.59 ff.) serves another example depicting this relentlessness when he regives the story of a trader who accidentally entered a buy-order for 5.000.000 shares into an execution algorithm when he actually meant 500.000. The algorithm immediately divided the order into four slices. After nine seconds the trader realized his failure and attempted to cancel the erroneous order. He successfully aborted the execution of three of the four slices. The fourth order had already been executed by the algorithms and 1.184.966 shares had been bought. Besides the fact that this case demonstrates how the algorithm's structure forces their users to be cautious with regards to the setting of relevant parameters, it also reveals the relentlessness of technological agency. Chaboud et al. (2009, p.1) point out that once these algorithms are established they process their built-in steps autarchically:

> "In algorithmic trading (AT), computers directly interface with trading platforms, placing orders without immediate human intervention. [...] Among the most recent developments in algorithmic trading, some algorithms now automatically read and interpret economic data releases, generating trading orders before economists have begun to read the first line."

But on the other side, operating this strict does not only characterize the trading process itself but also the monitoring and controlling of it. Since ambiguities are diminished, control mechanisms like breaks and limits can stop trading automatically if certain obviously noticeable limits are reached or exceeded. The exchange is always aware of the risks taken by market participants and can subsequently exclude them (Interview B, p.20 ff.; Interview G, p.8 ff.). For example, on an exchange like *Xetra* there exist so called volatility-breaks that can stop the market relentlessly if price fluctuations reach certain levels. The purpose of these breaks is to de-fold time again by opening up the process for human interaction because humans can then intervene and analyze the situation (Interview A, p.16; Interview B, p.20; Interview C, p.16; Interview G, p.9). At *Ex-*

change B for example, this process is so sophisticated that computers automatically interrupt the trading of isolated shares, so that it is not necessary to paralyze the whole exchange. And this interruption has exactly the purpose of gaining time for human interference (Interview B, p.18): "[...] dann hält unser Computer den Handel in dieser einen Aktie an, und zwar für zwei Minuten. In dieser Zeit können alle Aktienhändler ihre Orders überprüfen, denn vielleicht lag ja eine Fehleingabe vor, könnte ja sein." The initiatively expounded Flash Crash displays this, too. When the crash was in full play, the *CME Globex* system started a program called "Stop Logic Functionality" at 2:45:28 pm which has the purpose of pausing the complete trading for five seconds so that human traders can evaluate the situation, e.g. checking news for catastrophes. Those five seconds sufficed for the buy-side to recover and when trading was re-opened at 2:45:33 pm, E-mini stabilized (SEC, p.4; MacKenzie, 2013, p.42).

Just recently, there was another incident that impressively illustrates the relentlessness of algorithmic processing, namely the so called "Hash Crash". A hacker (supposedly a Syrian hacking organization) somehow managed to log into the *Twitter* Account belonging to the established press agency *Associated Press (AP)*. On April 23, 2013, at 1:08 p.m., she tweeted the following message in AP's name: "Breaking: Two Explosions in the White House and Barack Obama is injured." What was supposed to be a hoax, was taken for granted by algorithms that scan news and social network sites for market relevant information.[30] After the tweet, Dow Jones declined 145 points. About three minutes later, first denials from AP and the White House appeared so that after another three minutes courses had almost recovered (Lauricella, Stewart & Ovide, 2013). This whole event fits to assertions from *Person A* who pointed out that algorithms are capable of processing information coming from news agencies. Usually they react to certain scores given to the announcements and indicating how to evaluate them (Person A, p.4 ff.). But as this incident documents, there are also algorithms "understanding" the semantics and meanings delivered by

[30] According to a panel discussion about "Big Data: Herausforderungen und Chancen" (at the *D-A-C-H Kongress für Finanzinformation* on April 30, 2013, in Munich), making information that circulate on social network sites, blogs and forums assessable and treatable for algorithms is one of the big upcoming challenges for AT.

messages and reacting depending on that. The point being is that in this case they comprehended the semantics of that sentence but they have no intuition to deal with it. They do what is delegated to them and translate it according to their inscribed purpose.

7.4. Efficiency and Cost Reduction in AT and HFT

A crucial fact of AT and HFT, representing a major aspect mentioned in the interviews, is that technology increases efficiency and reduces costs which obviously derives from the just described delegations and their consequences of folding time and space. Besides speed and acceleration, the additional benefit of relying on algorithms for analysis, utilizing modern information and communication technologies and making use of co-location data centers, is simply that it is more efficient and consequentially reduces costs in two ways. The first one has been explained in the two previous sections, namely that windows of risk have been minimized which allows for a better assessment of risk (Interview C, p.6; Interview D, p.2; Interview E, p.3 ff.; Interview G, p.3). The second one concerns the optimization of actual business processes that have become much more efficient, too. The comparative frame that came up in the interviews is that automation enters financial industry just as it had entered other industries like the textile industry in the 19th or the automotive industry in the 20th century (Interview A, p.3 ff.; Interview B, p.1 ff.; Interview C, p.4 ff.). That, of course, is also the reason why traditional open outcry traders have not supported the emergence of AT and HFT since it has taken away their working basis and basically killed their profession (Interview A, p.7; Interview B, p.14; Interview C, p.5; Interview D, p.16, p.19; Interview G, p.4; Zaloom, 2006, p.51 ff.). Since these efficiency gains result from the delegations and translations it is a logical consequence that less human beings are necessary to operate modern financial markets which *Person E* illustrates with regards to trading rooms of banks (Interview E, p.6 ff.). Nowadays, they need one trader to manage all European cash markets instead of 800 who would have been needed in former times. Hence, he concludes: "Other people will not like it, other people who used to

work in dealing rooms in banks and sales traders, we cut a lot of their throats." (Interview E, p.8) The trading venue *Island* again serves as a nice example for this, too. In 1995, it started off as a small trading venue that after three years of existence already captured 4% of the trading on NASDAQ, with only four employees (MacKenzie, 2013, p.21). All this fits to the author's personal experience at the trading rooms of *Bank D* in Zürich where only six traders were running the business for at least the German speaking countries and Turkey. So, the question for the remaining humans sounds as relentless as the technologies displacing them: "*[...] kann ich die Person vielleicht noch in ein elektronisches Team bringen, wenn nicht, wird er noch gebraucht?*" (Interview D, p.16)

Another aspect displaying how these cost reductions are realized, concerns connectivity. To enable varying market access it is much more efficient to make use of a data center provider that is offering access to an "ecosystem" because it is significantly cheaper to pay one fee that allows you to connect to several trading platforms in one data center than connecting to every desired exchange on your own:

> "[...] if you are, say, a bank in Frankfurt and want to connect to the, you know, London LIFFE derivatives trading, the derivatives trading Eurex, the derivatives trading and the Chicago Mercantile Exchange. You would have to buy a network cable from, you know, Frankfurt to Frankfurt for Eurex. Frankfurt to London for LIFFE and Frankfurt to London to pick up a CME node. And those three lines, six circuits, would all cost you around 5000 Euros a month. And you can see that that is quickly gonna be running your bill round about 30.000 Euros a month. Now, you can come in to Infrastructure Provider F's Frankfurt data center and connect to Eurex, LIFFE and CME from there for a cross-connect which is about a 150 Euros a month." (Interview F, p.11 ff.)

7.5. Liquidity and Transparency in AT and HFT

It has already been pointed out how delegation and translation have produced an immediacy that is inherent for AT and even more for HFT. Besides allowing for reducing risks and realizing operations more efficiently, this immediacy - of course related to the explained relentlessness - results in another crucial alteration of the calculative agency of financial markets, namely an increase in transparency. This idea of transparency is crucially interwoven with the economic notion of liquidity. Carruthers and Stinchcombe (1999) provide a pivotal analysis of the social structure of liquidity that will serve as a basis for analyzing liquidity in terms of AT and HFT:

> "By liquidity of a market, economists mean that standardized products can be bought and sold continuously at a price that everyone in the market can know, and that products are not normally sold at a price that diverges substantially from the market price. The idea is that everyone can know at all times what the price is, and only one price obtains in the market. Liquidity, like efficiency, is considered one of the great virtues of a perfectly competitive market." (Carruthers & Stinchcombe, 1999, p.353)

They identify three central patterns that can realize liquid markets: (1) constantly exercised auctions, (2) the existence of market makers and (3) standardization of products (Carruthers & Stinchcombe, 1999, p.353). As it has been pointed out throughout the paper so far, all three aspects are represented in terms of AT and HFT.

Yet, the interesting case especially with regards to AT and HFT is the second mechanism, namely market making. Market makers provide liquidity by taking the risk of transferring large quantities and providing a constant price (Carruthers & Stinchcombe, 1999, p.353). Market makers' reality has changed with increasing proliferation of automation technology. In the past "They [sic] received buy or sell orders from other market participants, manually matched them and/or aced as dealers, continuously quoting prices at which they would themselves buy from or sell to other market participants." (MacKenzie et al.,

2012, p.5) Advancing the pace of exchanging market data allows everyone to gather and analyze the exact same information at the same time (Interview B, p.4 ff.; Interview D, p.10 ff.; Interview E, p.5 ff.). Market making algorithms persistently quote prices at which they will purchase and higher prices at which they will sell. Then, they profit from the difference between those, the "bid-offer spread" (MacKenzie, 2012, p.8).

Thus, HFT heavily contributes to providing liquidity in terms of market making which is usually measured via the spread between the lowest offer to buy and the highest offer to sell which nowadays moves around one or two cents (Interview E, p.5; MacKenzie, 2012, p.10 ff.). HFT traders that are represented by *Association E* for example, provide over 20 percent of the algo volume of the whole German market (Interview E, p.1 ff.). This holds for extreme situations where HFT trading does contribute to the rapid realization of drops like the Flash Crash. But, HFT also contributes to the fast recoveries as they are operating on both sides of the order-book, following different strategies (Eurex, 2013, p.27; Interview B, p.22; Interview C, p.16 ff.; Interview E, p.9) But, this also means that HFT is mostly happening in markets that are liquid since the algorithmic rules are relentless again, they do not realize trades in illiquid markets which do not fit to the programmed rules. For all instruments that are not liquid enough to fulfill the technology's demand, time and space are de-folded again and human intermediaries intervene (Interview A, p.2; Interview B, p.15;).

> "Die Aktien sind sehr bekannt, die sind sehr liquide, da kann ein Handelscomputer sehr effiziente Preise für stellen. Bei weniger bekannten Aktien auch aus der dritten Reihe, die aber auch gehandelt werden, kann das ein Computer nicht. *Dann würde häufig, wenn man einen Computer einsetzen würde, würde kein Handel zustande kommen übrigens ja, weil der Computer sagen würde, die Preise liegen hier zu weit auseinander*, es ist auch auf der einen Seite, auf der Kauf-Seite zu wenig los, die Aktie kann jetzt gar nicht verkauft werden, obwohl es vielleicht den Wunsch von einigen Kunden gibt." (Interview B, p.15, own emphasis)

A possible contrasting view is formulated by open outcry advocates who argue that the pit provided more and especially "deeper" liquidity, also for executing

larger orders or less traded products (Interview G, p.2 ff.; Zaloom, 2006, p.52). Furthermore, they argue that transparency was also better in the pit since peculiarities were identified in a stable and known social network where deviant and supposedly harmful behavior is located and sanctioned precisely (Zaloom, 2006, p.54). Due to their potent mutual knowledge of each other's behaviors, appearances and habits, pit-trades knew exactly how to read the body signs emitted by opponents (MacKenzie, 2013, p.9). Only one interview partner conforms to this position and asserts that it has been an advantage that pit traders knew who they were dealing with and could look into each others' eyes (Interview A, p.6). Yet, most of the evidence contradicts this and suggests that liquidity and transparency have increased massively due to electronic market making, the accompanying standardization and permanentness of processing. And again, it is the relentlessness of technology that eliminates any deviance and therefore produces this new kind of transparency:

> "And, it is about the transparency and the fairness. In the pit, I could not hear your price, I could ignore your price. *In the electronic world I cannot ignore your price. The price is there*. So, and the records are there that the price is there. So, we do not need to argue whether you yelled to me or not ,or I did not hear you or not. The fact is, it is out there, it is in technology, we can show it, we share it with the regulator." (Interview E, p.7; own emphasis)

Accordingly, informational asymmetries that have been characterizing non-automated markets are reduced due to this global immediacy of data. Before the information systems have been electrified and standardized, market participants had to rely on a few data and information providers which themselves were not organized globally and therefore had to deal with problems deriving from language differences between countries etc. As explained, this has changed and produced a new level of transparency that again enhances efficiency, not in terms of optimizing business operations, but in terms of market

efficiency[31] as a whole (Interview A, p.10 ff.; Interview B, p.11 ff; Interview D, p.3; Interview G, p.12). In terms of HFT, it is possible to state that their rapid taking advantage of price differences contributes to this transparency related efficiency. Due to their ability to exploit smallest price differences between markets they make these differences or anomalies obvious for the whole market what subsequently makes them obsolete (Interview A, p.9 ff; Interview D, p.11 ff.; Aldridge, 2010, p.3).

Additionally interesting and relevant is the fact that this transparency does not only foster liquidity in the immediate act of trading. It also enables post-analysis transparency since all the data are stored. It is possible to comprehend who has given what kind of orders at what time which, of course, has an influence on reconstructing responsibility in case of failures. Especially *Person C* emphasizes that granularity and quality of data has improved incredibly. Nowadays, it is feasible to comprehend positions that are hold for nano-seconds and to see what connection, gateway or line was used (Interview C, p.6, p.13 ff.; Interview D, p.8; Interview E, p. 5ff.). Again, the Flash Crash serves as good example for that point since the SEC and the CFTC were able to do an ex-post analysis of the events and publish the *Findings Regarding the Market Events of May 6, 2010* (SEC/CFTC, 2010).

These observations are interesting in terms of discussing whether algorithmic technologies function as intermediaries (transport) or mediators (translate) (see chapter 4.5.). According to the relentlessness and transparency one can probably conclude that algorithms are rather intermediaries than mediators since they are constantly maintained or updated and their performances are stored and can therefore be analyzed. If there are extreme situations, they are usually not cued by an algorithm but the result of algorithmic execution of failures (Interview

[31] The efficient market notion implies that (especially financial) markets incorporate all relevant information and that taking advantage of old information does not lead to making profits since all information are instantaneously utilized (Samuelson & Nordhaus, 2010, p.469 ff.). This idea is famously brought forward by Fama (1970, p.383 ff.) who states that a "market in which prices always 'fully reflect' available information is called 'efficient'. For more analysis of the role played by this notion see chapter 7.10..

D, p.22, p.24; Interview E, p.7 ff.; Interview G, p.8 ff.).[32] The availability of these data also facilitates comprehending for external parties like the *Bundesanstalt für Finanzdienstleistungsaufsicht,* which - at *Exchange B* for example - can constantly retrieve these market data (Interview B, p.20). It is the relentless adhering to build in steps that gives algorithms itself the shape of intermediaries. But, this does not mean that the whole process of algorithm design and application might not occur in the guise of an mediator. Therefore, it is necessary to de-black-box their creation (see section 7.8.).

Another very interesting change that is heavily related to the type of transparency expounded above is that power relations have shifted. When market access and information retrieval still was restricted to the actual place of the pit, a broker could take advantage of having this informational edge (MacKenzie, et al., 2012, p.5 ff.). *Person D* illustrates this:

> "Der Market Maker ist der, der auf dem Parkett steht und der Broker bin ich eben, der die Order annimmt, dem Kunden den Preis sagt. Und normalerweise ist es natürlich früher so gewesen, der Kunde hat gesagt: 'Kauf mal bestmöglich'. Dann hat der an der Börse gesagt: 'Ja, 50 Dollar', und das hast du zum Kunden gesagt: 'Ja, 55 Dollar', und die fünf waren dann eben für die Firma Kommission. Das funktionierte immer ganz gut, so lange das nicht so transparent ist. Mittlerweile sieht der Kunde natürlich auf seinem System, dass an der Börse natürlich kein Mensch für 55 was verkauft hat, sondern alle nur bei 50. Das heißt, als Broker leitest du eigentlich den Preis weiter und man bekommt eine Kommission." (Interview D, p.9)

This transparency related power shift towards the client is also represented by the already mentioned trading terminals that provide the client with the possibility to see all available algo-strategies of different brokers and the respective performances. There, clients have the power to choose without being dependent on the information forwarded by gatekeeping brokers. On the other side,

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[32] A nice example of how AT and HFT serve as intermediaries is provided by Eurex that are able to post-analyze HFT activities in extreme market situations and therefore have the ability to reconstruct which kind of trading contributed in which way. For explaining videos see http://www.eurexchange.com/exchange-en/technology/high-frequency_trading/

brokers have lost power and are now increasingly subject of the clients' control (Interview D, p.3 ff., p.9 ff., p.25 ff.).

7.6. Locality in AT and HFT

In a foregoing part it was pointed out that the pit as the local arena of trading has been displaced by technologies of AT and HFT that compress space and time so that actual bodily presence is not necessary anymore. Yet, this does not mean that locality itself has lost its relevance, but it significantly altered its shape. The financial industry produces highly mobile products and instruments, that are transmissible over the globe with the speed of light. Still, we can witness the existence of financial centers like New York, Chicago, London or Frankfurt that spatially agglomerate most relevant players of the financial industry. Sassen (2005, p.26 ff.) for example maintains that this is due to the fact that these centers provide important access to resources and social or cultural connectivity. Without having the intention to deny these thoughts, the present interview data and other literature suggest that there is another pivotal reason why locality and nearness play such a significant role, this reason is technology induced and especially important for HFT.

Despite the fact that traders do not need to be physically present any longer, their machines and servers do. Actually, this is a result of the delegations to technology. With modern information and communication technology, communicative acts of trading are nearly realized at the speed of light which means that exploiting speed advantages simultaneously means exploiting spatial advantages. Although AT and HFT folds space in the way explained above (allowing instantaneous market participation without actual co-presence), there remains a spatial residual that cannot be compressed because the speed of light marks the absolute limit of transaction speed. Thus, if High Frequency Traders aim at profiting from time and therefore information advantages, they need to find another way. If they cannot trade faster, they need to trade nearer. Thus, in that peculiar context, when the folding of time is reaching its climax, the "Time [sic]

shrinks, but space doesn't." (MacKenzie et al., 2012, p.12) It is exactly because analyses, matches and trades are already processes at the speed of light that being nearer becomes important again. Thomas Friedman's *The World is Flat (2006)* postulated that the world is flat since economy can move almost without constraints due to modern communication technologies. Yet, concerning financial markets in the guise of HFT, the world is not flat, but "spiky".[33] In HFT, competitive advantages can be gained from reducing spatial distances. If an order is sent to a trading venue's matching machine and back at the speed of light, it is the only logical consequence to settle the traders' servers containing the algorithms near the trading platform to reduce spatial distance. The closer you are to the exchanges, the faster you can receive price information because every 100 km of transportation in a glass-fibre cable adds one millisecond (Interview A, p.13; Interview B, p.8; Interview C, p.9; Interview E, p.4 ff.; Interview G, p.9 ff.; MacKenzie et al., 2012, p.12). This, for instance, is important for the derivatives industry that serves as a good example. Imagine someone trading DAX and Euro STOXX futures at the Eurex exchange. The underlying baskets are heavily correlated, thus, if one increases, the other one probably follows. So, if there is a huge trade in one of them, the market knows that the other one is relatively cheap. And for taking advantage of this information, you need to be the fastest and respectively the closest (Interview C, p.8; Interview G, p.10).

The solution for this is the already mentioned and briefly expounded idea of co-location. It simply means that market participants can locate their servers in the same building where the exchange keeps its matching engines, or at least in direct proximity (Interview C, p.8; Interview E, p.3 ff.; Interview F, p.2 ff., p.9 ff.). This is the main motivation for banks, funds and HFT representers to make use of co-location services as *Person F* explains:

> "You know, for example, a 20 km network line introduces around about 500 milliseconds of delay, called latency, network latency, and that is a round trip delay,

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[33] The term "spiky" is borrowed from Richard Florida who heavily criticizes Friedman's argumentation in his article *The World is Spiky (2005)* which mainly states that the category of place does play a crucial role for economic success, especially in terms competitiveness and innovation.

> so that is a quarter second there and a quarter second back. So, by moving the servers closer together, and turning 20 km networks into 20 m or 50 m cross-connects you are essentially removing the network latency and therefore allow trade to speed up." (Interview F, p.9)

One of the first venues, where this idea of co-location has been exercised, was the already mentioned trading venue called *Island*. They were one of the pioneers who informally allowed automated traders to place their servers in the same buildings as *Island's* own servers (MacKenzie & Pardo-Guerra, 2013, p.20 ff.) In the U.S. this has become an important revenue stream since trading venues gain profits by selling these spaces (MacKenzie & Pardo-Guerra, 2013, p.13). In Germany for example, trading venues do not consider this business model as an important revenue generator, they leave these solutions to infrastructure providers like *Equinix* or *interxion* that earn their money by renting out server cabinets in co-locations at important stock exchanges (Interview C, p.9). Another example illustrating that locality is treated as a serious advantage in the speed race is that new cable lines are constructed between Chicago and New York that build the ends of the so called "spinal cord", the most crucial connection between the derivatives market (Chicago) and share trading (New York). In 2010, the fastest one-way connection was around eight milliseconds. A High Frequency Trader called Daniel Spivey triggered an investment project aiming at the installation of new fibre-optic links as the existing ones followed old railway traces and did subsequently not follow the direct route. The result is a new cable connection that saves 1.3 milliseconds. The project costs around $300 million (MacKenzie et al., 2012, p.15). These huge efforts show that even though it is only about a few milliseconds, time and therefore distance matters. HFT heavily relies on exploiting these effects. For mere algorithmic brokers this is not so important as *Person D* explains. At *Bank D* every order goes to London and runs through its "Algo-Engine" which means that even if you are in Switzerland and trading the Swiss Stock Exchange, the order crosses half the continent two times. Although, technology allows this to be done in milliseconds, it obviously is not the nearest and therefore fastest solution (Interview D, p.14).

A side effect of the heavy proliferation of automated trading and co-location is that important trading engines and the clients' servers have moved out of the prestigious cities and districts like Manhattan, Chicago or London. Because these co-location spaces need expensive room and space, they have been re-located, out of the centers to cheaper places. The major trading engines of the U.S. are located in New Jersey, *NYSE* engines are in Mahwah, *NASDAQ* in Carteret and the *CME's* engines are now situated in Aurora, Illinois. Moreover, financial industry is also confronted with enormous energy consumption. In New Jersey for example, the financial industry is already the branch absorbing the most energy for running their data centers (MacKenzie et al., 2012, p.13).

A very interesting and astonishing effect of co-location and the speeding up of trades to the speed of light is that "It [sic] moves the latency bottle neck into other things such as the matching engine latency, the speed of which your matching engine can match trades, it moves it to the algorithms." (Interview F, p.9) But according to *Person F,* the algorithms are already working incredibly fast and are able to analyze market data and operate pre-trade risk calculations in a few hundred nanoseconds. Thus, the next logical idea to be even faster - although it is not executed yet and might never be - is placing the participants' algorithms next to or even on the actual physical processor which runs the matching engine (Interview F, p.15). That would represent the ultimate end of nearness. Of course, it is a vague idea but it depicts that every time-bit seems to be a decisive element.

7.7. Power and Fairness in AT and HFT

In a previous section, power has already been touched in terms of power alterations that derive from increasing transparency and mainly concern relations between clients and brokers. Another crucial understanding of power concerns the issue of being powerful enough to succeed in a certain market. Who is more powerful in the calculative agency of AT and HFT? Subsequently, this also evokes fairness issues since asymmetrical power distributions might counteract

the idea of having equal opportunities. It has been stated that being powerful in calculative agencies is a result of the ability to create manifold, extensive and complex patterns of calculation (see p.30). This holds for AT and HFT, too. The comprehensive delegations of analyzing and executing trades of complex financial products requires investments in technology and differently trained personnel. Since speed and respectively locality is so important for AT and especially for HFT, having faster and better technology for analyzing and execution provides you with a competitive advantage (Interview F, p.10 ff.; Interview G, p.1 ff.; MacKenzie, 2012, p.18). *Person G* emphasizes that those "with the deepest pockets all have a competitive advantage in the long term " since they can afford the necessary investments in being the fastest in the market which is the crucial condition for succeeding in HFT (Interview G, p.13). So, those who are not the closest lose their competitive edge (Interview G, p.10; MacKenzie et al., 2012, p.15). MacKenzie emphasizes that the speed dependence that results of the technological and material development affects the idea of fairness:

> "That Einstein's theory of relativity might be relevant to the regulation of financial markets would have seemed bizarre in 1999 [...]. In 2012, it is no longer bizarre. The material foundations of liquid markets have shifted, and the consequences are only beginning to unfold." (MacKenzie, 2012, p.22)

Obviously, this also affects the capacity of being innovative in AT and HFT since successful trading depends on innovating the technological means enabling it. Competition manifests in the ability to create the best technological tools which is a resource consuming task (Beunza & Stark, 2004, p.372; Lenglet, 2011, p.48). While *Person G* is critical about this evolution, others simply state that this is the competition of the business. It is up to everyone to decide whether to pursue the efforts necessary to invest in cutting-edge technology or not, depending on your business model. High Frequency Traders who provide lots of liquidity depend on technology to be persistently present in the markets while brokers who only do a few trades a day do not (Interview C, p.14; Interview E., p.3 ff.; MacKenzie, 2012, p.18 ff.). Another aspect of this calculative power is that bigger institutions with more money can afford more accesses to varying

exchanges and trading venues which of course contributes to the potential variety of its calculations: "Und wir haben jetzt irgendwie 158 Börsen angebunden, während ein anderer Broker vielleicht nur drei hat. Also, da gibt es erst mal ein Produktproblem, dass man sagt, man kann nicht so viel anbieten." (Interview D, p.25) As a consequence, *Person D* concludes that smaller brokers attract smaller customers who still forward their order via phone or other inferior ways. This de-folds time again for the broker who then has to deal with disadvantages. So, a lack of technology on the customer's side - emerging due to the broker's lack of accesses - disadvantages the broker (Interview D, p.25).

And this discussion about the fairness of a market, where success heavily depends on the investment capacities for technologies, leads to the question how this kind of power was shaped in the calculative agency of traditional pit-trading. There, too, was a factor that evidently affected the distribution of power and therefore market success, namely corporeality. When markets are realized via human interaction in loud crowds, traders who were physically strong, had a loud voice and bodily presence possessed a competitive edge. In Chicago for example, it was actually common to employ football or basketball players due to their physical appearance (Interview A, p.15 ff.; Interview D, p.15 ff.; Interview E, p.6; MacKenzie, 2013, p.13). A circumstance that has changed in the calculative agency of AT and HFT as *Person E* aptly grasps (Interview E, p.6): "But they need to be able to be skilled programmers these days rather than the physical, big, tall, loud guy." The work in front of trading screens is also bodily but it requires different factors of involvement. Preda (2009, p.684 ff.) and Zaloom (2006, p.10 ff.) show that actual physical engagement is an essential part of trading, also in situations were sole traders are only confronted with their computers and screens. The identification of relevant spots on the trading screen and the corresponding evaluation is a bodily process since it requires eye-hand coordination, leaning towards the screen, pointing at relevant appearances etc. (Interview G, p.3). This demonstrates nicely that bodily engagement in the calculative agency has changed and so did the distribution of power.

An idea of circumventing these asymmetrical power relations is also enabled by the actor-networks of AT and HFT. Due to the delegations it is possible to create so called "level playing fields", fair arenas of competition in which every participants has similar conditions of access. This idea is realized by Exchanges like the *Deutsche Börse* or the *Swiss Stock Exchange* by organizing that cable-lengths and cross-connects in the co-location data centers are unified (Interview C, p.2 ff.; Interview E., p.4; Interview F, 9 ff.; MacKenzie et al., 2012, p.17 ff.). Thus, at least in the areas of the calculative agency that belong to the realm of the exchanges they can provide fair conditions in terms of distance. But still, participants at least need to fulfill the technological prerequisites to participate in co-location to benefit from these "level playing fields".

7.8. Inscription and Description in AT and HFT

This part presents an important aspect of the present work since it is concerned with the in- and descriptions (see chapter 4.4) of the respective technologies involved in AT and HFT. It is has already been pointed out that the interviewees do not see infrastructure providers as having influence on AT and HFT. Despite of that, it has been shown that these providers take a pivotal place in its calculative agency (See p.). The fact that infrastructure providers play an influential part can also be witnessed when taking a look in how they contribute to inscription processes with regards to AT and HFT. They do not realize their inscription by actually affecting the utilized algorithms or trading decisions. They inscribe their notions via the consulting and maintaing processes that forego and accompany the application of co-location services. Referring to Kubrick's *2001* again, they hand the stick to the ape who then discovers the resulting opportunities (Interview F, p.4 ff.):

> "We help them realize that there is an opportunity to come to Infrastructure Provider F. [...] *We come up with ideas of how customers could use that services, or sell their services, or provide their services, or access services that they need that are available in our data center.* So, what we do is, we spent a lot of time

> with customers understanding what it is they are actually selling as a service and then we can go and talk to the rest of the community and we can essentially be very much like a concierge service. (Interview F, p.6; own emphasis)"

The already mentioned case in which *Infrastructure Provider F* helped its customers in the MF Global issue (see p.41) provides another good example of how they can inscribe their ideas. And currently, *Infrastructure Provider F* aspires to inscribe additional ideas to the calculative agency of AT and HFT. They are working on involving additional players that take care of clearing and settlement into their "ecosystems" as well (Interview F, p. 16 ff.) which would subsequently alter calculative agency again.

Most of the other players involved inscribe their notions by directly affecting the algorithmic shape of trading. Thus, a crucial step to dig deeper into the analysis of AT is to inquire into algorithms. What is it that makes algorithms so interesting and significant in comparison to all the other devices utilized in trading? It has been pointed out so far that there are a lot of technical devices involved in realizing trading, even in trading environments that are not fully automated. There are computer screens, keyboards, telephones, all objects that contribute to building up calculative agency. Algorithms are peculiar since they are not a mere tool that is utilized. They take over parts of the actual decision process:

> "Algorithms are entities in their own rights, places where extensive financial practices are encapsulated: as codings, they amount to a specific kind of text describing the market's materiality. As a text, the algorithm is a definitional device that makes the financial world different each time it 'decides' to fire an order into the market." (Lenglet, 2011, p.47)

The crucial question at this point is how these algorithms come into being. As a technology they, too, are the result of contemplations, wishes and necessities and they are "Built [sic] as a result of conversations defining needs between users (clients and traders) and designers (engineers and regulators [...])." (Lenglet, 2011, p.47). According to this, the notions of in- and description seem to fit well. The process of shaping and designing in which different actors try to

inscribe their visions is pivotal for understanding AT. Moreover, how are these inscriptions described and how does this feed back on the inscriptions? Justifiably, Lenglet (2011, p.51) emphasizes the involvement of manifold actors in creating an algorithm and therefore wonders about the politics begetting it. Coders, exchanges, sales persons, brokers, clients, traders, technicians etc., all contribute to the algorithm's existence and shape, a fitting show case for the idea of distributed agency. The eventual code portrays their common interest (Interview A, p.8; Interview C, p. 2ff.). This again fits to the understanding of technology as a script, because "Ein [sic] Algorithmus programmiert sich ja nicht selbst, sondern ein Mensch hat Berechnugnsvorschriften diesem Computer gegeben [...]." (Interview B, p.2) But, it is not individual agency shaping the algorithm, the question is how actors inscribe their notions via the programmer who is associated with them in the actor-network. Accordingly, algorithms generate a dimension of conflicting views, not only between those designing them and those using them, but also between those advocating for their dissemination (IT developers, banks, traders, sales etc.) and those being responsible for their regulation. Those creating the algorithms inscribe a vision that does not only contain the aim of making profits, but also comprise an idea of the world in which such tools are generally estimated as being useful. The description in this case is done by the regulators whose vision conflicts with those inscribed since they are uncomfortable with those intangible codes which are difficult to grasp and float around on machines, cables and servers (Lenglet, 2011, p.51). In their description they estimate the prescriptive power of algorithms as potentially difficult and advocate for re-inscriptions, which then leads to an ongoing process of contemplation. Lenglet (2011, p.55 ff.) assumes that those who are in charge of controlling and regulating market actions (e.g. stock exchanges, compliance officers) have difficulties in assessing algorithms and would prefer interactions with humans as they are easily locatable and addressable. The results presented so far contradict this position for one reason: the algorithms might be shadowy in their accessibility but they do create transparency. But, the peculiar attribute of an algorithm to be almost intangible on first sight additionally vindicates to examine and de-black-box the hybrid networks realizing them: "By reflecting on

the algorithm's existence, I understand it is subject to the developing views expressed by those who are in close association with it [...]." (Lenglet, 2011, p.52)

A first possible tackling point for algorithms is to analyze them with regards to the developers' and IT-experts' perspective (Lenglet, 2011, p.53). This perspective literally fits to the inscription/description concept. Developers code (inscribe) and try to make sense of their world according to their language while users (e.g. traders, clients) apply (describe) those algorithms. An interesting process that foregoes this, concerns the question of who inscribes the economic ideas into the coders of the algorithms? There are programmers and IT experts who manage the technological implementation but who are guided by economic needs. The desired economic requirements are actually inscribed into them since they are the specialists as *Person D* points out (Interview D, p.6):

> "Genau, also sie sind wirklich nur ausführend. Also, es gibt… Sie führen unsere Wünsche aus, weil wir als Sales-Leute natürlich mit dem Kunden, oder Sales und auch die Trader, wir haben eigentlich mit dem Kunden täglich wenn nicht wöchentlich zu tun… Und, die Kunden geben uns die Wünsche weiter oder wir sehen am Trade, der ist nicht so optimal gelaufen, da müssen wir irgendwas machen. Wir würden dann den Kunden anrufen und sagen: 'Also, würde dich das stören, wenn wir die Volumenkurve ein bisschen machen?' Wir entscheiden eigentlich was der Algo machen soll und die setzen das um."

This fits to the idea that algorithms are the product of constant negotiations when in- and description are not congruent. Lenglet (2011, p.54) also shows this expressively by documenting a trader's complaint put forward to the IT department developing the utilized algorithm:

> "When client puts an end-time including the fixing (say, 5:35:00), it's obvious he wants to take part to the fixing. Today, POV [the '% of Volume' algorithm]" till 5:35:00, auction @ 5:35:16, the algo was cancelled ... we are long 3.5 million. I remember asking the algo being kept alive till the real fixing time."

This shows that the inscribed notion of the algorithm generated the assumption that it is correct to stick to the parameters set by the user while the description shows that it is not suitable to trading reality. As a consequence the describers urge re-inscriptions. So feedback from describers to inscribers is a crucial feature of AT (Interview C, p.2 ff.). To avoid these tensions beforehand, *Person G* emphasizes that her proprietary trading organization mostly employs traders who are also able to code since this circumvents negotiation processes between economic ideas and programming practices. Therefore, coders attend workshops about economic and financial markets which are provided by the exchanges which again aptly illustrates that calculative agency of AT and HFT is also distributed between different organizations. *Fitting to the terms used in this paper, Trader G points out that it is the goal to translate economic ideas of how to exploit a market into algorithms* (Interview G, p.5 ff.).

That algorithm design is a constant process of inscribing and describing, can also be confirmed due to the fact that they are subject to constant tests, maintenance and refinement, trying to solve the tensions emerging between inscribers and describers. They are not set in stone but constantly observed and valuated (Interview B, p.2 ff.; Interview C, p.2 ff.; Interview D, p.4 ff.; Interview E, p.7; Interview G, p.5 ff.). Moreover, exchanges for example are in close contact with the IT departments of their participants before they release a new version of their electronic trading system (Interview B, p.10 ff.; Interview C, p.2;) which has the purpose of circumventing severe deviances between their inscribed notions and the actual descriptions of those. So, applying algorithmic systems is a constant stream of negotiations that derive from ongoing in- and descriptions (Interview C, p.3): "If client A comes up with an interesting idea, then we of course analyze it and if we find that it makes sense to discuss it a little bit further, we involve other clients to get their feedback on that as well. So, it is a mixture of own ideas and ideas of clients." Thus, innovations in AT and HFT or innovations as AT and HFT themselves are product of collaborative endeavors that are pursued in constant feedback loops that create innovation as "bricolage" (MacKenzie & Pardo-Guerra, 2013, p.6 ff.; Interview E, p.10). Again, this can be witnessed in the case of the progressive trading venue *Island*: "Every-

thing we did was a collaborative effort between us and our users." (Levine, Island's chief developer, in MacKenzie & Pardo-Guerra, 2013, p.32)

Another way of describing algorithms is shown by the trader's perspective. Usually, traders can choose among different algorithms that are presented to them like a toolbox when they start their workstation. They choose the algorithm that exerts the desired strategy. First, this requires a process of description since the trader mentally needs to reconstruct what the algorithm is doing. Second, the traders describe the algorithm by finetuning it according to their actual needs. This whole process interestingly displays the *prescriptive* power of algorithmic technology because traders are forced to decide carefully what kind of algorithm they apply in what manner. When algorithms are set up for actual usage, traders need to define parameters that in some cases cannot be remodified, e.g. the number and size of a trade's slices (Lenglet, 2011, p.54 ff.). Like the prescriptive power of a fast closing door that is forcing its passerby to transit rapidly, the algorithm imposes careful thought processes on the trader since it inherits a certain path dependency that cannot be altered in case of reconsiderations in the future. Thus, AT is prescriptive because it relentlessly adheres to rules and imposes this on the user. It limits the scope of possible trading strategies "since any algorithmic strategy must be completely rule-based and pre-programmed." (Chaboud et al., 2011, p.24) Another facet of this prescription is that traders need to adhere to certain ways of entering orders, quantities, prices and exchanges into their computer interfaces since there are certain necessities that need to be abided by, so that frictional losses between different computer systems can be avoided (Interview D, p.24).

Another tackling point for narrowing down an algorithm's existence is the sales and marketers' perspective, those that are selling algorithms to clients. *Person D* does exactly this and is responsible for marketing algo-strategies to clients. This can already be described as a way of inscription since she also hands the stick to the ape and thereby shows what is possible by introducing the products and consulting the client with regards to which strategy to choose (Interview D, p.1). Besides, an important aspect which is relevant for the creation of algo-

rithms is that they need to be economically sound. Not everything that is possible is also preferable. So comparing costs and benefits is also an essential part that has inscriptive influence on algorithmic means (Interview A, p.8; Interview C, p.2)

A special form of inscription concerns the including of notions that derive from economics as a scientific discipline. Obviously, that represents the idea of performativity (see chapter 5.3.). The first interesting penetration by economic thought is the idea of the "level playing field", that, according to the interviews, turned out to be a guiding principle for the design of electronic markets (Interview, E, p.5; Interview F, p.9 ff.). Accordingly, *Person C* states that giving all participants equal chances builds the backbone for designing the trading system at *Exchange C* (Interview C, p.2 ff.). And that is obviously connected to the economic idea that interfering in markets distorts finding equilibria and therefore diminishes market efficiency: "So that is basically the idea behind the fairness principle; creating a benefit for one group of participants will disadvantage other participants, distorting equilibrium." (Interview C, p.4) Thus, *Person E* emphasizes that electrified markets adhere to this crucial idea that results in "a way way better, a much better level playing field than we have seen ever before." (Interview E, p.5)

Furthermore, the actual creating of algorithms as illuminated before can also be understood as a vehicle of transferring economic thought into electronic markets since economic ideas that follow the notions provided of certain models and conceptionalization initiate the process. Again, this is nicely illustrated by *Trader G* who provides its coders with workshops, so that they learn the economic ideas that stand behind the financial industry (Interview G, p.5 ff.). Furthermore, there is the idea that liquidity is generally a good feature of markets (Interview A, p.3 ff.; Interview D, p.22). Exchanges therefore have an interest in creating highly liquid markets because liquidity is an important feature for trading venues since it helps to attract participants. Therefore, trading platforms inscribe this vision of liquidity by adapting to the infrastructural needs of High Frequency Traders and by providing them with "rebates", little monetary incentives

(e.g. 0.1 cents per share) for those giving liquidity and little monetary fees (e.g. 0.25 cents per share) for those taking liquidity (MacKenzie et al., 2012, p.11). In general, there is the idea that liquid and therefore efficient markets are desirable as *Person C* fittingly illustrates with regards to the vanishing pit-trading: "However, should you impede the industrialization, should you reduce the efficiency gains? I do not think so, that would be against any economics 101 course." (Interview C, p.5)

The notion of desiring the emergence of efficient markets is actually a good example for the performativity of economics. First of all, it is one of the most influential economic thoughts that has already had tremendous influence on actual economic practices (MacKenzie et al., 2007, p.4 ff.; MacKenzie, 2006, p.104 ff.). The interesting point with regards to performing the idea of market efficiency is that although they might be signs suggesting that there are possible strategies to exploit informational edges - which according to the efficient market hypothesis should not be possible - and make profits. Usually, when such incidents occur, economics and related fields tend to speak of "anomalies". The really interesting result of identifying those anomalies is that economic researchers and related agents (e.g. market participants who are close to academia) then try to take advantage of exactly these anomalies. Thereby, they simultaneously re-instate the hypothesis of an efficient market that has been doubted before since exploiting these anomalies makes them obsolete (MacKenzie et al., 2007, p.5; MacKenzie, 2006, p.98 ff.). This pattern can especially be found with regards to HFT. As presented above, HFT is seen as reducing informational inefficiencies by taking advantage of them. Simultaneously it is taking advantage of an informational edge that should not exist. Therefore, the efficient market hypothesis is kept vivid by contradicting it to sustain it. In the Interview with *Person B* she pointed out that markets have become efficient since price differences between markets are almost annihilated due to the ever increasing availability and usability of immediate information. She states that during the 80s it was common that DAX-shares were priced differently. It happened that *Siemens* shares for example were cheaper in New York than in Frankfurt although *Siemens* only exists as one single entity. Thus, there was no rational

explanation for that, except markets inefficiently dealing with information (Interview B, p.11 ff.). The following quotation shows that HFT related acceleration is simultaneously supposed to make markets more efficient while exploiting its informational asymmetries:

> Person B: "Das hing einfach mit Informationsasymmetrien zusammen, die nicht so schnell ausgeglichen werden konnten. Dafür sorgen aber heutzutage schnelle Börsencomputer und die Spezies der Hochfrequenzhändler."
>
> Interviewer: "Aber, ist es nicht so, dass auch Hochfrequenzhändler teilweise immer noch genau versuchen so Arbitragegeschäfte zu machen?"
>
> Respondent: "Genau das machen sie, richtig. Genau das machen sie."

7.9. Accountability and Responsibility in AT and HFT

After these insights in how calculative agency is distributed in AT and HFT, it makes sense to analyze accountability and responsibility. The foregoing parts have shown that AT and HFT as a whole are product of a complex actor-network. Moreover, the previous part displays that special elements, like the crucial algorithms, are configured through a distributed process and "if trading algorithms add a strong mediation between traders and markets, they also express *a mix of different views that further impedes the attribution of accountability*." (Lenglet, 2011, p.62) Accordingly, attributing responsibility is difficult, since identifying singular sources of agency is impossible or at least - as the present work illustrates by attempting to partially illuminate the ramifications - incredibly effortful. An impressive example of these blurrings is given by *Person G* who explains that in her industry they also deal with the issue of not knowing how to distribute bonuses (see also Interview C, p.7). Comparing it to the cockpit (see p.19), they exactly have to deal with the problem of having a whole cockpit realizing their business rather than one pilot steering the direction. Who gets the reward if trades are performing well, the trader executing them or the developers who have crafted the algorithms allowing for success?

> "I discussed that with a developer, in other companies there are certain people having the ideas, they are having those ideas being implemented into strategies and again different persons doom the execution or as we call them, pilots, setting the parameters and just monitoring the system to make sure it is not doing something stupid. [...] And it is difficult to find a good way of how to allocate the bonus so to say between the different parties involved." (Interview G, p.7 ff.)

Especially representers of exchanges do not follow this argumentation that elaborates on the difficulties emerging due to the distributive shape of AT and HFT. Representers of exchanges only need to know which organization or which (juristic) person initiated the trade because that is the address to contact in case of deviances and this is the entity that programmed the algorithm (Interview A, p.10 ff.; Interview B, p.2;). Or, as *Person C* bluntly puts it: "The trader is responsible!" (Interview C, p.6) And due to the sophisticated transparency they can usually comprehend who did what. They do not have to consider the filigree and complex networks that produce the algorithms and realize the trading etc. (Interview C, p.6 ff.). Thus, they address those human beings that stand behind the trade: "Ja gut, aus der Sicht der Börse [...] würde ich halt immer sagen, uns, wir sehen ja nur den Handelsteilnehmer, der die Order verschickt. *Wir wissen ja nicht, was dahinter steckt*. [...] prinzipiell ist der Handelsteilnehmer für seine Aktion verantwortlich." (Interview A, p.10 ff., own emphasis) That is a nice example of punctualization (see chapter 4.6.) because traders and algorithms are taken as black-boxed calculative resources, reducing complexity since it would be immensely effortful to trace all the ramifications that realize them.

Of course, another important way of talking about responsibility concerns attributing it in cases of failure like the Flash Crash. Similar to MacKenzie (2013, p.40 ff.), *Person E* emphasizes that this crash was not the result of technological defects but product of human failure because a broker tried to execute a large order with an outdated and simple algorithm "my son would not even use" (Interview E, p.9). What this Flash Crash and its consequences most impressively illustrate is the concept of punctualization (see chapter 4.6.). As long as AT and HFT work according to the expected and usual patterns, the heterogenous network realizing it is not of interest. But in the moment of failure, people suddenly

start wondering who or what is actually associated in the task of contemporary trading. That is also the moment when AT suddenly loses its role as an intermediary and switches to being a mediator that is difficult to understand and which requires effortful tracings of associations to be understood. The interview partners confirm this by acknowledging that attention by externals has been increasing heavily after May 6, 2010, mostly in form of attacking the AT and HFT industry for being responsible or in form of clients' concerns (Interview A, p.16; Interview C, p.16; Interview E, p.9; Interview F, p.8; Interview G, p.9). These de-black-boxings that follow such incidents serve as the basis for alterations of the calculative agency, so that the disturbing event becomes more unlikely to happen again. The SEC/CFTC report on May 6 documents this aptly. As a result of the examination of the Flash Crash, it suggests to install a mechanism that allows for pausing the trade of singular securities for five minutes (SEC/CFTC, 2010, p.6 ff.). And, as it has been pointed out in the section about transparency, resolving these punctualizations is possible due to the storing of data which makes post-hoc comprehension feasible (Interview E, p.8). *Person E* gives this fact an interesting spin concerning the occurrence and perception of crises with regards to modern trading (Interview E, p.8): "We had flash crashes, I have been through 100 plus flash crashes in my life. The May 6 flash crash is probably on number one if you like. *But, we are only able to see it because we stored the data*. Before, no one stored the data and we were unable to see it." (own emphasis)

7.10. Framing in AT and HFT

Framing has been conceptionalized as the ability to identify tradeable entities that need to be singularized and objectified to allow for disentanglement and therefore market circulation (see chapter 5.2.). Evidently, the proliferation of AT and HFT has changed the way this is done for financial markets. A first obvious feature of AT and HFT is that framing processes are automated and accelerated through the compression of time. Just think of days when trades only have been realized in one auction a day, and now there is constant emitting of prices which

also requires constant abilities to frame. In AT and HFT, framing is processed in milliseconds, products are objectified and singularized in a time window that is so small that it could not be done by a human being (Interview F, p.15). The moment you deal with less liquid markets, where interference of human market makers is necessary to provide liquidity, time and space are de-folded again and framing necessities change (Interview A, p.3; Interview B, p.4 ff., p.14 ff.). In terms of AT and HFT, framing could be grasped by the following steps that are realized in milliseconds and below: "[...] trading is a life cycle. It is a life cycle of pre-trade which is about getting market data and getting all the pre-trade risks done. And then there is the execution, the order-placing and execution." (Interview F, p.17) In the pit, these steps have been realized by humans; observing the market, evaluating opportunities, identifying counterparties, prices and quantities (Interview E, p.2).

Again, the relentlessness is a factor that also counts for framing since it is another attempt of achieving the strict disentanglements that shall avoid overflowing, so to speak, a way of unbounding rationality again (Mirowski, 2002, p.456 ff.; Zaloom, 2006, p.54) The mechanical patterns that have been expounded above do not allow for overflowings to occur. In HFT, traded instruments are singularized and objectified in split-seconds by algorithms and machines. The temporal compression of these processes does not leave time for overflowing since overflowing is the result of human mind that is not able to disentangle entities completely. But, human perception and cognition cannot follow those accelerated processes of framing. One could state that the actual act of framing is sourced out to machines that relentlessly follow the ideas and rules of framing which have been inscribed to them. So, humans still know and control what to frame but they cannot frame by themselves (Interview E, p.2). Machines make use of cohorts of numbers, operating in binary code, inaccessible for human minds. But in the end, results and performances need to be visualized in graphics, charts, curves and so on because humans need to evaluate what has been

framed and subsequently realized: "At the end of the day an eye has to capture the data!" (DKF 2013)[34]

An outcome of these conditions of framing can also be witnessed in new products. More calculative power and speed could enable other ways of objectifying and singularizing products for trade (Interview B, p.5 ff.; Interview D, p.7; Interview E, p.10). Yet, *Person G* and *Person C* contradict this view and maintain that tradeable products have not really changed (Interview C, p.12; Interview G, p.11). But *Person G* asserts that volumes of trades did increase significantly because capacity to deal with multiplying amounts is easily achievable. Furthermore, she acknowledges that the variety of complex products like derivatives, futures or warrants has inclined with respect to technological possibilities because these instruments deal with complex framing processes that require more calculative power (Interview G, p.11). This ever increasing variety also manifests in the compression of space in terms of co-location data centers. There, it is possible to easily engage with more counterparties on different trading venues, trying to deal with different asset-classes (Interview F, p.4 ff.). The access to "ecosystems" via co-location centers punctualizes all relations to other agents that otherwise needed to be framed individually. Thus, co-location can be deployed as black-boxed resources of calculation. They are like a warehouse where the already framed entities of trade are stored and useable for algorithms. The moment you can place your machines in these centers, you have access to already framed buyers and sellers, compatible with your algorithms that further frame tradeable products on that basis according to the rules inscribed to them (Interview B, p.10).

[34] This statement has been made at the panel discussion about "Big Data: Herausforderungen und Chancen" (at the *D-A-C-H Kongress für Finanzinformation* on April 30, 2013, in Munich).

8. Concluding Remarks

According to the outline of this work, the author analyzed the actor-network that generates the agency of AT and HFT in an exploratory approach. With reference to the social theoretical paradigms of ANT and SSF, the associations of relevant players and technologies have been traced, so that this work could at least contribute to opening up the black-box of modern finance.[35] Recapturing all results and theoretical reflections of the analysis at this point would not be appropriate as they are manifold and concretely presented in the preceding parts. Hence, the following remarks initially regive some general findings before reflecting on the research process and its limitations.

A crucial result is that technology does play an essential role in realizing AT and HFT which supports the broad underlying thesis that material entities do contribute to the emergence and shape of social order as it is postulated by ANT, and therefore also to the shape of markets as it is particularly postulated by SSF proponents. Thus, the accompanying idea of blurring the distinction of "the social" and "the technical" also finds support in the present work (in terms of HFT also acknowledged by MacKenzie et al., 2012, p.22). Material devices do occupy a significant place in the agencements of AT and HFT and correspondingly influence their calculative agency. Algorithms, server parks, fibre-optic cables, trading screens etc. are not mere means to an end, they are embedded in a constant web of utilization and feedback. Buy-sides, sell-sides, exchanges and infrastructure providers mutually construct AT and HFT in heterogenous networks. One example is the importance of infrastructure providers that supply traders with co-location solutions and servers. Without really interfering in financial decision making of market participants, their technological infrastructure fundamentally shapes what is possible (e.g. in terms of framing), and in consequence, what is calculable. Another example documenting the essential role of materiality is the importance of speed and nearness for HFT. To be successful you need prime technology and physical nearness of your machines. This has

[35] According to Preda (2012, p.34 ff), it is doubtful that the bottom of the box will eventually reveal a satisfying answer to the question of what finance really is and how it should be treated.

implications for calculative power as being competitive consequentially means being able to afford high-end technology. Generally, through the delegation of tasks to nonhuman devices, time and space of trading are compressed - to a certain extent as the part about the still important locality demonstrates - which produces an extreme immediacy that enhances efficiency, transparency and reconfigures the distribution of power between brokers and clients. The technologies - especially the algorithms - are developed in processes of inscription and description, but once they are in place, they follow their rules and do not allow for any deviance and subsequently reduce contingencies. The found distribution of calculative agency softens the concept of accountability and hampers the attribution of responsibility but simultaneously increases possibilities of post-hoc comprehension of market crises. Besides depicting AT's and HFT's actor-networks, this thesis also developed a comprehensive theoretical framework - one of its main purposes - that enables the researcher to analyze and classify the particular elements and relations of investigated actor-networks. Conceptions like agencements and calculative agency compress a lot of underlying ideas. Fitting to this paper, these terms are punctualized concepts that serve as resources for analysis. Therefore, it makes sense to establish them for examining phenomena like AT and HFT - also for further research. Besides, more concrete ideas like delegation, the resulting relentlessness, inscription or description serve as valuable exploratory frames because they do not only help to discover elements and their relations, they help to explain their consequences with regards to social order. These understandings assist in evaluating AT and HFT with regards to political and social implications. Similar to Lenglet's account (2011, p.63), the present work has shown that the question is not wether algorithms themselves are dangerous, but their manifold linkages and possibilities of inscription/description can be. If we want to assess the new guise of financial markets, we need to understand these interrelations (besides a purely economical understanding), so that they can be incorporated in ideas of regulation and policies. Comprehending AT and HFT as socio-technical agencements fits to what Callon calls habilitation policy that aims at arranging the agencements according to the desired state rather than trying to treat singular elements as simple prostheses of individuals (Callon, 2008, p.42 ff.).

A potential challenge that results from the present work is captured best by referring to Tarde's idea that the whole is always small than its parts (see p.16). By attempting to analyze AT and HFT as whole entities, more and more facets and aspects of different elements of the actor-network have become visible. The actual interplay of humans and nonhumans, which brings forth calculative agency, depends on varying factors for different elements. For a proprietary trader it makes a difference if he can achieve maximum transaction speed while this is not so relevant for usual brokerage. For an exchange, the fraying out of responsibility is not of concern while it is for a trading firm that tries to allocate its bonuses. Thus, future SSF research should try to narrow down the perspective to certain players (monads). For example, it could focus on analyzing the materiality and technology of a proprietary trader or a broker or an infrastructure provider and so on (see e.g. Hardie & MacKenzie (2007), who are doing this in terms of a hedge fund). Another limitation of this work is that its empirical evidence is mainly build on expert interviews. Despite the fact that they served as good sources for this explorative approach, they also bring along difficulties. First of all, most interviewees somehow tried to vindicate the existence of AT and HFT since they were aware of the public criticism and felt the need to justify themselves. Second, an interview situation already provides a reflective frame in which participants try to give their assertions a certain drive. For that reason, it would make sense to add ethnographic field work and participant observation as this would really give the researcher the opportunity to discover how sociotechnical networks of certain AT or HFT related entities are realized (e.g. Beunza & Stark, 2004; Hardie & MacKenzie, 2007). Unfortunately, this could not be achieved in this thesis as it is very effortful and difficult due to the secretive culture of involved organizations.[36] Nevertheless, the present paper tried to set the stage for further investigations of a rather new approach to a rather new phenomenon. As Lenglet trenchantly formulates, there still is work to do (2011, p.63): "If the rise of the machines has obviously begun, the *homo algorithmicus* is not a grown adult yet."

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[36] Caitlin Zaloom (2006) for example actually became a trader at the Chicago Board of Trade to conduct her ethnographic field study of financial markets.

9. Appendix

Appendix 1: Interview transcription

Please find the transcribed interviews (Interview A-G) on the attached DVD.

Appendix 2: Interview guidelines

Interview guideline - Exchange A
Date: 18. April 2013, 09:00 - 09:30

Fragen:

- Könnten sie kurz zusammenfassen, was die Börse Stuttgart macht, besonders in Hinblick auf elektronischen und algorithmisierten Handel?

- Wie schätzen Sie den Einfluss von Technologie auf moderne Finanzmärkte ein, besonders in Hinblick auf algorithmisierten und hochfrequenten Handel? Wie beeinflusst die zunehmende Automatisierung die Arbeit und Organisation eines Handelsplatzes, welche Aufgaben haben sich geändert oder wurden abgeschafft?

- Wie werden elektronische Schnittstellen entwickelt? Welche Aspekte spielen eine Rolle: Regulierung, Funktionalität, Kundenwünsche etc.?

- Wer codet/kreiert die Algorithmen? Wer handelt eigentlich und trifft Entscheidungen: Maschinen, Ingenieure, Mathematiker, Trader? Folgen die Entwickler ökonomischen Theorien oder simpler technologischer Machbarkeit?

- Was bedeutet diese Entwicklung für die Zurechnung von Verantwortung?

- Welche Bedeutung hat Lokalität für elektronischen Handel, besonders für algorithmisierten und hochfrequenten Handel? Ist Lokalität in den letzten wichtiger oder unwichtiger geworden?

- Welche Rolle spielen Infrastrukturanbieter wie Equinix? Beeinflussen sie was möglich ist und was nicht? Wie (intensiv) wird mit ihnen zusammengearbeitet?

- Hat die Automatisierung und Algorithmisierung einen Einfluss auf die Produkte die gehandelt werden? Werden neue Produkte durch die neuen technologischen Produkte möglich?

- Glauben Sie, dass die zunehmende Automatisierung und Algortihmisierung Märkte rationaler, besser einsehbar und vorhersehbarer gemacht hat? Oder, sind Algorithmen Black-Boxes, deren Handlungen kaum verständlich oder vorhersehbar sind?

- Hat ein Event wie der Flash-Crash 2010 einen Einfluss auf Ihre Arbeit gehabt?

- Wer sind Ihrer Meinung nach die wichtigsten Akteure in der Realisierung von elektronischem Handel, besonders von High Frequency Trading Banken, Börsen, Infrastrukturanbieter, Trader etc?

- Gibt es sonst noch wichtige Punkte, die es zu beachten gilt?

Interview guideline - Exchange B
Datum: April 15, 2013 - 15:00 - 16:00

Fragen:
- Was macht die Deutsche Börse, besonders in Hinblick auf Angebote / Umsetzungen bezüglich elektronisiertem/algorithmisiertem Handel

- Verantwortung / Zurechenbarkeit von Entscheidungen: Wenn Algorithmen entscheiden, welche Rolle spielen die Menschen in der Realisierung des Marktes?

- Wer schreibt die Algorithmen? Nach welchen Kriterien werden diese kreiert?

- Beurteilung Infrastruktur und Technologie: Wie hat sich Handel verändert? Welche Aufgaben übernehmen jetzt Maschinen, die früher von Menschen bewältigt wurden?

- Welche Rolle spielt Nähe und Lokalität in der neuen Marktrealität (für wen)?

- Hat die Elektronisierung die gehandelten Produkte verändert? Wurde der Handel neuer Finanzprodukte und deren Kreation durch die zunehmende Algorithmisierung verändert?

- Wie veränderte der Flash Crash 2010 die Arbeit der Deutschen Börse?

- Wie gestaltet sich die Zusammenarbeit mit Marktteilnehmern und Infrastrukturanbietern? Wie werden Schnittstellen und Möglichkeiten ausgelotet?

- Wer sind Ihrer Meinung nach die treibenden Kräfte in AT/HFT (Banken, Trader, Börsen?)

- Glauben Sie die Märkte sind durch die Elektronisierung besser geworden (rationaler, vorhersehbarer, effizienter)?

- Würden Sie AT und HFT als Black-Boxes beschreiben, von denen keiner genau weiß, wie sie funktionieren und was sie als nächstes tun oder eher als Vehikel der Transparenz, da sie ja gerade vorgegebenen Regeln folgen?

- Irgendwelche anderen wichtigen Punkte?

Interview guideline - Exchange C
Date: April 29, 2013

Questions:

- Could you please briefly summarize what Exchange C is doing and what you are doing at Exchange C?

- How do you estimate the impact of technology for modern financial markets, especially in terms of Algorithmic and High Frequency Trading? How does the increasing automation affect the work of an exchange? What kind of tasks have been replaced or abolished?

- How are the interfaces/architectures developed? What aspects play a role: regulation, functionality, client-wishes? Collaboration with participants? Who states that new functionalities are necessary?

- Who codes the algorithms? Who/what is trading and making decisions: machines, engineers, mathematicians? Who influences the shape of algorithms? How is the relation between technological realization and economic principles coordinated?

- What does the technological shift mean in terms of responsibility? Is there still an individual trader orchestrating the trading?

- What role does locality play in algorithmic, high frequency and electronic trading? Has locality become more or less important?

- How important are infrastructure providers like Equinix? Do they affect what is possible and what is not? How (intense) do you collaborate with Equinix?

- Does automation, electrification and the usage of algorithms change the goods and products that are traded? Is the trading of new products feasible as a result of new technologies and algorithms?

- Do you think that the increasing automation and utilization of algorithms produces more rational, better assessable and more predictable financial markets? Do algorithms work like black-boxes acting on their own or are their actions foreseeable?

- Do events like the famous „flash-crash“ of 2010 affect your work at Exchange C?

- In your opinion, who are the most important agents in realizing modern electronically organized financial markets: banks, traders, stock exchanges, infrastructure providers?

- Is there anything you think is important for the issues we have talked about throughout this interview?

Interview guideline - Bank D, Zürich
Date: April 08, 2013 - 13:00 - 14:00

Fragen:
- Was genau macht Ihre Abteilung und wofür sind Sie verantwortlich bzw. was sind Ihre Verantwortlichkeiten?

- Wenn mehr und mehr Handel von Algorithmen abgewickelt wird, welcher Einfluss kann dann noch dem Trader zugerechnet werden?

- Welche (groben) Strategien verfolgen Ihre Algorithmen?

- Wer bestimmt, wie die Algortihmen funktionieren / wer schreibt die Algorithmen (Inspiration durch ökonomische Theorie)?

- Haben Trader Einfluss auf Algorithmen, wenn diese einmal laufen? Oder sind diese in "Stein gemeißelt", wenn sie einmal in Betrieb genommen wurden?

- Wie wichtig ist Infrastruktur und Technologie?

- (Welche Aufgaben werden von Algorithmen und Computern übernommen, die "früher" von Menschen verrichtet wurden)?

- Hat die Technologisierung (und Zunahme der Algorithmisierung) einen Einfluss auf das, was gehandelt wird? Werden neue Produkte durch die technologischen Möglichkeiten handelbar?

- Werden die Entscheidungen durch zunehmende Verwendung von Algorithmen "besser" (gnadenlos, fehlerlos, rational)?

- Hat der berühmte Flash-Crash im Mai 2010 Ihre Arbeit beeinflusst, nachhaltig verändert?

- Wie ändert sich generell die Verantwortlichkeit ("Haben die Maschinen das sagen?")

- Wie fair ist HFT?

- Welche sind die wichtigsten Akteure, damit AT und HFT realisiert werden kann (Banken, Börsen, Datencenter)?

- Irgendetwas wissenswertes, dass es noch zu sagen gibt?

Interview guideline - Association E
Date: April 10, 2013 - 12:30 - 13:30

Questions:

- Could you please briefly summarize what Association E is doing in general and what you are responsible for at Association E?

- If algorithms are analyzing and executing most of the deals, what is the traders contribution and responsibility? Are the machines making the markets? What happened with the classical brokers managing trading via open outcry in the pits?

- Who codes the algorithms (education, influence of economic theory)? Do algorithms work like black-boxes acting on their own or are their actions foreseeable?

- Influence of infrastructure and technology: How has trading changed, what kind of tasks are shifted to machines?

- How do you estimate the importance of locality and infrastructure (in terms of fairness)?

- Does automation, electronofication and the usage of algorithms change the goods and products that are traded? Is the trading of new products feasible as a result of new technologies and algorithms?

- How did the famous flash crash of 2010 affect the algo-trading industry?

- Who are the most important agents, organizations and institutions in realizing algorithmic and high frequency trading (banks, traders, coders, exchanges etc.)?

- Do you think that the increasing automation and utilization of algorithms produces more rational, better assessable and more predictable financial markets?

- Now that we are coming to an end, is there anything you think is important for the issues we have talked about throughout this interview?

Interview guideline - Infrastructure Provider F
Date: March 25, 2013 - 10:00 - 11:00

Questions:

- Could you please briefly summarize what equinix is doing in general and the services equinix is offering for the financial services industry in detail?

- Do equinix products influence actual trading? Do you provide blank infrastructure for financial services or do your products impose certain conditions determining what kind of trading (products, strategies) are executable?

- (Accordingly, do you have expertise in actual trading?)

- (Do you provide information? How is information selected and do you then have a direct influence on the shape of liquidity? Are you neutral?)

- Are equinix products inspired by economic theory or are they a mere product of engineering?

- Do you work together with traders, banks and stock exchanges? How does this collaboration look like?

- What role does locality play in algorithmic, high frequency and electronic trading?

- Do you think that the increasing automation and utilization of algorithms produces more rational, better assessable and more predictable financial markets?

- Do events like the famous „flash-crash“ of 2010 affect your work at equinix or is this a mere issue for those who are trading? What does this mean for the diea of responsibility with regards to trading decisions?

- In your opinion, who are the most important agents in realizing modern electronically organized financial markets: banks, traders, stock exchanges, infrastructure providers (like Equinix).

- Now that we are coming to an end, is there anything you think is important for the issues we have talked about throughout this interview?

Interview guideline - Trader G
Date: April 16, 2013 - 14:00 - 15:00

Questions:

- Could you please briefly summarize what Trader G is doing and what you are doing at Trader G?

- How do you estimate the impact of technology for modern financial markets, especially in terms of Algorithmic and High Frequency Trading?

- Do you have expertise in open outcry trading? What has changed? What kind of tasks have been accomplished by human beings that are now transferred to machines? What happened with the classical brokers managing trading via open outcry in the pits?

- Who codes the algorithms? Who/what is trading and making decisions: machines, engineers, mathematicians? Who influences the shape of algorithms? How is the relation between technological realization and economic principles coordinated?

- What does the technological shift mean in terms of responsibility? Is there still an individual trader orchestrating the trading or is algorithmic trading a complex ?

- What role does locality play in algorithmic, high frequency and electronic trading? Has locality become more or less important?

- Does automation, electrification and the usage of algorithms change the goods and products that are traded? Is the trading of new products feasible as a result of new technologies and algorithms?

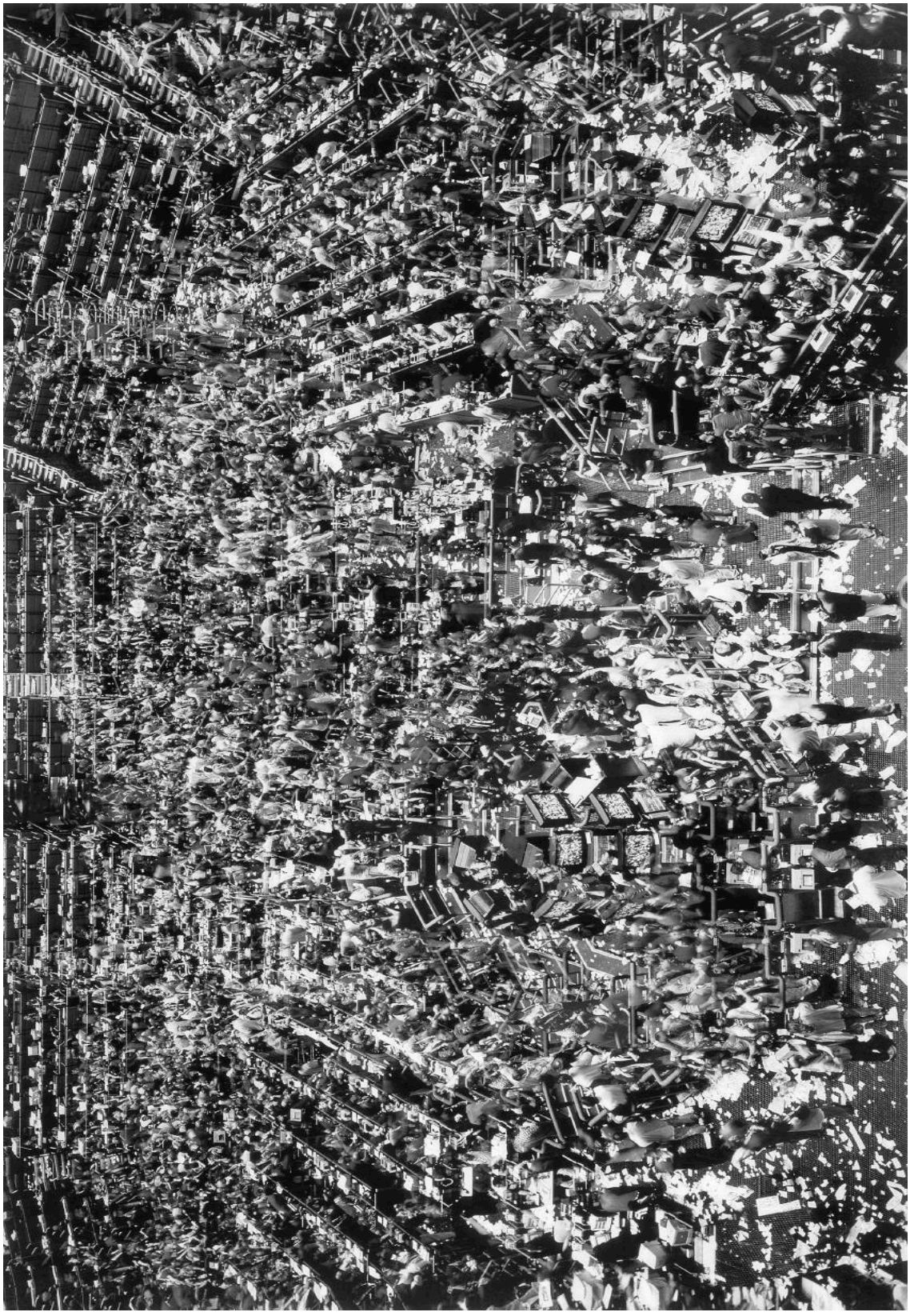
- Do you think that the increasing automation and utilization of algorithms produces more rational, better assessable and more predictable financial markets? Do algorithms work like black-boxes acting on their own or are their actions foreseeable?

- Do events like the famous „flash-crash“ of 2010 affect your work at Trader G?

- In your opinion, who are the most important agents in realizing modern electronically organized financial markets: banks, traders, stock exchanges, infrastructure providers?

- Now that we are coming to an end, is there anything you think is important for the issues we have talked about throughout this interview?

Appendix 3: Picture of the Chicago Board of Trade



Chicago Board of Trade II, taken by Andreas Gursky in 1999 (available at: http://www.tate.org.uk/art/artworks/gursky-chicago-board-of-trade-ii-p20191)

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Ehrenwörtliche Erklärung

Ich erkläre hiermit ehrenwörtlich, dass ich die vorliegende Arbeit selbständig angefertigt habe; die aus fremden Quellen direkt oder indirekt übernommenen Gedanken sind als solche kenntlich gemacht.

Die Arbeit wurde bisher keiner anderen Prüfungsbehörde vorgelegt und auch noch nicht veröffentlicht.

Friedrichshafen, den 06. Juni 2013

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