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The order of technology: Complexity and control in a connected world

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Abstract

This paper examines some of the implications associated with the growing complexity of the contemporary world, consequent upon the expanding economic and organizational involvement of ICT-based systems and artefacts. Drawing on Luhmann, traditional forms of technological control are analyzed in terms of functional simplification and closure. Functional simplification involves the demarcation of an operational domain within which the complexity of the world is reconstructed as a simplified set of causal or instrumental relations. Functional closure implies the construction of a protective cocoon that is placed around the selected causal sequences to ensure their recurrent unfolding. While possible to analyze in similar terms, current developments, as manifested in the diffusion of large-scale information systems and mostly the internet spin a web of technological relations that challenge the strategies of functional simplification and closure and the organizational practices that have traditionally accommodated them.

Keywords: Connectivity; Control; Functional simplification; Functional closure; Organization; Technology

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1. Introduction

Information and communication technology (ICT) is increasingly involved in the constitution and monitoring of complex institutional systems and activities, e.g., organizations, electronic markets, media and politics. The expanding economic and organizational involvement of ICT represents strong evidence of the greater leeway it keeps obtaining in the making of human affairs. Such a claim may sound trivial. It must though be stated clearly, in view of a widespread distrust against categorical statements that attribute technology a causal status (see, e.g., Arnold, 2003; Cutcliffe & Mitcham, 2001; Woolgar, 2002).

Claiming that ICT obtains a greater leeway in contemporary institutional life does not imply a univocal causation, whereby ICT-based systems or artefacts are assumed to impose their order on human affairs. But it does attribute technology a wide space of possibilities for influencing human conduct. Technologies in general and information and communication technologies in particular represent complex layers of objectified intentions that embody the lessons of experience or science into various sorts of artefacts and technical systems (e.g., Mumford, 1952). Evolving often over considerable time periods, technologies are getting gradually solidified while their deployment invokes regimes of institutional and cultural rules that are usually taken for granted. Under these circumstances, technology comes to exert a significance influence on those contexts in which it is getting involved (Hughes, 1987), choreographing, as Misa, Brey, and Feenberg (2003) expresses it, the human effort in an intricate pattern of routines and standard operating procedures.

The momentum ICT keeps acquiring in the contemporary world is manifested, among other things, in the growing interlocking and standardization (a prerequisite for interlocking) of the rapidly expanding population of ICT-based systems and artefacts. The construction of a relatively standardized infospace within and across organizations and regions would seem to inaugurate a distinct stage in the contemporary technology's involvement with the world. For all its significance, information that remains locally confined cannot respond to the challenge of a market-oriented, global world. Locally produced information needs to be communicated, transferred and processed, rapidly and effectively, within/across organizations and regions and over time. The diffusion of standards across industries and regions responds to such a quest and increasingly establishes the requirements for global systems of information handling, exchange and communication (Hanseth, 2000; Leigh-Star & Bowker, 1999). The internet is the most conspicuous manifestation of these developments but many other less encompassing local or function-based networks exist as well (Castells, 2001; Rifkin, 2000). At the same time, the organizational deployment of large scale information packages, like Enterprise Resource Planning Systems (ERP) or Customer Relationship Management Systems (CRM), make their own contribution to the unification of the information habitat of organizations. Though configurable and adaptable to local settings, commercial, off-the-shelf packages of this sort help disseminate similar information structures and processes across organizations and regions (Kallinikos, 2004b).

Taken together these developments seem to suggest that ICT is instrumental in bringing together aspects of the world that had previously remained unrelated in terms of function or locality. The positive outcomes of an interconnected world, manifested in the rapid and effective processing and transfer of information across organizational, institutional and geographical boundaries, are rather conspicuous to need lengthy treatment in this context (see, e.g., Castells, 1996, 2001). But, as the editors of this volume note, encompassing processes of this sort hardly remain univocal in their organizing or dis-organizing consequences. There is the general issue of unintended consequences, so well epitomized by the food and pharmaceutical industries or the wider environmental effects of industrial technologies (Beck, 1992). There is evidence to suggest that analogous phenomena are emerging in the connected world of the information age (Hanseth, Ciborra, & Bra, 2001; Johnson & Nissenbaum, 1995; Knights, Noble, Vurdubakis, & Willmott, 2002). Electronic ''identity'' theft and fraud, internet-mediated pornography and electronic crime in general are some conspicuous unintended consequences brought about by the global interlocking of ICT-based systems and artefacts. A recent, government-commissioned report in Britain identifies cyber-criminality and the vulnerability of the internet as major security issues whose significance is bound to raise in the future, as contemporary technologies of information and communication make the world increasingly interconnected (www.foresight.gov.uk).

A case could indeed be made for the fact that the interconnectedness which contemporary technologies of information and communication help to bring to being challenges the old wisdom of control accomplished though the separation or loose coupling of social, organizational or technological processes (Foucault, 1977; Perrow, 1984; Simon, 1969). The interaction between previously unrelated processes or functionalities may set out a dynamics with vaguely imagined and, quite often, unforeseen results. In other cases, integration may unwittingly undo defence mechanisms that secure the smooth function of the processes or systems involved, or simply provide new opportunities that can be used in adverse ways, as most electronic crime exemplifies. Negative effects of one or another incidence that were before locally contained may rapidly propagate across the now interconnected networked space. ''Ill will has become more potent and destructive'' in a connected world, the renown American philosopher Borgman (1999, p. 196) claims. In such a context, the old but reliable strategy of coping with threats or dangers by isolating them may not be easily applicable. Control is, after all, an exercise in boundary drawing and boundary management. In his acclaimed study of 'normal accidents' Perrow (1986) demonstrates that interconnectedness is often double-edged. While it may be enabling in one way or another, it may too significantly raise the complexity of the interacting components and cause unintended and deeply regretful consequences. Indeed, Perrow suggests that accidents of this sort are unavoidable (hence the name normal accidents) in tightly interconnected systems, whose components may involve non-linear, and for this reason hardly predictable, forms of causality (Grabowski & Roberts, 1999).

The pervasive character of the informational habitat, which contemporary information and communication technologies are instrumental in bringing forth, reframes some of the dominant strategies of technological control that have been expressed with the construction of largely self-contained technological systems. An appreciation of what such a reframing may entail, necessitates the analytical treatment of the distinct forms by which technology has traditionally been involved in the construction of predictable worlds. For, such an analysis helps disclose the distinct modes by which current technological developments challenge traditional strategies of technological control (e.g., interconnectedness versus loose coupling) and the organizational practices commonly associated with them.

Attributing such a significance to the reframing of the traditional strategies of technological control, which current developments signify, may need motivation. The extensive social and organizational involvement of ICT-based systems and artefacts are commonly assumed to have far reaching effects on the forms by which contemporary economy and society is organized (e.g., Castells, 1996, 2001; Rifkin, 2000; Sassen, 2004). However, these effects have at least so far been gauged in terms of complex imbrications of technical, social and organizational dimensions. Rarely are such claims being traced back to a thorough analysis of the generic strategies or forms by which current technological developments challenge some of the basic premises of traditional forms of technological control and by, extension, the organizational practices by which these last have been accommodated.

There is a widespread assumption that ICT-based systems and artefacts change the transactional patterns of social interaction and, in so doing, alter some of the premises on which traditional organizational forms have been predicated (e.g., Castells, 1996; DiMaggio, 2001). Besides being rather vague such an assumption has often assumed the status of an unquestioned axiom. The ghost of technological reductionism has perhaps discouraged what at first glance may seem as a study of technological processes alone. With few perhaps exceptions (e.g., Beniger, 1986; Luhmann, 1993; Simon, 1969), theories of how ICT is involved in the remaking of the traditional premises of technological control have been rare. And yet, the challenge current technological developments posit "to conceptualise and articulate more adequately the nature of the ongoing transformation(s) being undergone by contemporary organizations", as the call to this special issue suggests, makes necessary the theorizing of how the organizational involvement of ICT-based systems and artefacts changes some of the traditional premises of technological control. For these last are too social processes of control that have far reaching implications for the understanding of organizational practices and forms.

In what follows, I seek to develop the theoretical claims that depict the distinct forms by which technology has traditionally been involved in the making and regulation of human affairs. In so doing, I draw heavily on Luhmann (1993) and his conception of technology as *functional simplification and closure*. Luhmann's account of technology is particularly germane for framing some of the issues that are associated with the growing interlocking of ICT-based systems and artefacts, and the changing reality forms they construct. For it provides the conceptual background against which contemporary technological developments contrast with the traditional strategies of technological control. Next to it, I endeavour to reflect on the limits which traditional strategies of technological control are subject to. The impressive diffusion of large-scale software packages and the internet challenge, and in some cases radically, the key technological strategies of functional simplification and closure and the organizational practices (perhaps even forms) within which such strategies have usually been accommodated.

2. Functional simplification and closure

It is a widespread habit to conceive technology in instrumental or, perhaps more correctly, productivist terms, i.e. as a complex array of designed processes and devices (i.e. means) that increase the effectiveness of human operations. Technology is assumed to duplicate/magnify natural processes and extend/improve human skills, whether sensorimotor/manipulative or cognitive (see, e.g., Simon, 1969) and thus contribute to the better accomplishment of human ends. Hardly contestable as it may be, the understanding of technology in terms of means-ends puts the emphasis on the very objectives technology is called upon to serve. In so doing, it tends to conceal the distinctive forms and processes by which technology is involved in the making and regulation of human affairs.

Drawing on Luhmann (1993), I will portray technology as a *structural form* that supports human action in a world beset with contingencies of every sort. Thus viewed, technology emerges as a standardized and closed arrangement of artefacts/processes designed and deployed to produce a minimum platform of predictable relations, in an otherwise shifting and contingent world (Bloomfield & Vurdubakis, 2001; Luhmann, 1998). In a view of widespread misunderstanding, I would like to stress that the *geist* of technology is revealed in its reifying strategies. Or, in Latour's much quoted phrase, technology is society made durable. Any reliable technological system is expected to function in a largely recurrent fashion over time and across contexts. The standardized and recurrent status of technological operations does not deny the variety of purposes to which any particular technology can be called upon to serve. Indeed, and contrary to a widespread misconception, standardization (a successful reification) is essential to contextual adaptation. The frustration caused by technological devices that fail to deliver their promise is a reminder of the complex relationship standardization entertains with human purpose. Reflection on language and other resilient and highly flexible systems of human making suggest that a certain degree of standardization is essential for sustaining purposeful activity (Bolter, 1991; McArthur, 1986; Ong, 1982; Mumford, 1952).

The instrumentation of standardized, quasi-predictable relations are embodied on the twin strategy of *functional closure* and *simplification* (Luhmann, 1993). Functional simplification (funktionierende simpifizierung)[1] involves the demarcation of an operational domain, within which the complexity of the world is reconstructed as a simplified set of causal or instrumental relations. These last can be quite complex

[1] The German term alludes to the dynamic character of this process. To translate however literally to the English correspondence 'Functioning Simplification' would have been awkward and perhaps slightly misleading.

in themselves and their causal force significantly magnified, e.g., nuclear power, process technologies, freeway traffic systems. However, due to the initial reduction of the factors involved, the relative processes remain potentially inspectable and controllable, while the knowledge on which they are made possible allows for the accomplishment of these goals. Functional closure, on the other hand, implies the construction of a protective cocoon that is placed around the selected causal sequences or processes to safeguard undesired interference and ensure their recurrent unfolding. Functional simplification and closure implicate one another and straightforwardly express, Luhmann claims, the *geist* of technology in modern times. The predictable forms by which technology often (but not always) operates are precisely due to the construction of simplified or planned causalities, whose recurrent unfolding is ensured through the exclusion (or the attempt to such an exclusion) of any possible factor that could impinge on and disturb such a functionally simplified order.

Abstract as it may be, such an account of technology is well captured in the widely used engineering term blackboxing. It is also re-encountered across a number of authoritative texts on organizations (e.g., Mintzberg, 1979; Thomson, 1967). While the pattern of causal sequences may vary (e.g., pooled, serial and reciprocal patterns of interdependencies), organizations construct the protective cocoon of technology by the closed loops of technological sequences. They further re-enhance technological closure through extensive reliance on such methods as forecasting, stock piling, procedural control of inputs and other kinds of buffers (Thomson, 1967). All these methods and techniques aim to ensure the undisturbed unfolding of technological sequences. Closure or blackboxing by definition implies the very decoupling of the operations of the technical system from the wider organizational and social relations within which such a system is embedded. Social contact with technological process is highly regulated through prescriptions, the specification of skill profiles and requirements and role formation. Technological and organizational design thus make abundant use of local containment, separation and loose coupling as basic strategies of control (Perrow, 1984; Weick, 1976).

The understanding of technology as a system that is predicated on the principles of functional simplification and closure could be said to predominantly derive from the industrial experience. Cognitive systems like those constructed or enabled by computer-based technology are premised upon differences (binary alterations) rather than material causes (Bateson, 1972). The conception of technology as a system premised on functional simplification and closure has therefore to be modified to account for the cognitive, sign-based constitution of ICT. In this last case, causal simplification and closure are transformed to the related strategies of *procedural standardization* and *cognitive closure*. Software technology entails elaborate systems of rules and procedures on the basis of which symbol tokens and cognitive relations are established and manipulated. The functionality of particular programs is accomplished through the painstaking elaboration of the steps involved, and the closed loops by which such steps are combined to fixed sequences.

Procedural standardization is essential to software technology and large scale information systems like ERP and CRM very well exemplify it even at the level of the user. Monitoring of customers through CRM always entails a number of steps through which the customer's profile is constructed. Such steps may ramify to various aspects of organizational life but they are always tied to procedural sequences and combinations by which profiling techniques are constructed. For instance, customer's buying and paying behaviour is decomposed into various steps, assigned to pre-defined categories and regrouped by recourse to combinatorial rules to construct the relevant profile. In a similar fashion, logistic operations mediated by ERP packages are organized as large series of steps that ramify into cross-functional operations, e.g., materials management, finance and accounting and warehouse management. Such steps are tied to procedural sequences that define a greater task, e.g., the task of buying is sequenced as following: reviewing materials, checking price, quality and delivery conditions, making a choice, placing the order, receiving invoice, making the payment, follow-up the product delivery, etc. (Kallinikos, 2004b).

We could thus make a case for the fact that the functional simplification in the case of software technology entails the careful demarcation of an operational domain (i.e. the functionality of the program), the definition of the tasks that embody the functionality of the program and the lay out of the steps that have to be followed in order to accomplish a task or series of tasks. The program itself may be quite complex but the tasks it performs have been substantially cleared up from ambiguities, and their execution standardized in an elaborate system of procedures. The brilliant analysis of the limitations of the Von Neumannian games once performed by Bateson (1972) is instructive for understanding the nature of the functional simplification/closure underlying particular programs. The problem with the Von Neumann's 'player', Bateson (1972, pp. 285–287) noted, is that it cannot learn from experience. Negative outcomes that are due to the 'player's' misperception of the confronted relationships cannot be fed back into the cognitive reorganization of the 'player'. The mathematical fiction the 'player' is will perform exactly the same way (dictated by the abstract and general character of mathematical relations the model of the 'player' epitomizes) in the next encounter. Unforeseen relations cannot be handled in situ. They could possibly be incorporated into the model by the programmer in a future periodic revision of the model but the 'player' itself cannot respond contingently. Functional simplification is precisely manifested in the closed loops the program performs, the implicit conduit metaphor upon which software engineering is predicated (Lackoff, 1995). The learning algorithms currently constructed by the technology of neural networks do not radically alter this situation, even though they claim to do so. They just push it one step back on the procedural standardization of the learning mechanism which is but an algorithm.[2]

The algorithmic status of programs thus suggests that the technological goals of recurrence and predictability of ICT-based artefacts are accomplished through the selection and standardization of the cognitive operations the program entails, and their procedural execution. Automation of procedures and rules ensure the

[2] This claim raises some intricate and central questions in Artificial Intelligence that in the very end call for the explication of what we mean by humans and human learning. For obvious reasons we cannot discuss these questions here.

procedural standardization and cognitive closure of the program and correspond, by and large, to the Luhmannian concepts of functional simplification and closure. Functional closure is furthermore accomplished through the specification of the information requirements (the program admits only certain inputs), various forms that regulate access to the program, cryptography, protocols and other security mechanisms that function as a kind of protective cocoon.

Such an account of technology may strike latecomers in constructivism/interpretivism as utterly devoid of humans and marked by a strong flavour of determinism. Whatever is meant by it, determinism is a bad word these days. This is not the place to raise these issues (see, e.g., Hacking, 1999; Searle, 1995) but a few clarifying comments are urgently needed. The understanding of the forms by which technology influences human choice can never be exhausted at the human-technology interface, no matter how compelling this may be felt to be (Borgman, 1984). Technologies are embedded in complex social and historical patterns that reach far beyond their situated use (Misa et al., 2003). Most significantly, technologies participate in constituting aspects of human agency through extensive training, education and practice formation (Kallinikos, 2002, 2004c). To treat functional closure and simplification (i.e. blackboxing) as determinist is to miss utterly the point concerning the *distinctive forms* by which technology is involved in human affairs. Distinctiveness, it should be noted, does not imply an appeal to a 'technical bottom line' kind of argument (Knights et al., 2002). Functional closure and simplification are not causes but formative contexts (Ciborra & Lanzara, 1994), socially constructed, under particular regimes of knowledge, and with the view of serving specific goals, interests, values or preoccupations. Their operations are similarly supported through routines, standard operating procedures and organizational models or practices that reflect wider forms of social learning but also the experience of the very contexts into which technologies find themselves embedded.

It should be made clear that functional closure and simplification vary significantly from technology to technology and so does the forms by which various technologies admit or invite human participation/intervention. Mobile devices, for instance, may differ from ERP systems with respect to how they embody the strategies of functional simplification and closure. It is a crucial task of the social study of technology to disclose and reconstruct the ensemble of both wider societal and context-embedded factors that account for these differences and the role technology plays in that game. This is the point made by authors as different as Borgman (1984, 1992), Hughes (1987), Kling (1992, 1996), Luhmann (1993, 1995) Mumford (1934, 1952), Winner (1977, 1993), Perrow (1967, 1986) to name but a few. Unless placed, in its proper context, the concept and antidote to determinism known as *interpretive flexibility* (Bjiker, Hughes, & Pinch, 1987; Bjiker, 2001) may well lead to a sort of contextual relativism, that in the very end undoes and render superfluous the very concept of technology (Strathern, 2002). If technology is infinitely malleable and contextually configurable and interpretable then why bothering deploying and analyzing its implications? All we need to study is the context. If, on the other hand, the contextual assimilation of technology is partly controlled by the complex and time-evolving strategies of objectification which artefacts embody, then these strategies need to be exposed to critical interrogation that helps disclose the distinctive forms by which technology may participate in the making of human affairs.

3. Limits to control

For all their difference to industrial technology, the principles of cognitive/semantic closure and simplification underlying computer programs/software packages recount the basic strategy by which technology in general attempts to deal with the contingent character of the world (Bloomfield & Vurdubakis, 2001; Luhmann, 1998). Computer programs embody clear rules of reality representation and automated procedures of information processing and inference making (Zuboff, 1988). In so doing, they participate in the reproduction of an order in roughly similar ways to those Luhmann (1993) subsumes under the labels of functional simplification and closure. That is, they guarantee the recurrence of the operations internal to the system, while their interface with the reality, which is external to the program, takes place along highly selective paths (i.e. strict input requirements, formation of skill and role profiles, security arrangements) that ensure the reproduction of the program's operations through the exclusion of unwanted interference.

Frequent technological failures and malfunctioning (Perrow, 1984) suggest, however, that the project of functional simplification and closure is but partly achieved. The control of the internal loops that make up the system is never complete while the risk of external interference can be reduced but never eliminated. Contingent events that manage to intrude the closed circuits of technological interactions may cause significant problems and, at times, wreck havoc as they may ride on the intensified/magnified nature of these interactions. Technologically induced accidents give an indication of the magnified forces that under adverse conditions manage to escape technological control. The pattern is well-known: Functional simplification and closure enable the magnification of the causal or instrumental processes involved. But once the closed circuit of technological processes is broken, the forces that are set free often have grave or even devastating effects. Nuclear accidents stand as the epitome here. A less dramatic and instructive example is provided by freeway traffic systems. Functional simplification of driving conditions and closure from other external interference enable the high speed traffic of huge number of cars. But due to traffic magnification, malfunctioning or disturbances in freeway traffic usually bring forth grave consequences in the form of long traffic delays (i.e. huge car queues) caused by the time consuming effort to bring the system back to its normal functioning.

These observations suggest that the unexpected events that manage to intrude the closed circuits of technological systems cannot be coped with by the intrinsically blind character of technological sequences, at the very level which these sequences operate. Additional, ancillary mechanisms, ranging from routine safety tests to contingency plans, must be added to the system, initiating a vicious circle of increasing complexity (Luhmann, 1993). The forces or processes that, through the strategies of functional simplification and closure, have been placed outside the technological system threaten to come back and unsettle its operations. They stand as an imminent danger which must be coped with, through the careful reintroduction of complexity, annexed onto the core processes of the system in the form of safety or security mechanisms. The flipside of technological simplification is *loss of flexibility and contingent response* that have to be re-instituted through artificial mechanisms. Technological sequences cannot handle (i.e. absorb, ignore, forget or dissimulate) unforeseen incidents at the level on which they operate, even though technologists currently attempt to construct systems that respond to emergent events on the basis of learning from experience (i.e. neural networks). Such simple behavioural characteristics as forgetfulness, dissimulation and indifference, that we often assume to be part and parcel of the limitations of humans, play an extremely important and adaptive role under conditions of emergence, complexity and unpredictability (Bateson, 1972; Luhmann, 1993, 1995; March, 1988).

While representing a major means for managing complexity, the technological strategies of functional simplification and closure are therefore subject to severe limits. Most crucial among them are the incapacity of a technological system thus constructed to deal with intruding and unexpected contingencies, and the consequent need to pre-program how such an intrusion, if it takes place, should be dealt with. But it belongs to the nature, as it were, of contingency (as disasters and accidents so well demonstrate) to be only modestly managed through antecedent preparation. But there are limits too, as we will endeavour to show in the next section, to how much complexity can be reintroduced in the system in the form of ancillary security mechanisms. It comes therefore as no surprise that failing functional simplification and closure may bring consequences of one or another kind, some of which may indeed be grave. Luhmann (1993) sorts out these effects into three basic groups:

- *Chaos effects*, i.e. locally produced incidences of often minor character may disseminate rapidly across the entire system and trigger unpredictable chain effects wrecking havoc. Catastrophes like those exemplified by airplane crashes, nuclear power or chemical industry accidents may well conform to the pattern of chaos effects. Similar effects may be less dramatic in tightly connected information systems but they can still bring serious economic consequences as they may seriously inhibit intra- and inter-organizational transactions. In cases in which ICT-based systems are deployed to monitor complex physical processes, as it now happens in aircraft or submarine navigation, nuclear power installations, etc., the effects may though be far-reaching and devastating.
- *Interference effects*, i.e. hardly predictable effects created by human intervention. Once manifested, effects of this kind are subject to learning (e.g., pollution, X-rays, antibiotics) and the operations of technology could over time be readjusted to accommodate at least some of these effects. Issues relating to information overload, the management of junk e-mail or software virus spreading, or the lessons taught by the dotcom fever could perhaps be thought as analogous phenomena in the age of information.
- *One-off incidences* of unique and haphazard nature not straightforwardly subject to learning.

4. Beyond functional simplification and closure

Contemporary technologies of information and communication are deployed to render the operations which are brought to bear upon more predictable and manageable. They do so along lines that, by and large, recount the project of functional simplification and closure. However, as indicated in the introduction of this article, they too increase complexity in the form of an increasing interconnectedness between systems and applications but also in the form of expanding the regulative jurisdictions of technology to new fields and processes. These developments accentuate the limitations to control accomplished through functional simplification and closure. Let me elaborate.

The reduction of complexity through the deployment of ICT-based systems often drives or 'exports' the handling of contingencies at a more inclusive level, in a roughly similar fashion to that presented above in connection with ancillary security arrangements. ICT-based systems and artefacts often assume the role of a *meta-technology* controlling other technologies. They do so either in the form of providing straightforwardly security arrangements or through the planning and monitoring of technological processes (e.g., process industries, aircraft navigation, nuclear power generation). In other instances, ICT emerges as a primary technology, restructuring, regulating and monitoring processes that were previously performed in various, loosely coupled settings, in which a variety of technologies and often organizations have been involved (e.g., bank and insurance offices, tax authorities, public e-procurement systems, etc.). In all or, at least, most of these circumstances, *ICT becomes a central medium for compressing risks and transporting them to a more comprehensive level*. The common, and in many respects reasonable, assumption is that the superior information processing and controlling capacity of ICT furnishes the means for spotting and adequately handling local failures, deviations or intruding contingencies. But there are side effects and unintended consequences and is important to understand how they may arise.

The rule so far has been that second-order (often security arrangements) mechanisms must be added onto any technological system, to take care of unforeseen incidents. But these second-order technologies cannot but be themselves based on the principles of functional simplification and closure (Luhmann, 1993). For, second-order, safety technologies cannot but be constructed on the basic of conjectures about possible incidents and dysfunctions and this applies to ICT as well. By definition, they entail a *fixed set of responses* that could be invoked to cope with disruptive effects, as these last have been envisaged at the moment safety technology was designed. But if second-order technologies cannot control themselves, their possible failing must be controlled either by third-order technologies or other means that may involve direct human involvement. The growth of ICT-based security devices over the last decade (in many cases security arrangements are as elaborate as the core functionality of the system or application which they bear upon) suggest the control of technology through technology to be a tempting alternative.

A complex technical scaffold is often the outcome of these processes, where second-order technologies control primary processes, tertiary technologies control security mechanisms of the second order and so forth. But, as indicated above, this technological scaffold must be constructed in advance and 'spot' responses pre-specified. The handling of contingencies and the risks such handling implicates are compressed into a complex net or hierarchy of technologies with the consequence of possible, large-scale disruptive effects (Borgman, 1999). Scaffolds are known to often collapse in one blow. It may seem as a paradox yet control is a double-edged process that both increases (in some respects) and decreases (in some other respects) safety. Luhmann (1993, pp. 92–93) refers to the great German romantic poet Holderlin to make the point that the quest of control may end up increasing rather than reducing risks.[3] I would like myself to remind of Herakleitus old maxim that the same road goes up and down.

The disruptive effects of what is here construed as 'scaffold' collapse are often modest and represent perhaps a hybrid of the first two types of effects described by Luhmann (i.e. chaos and interference effects). Examples represent servers that break down (and this happens not infrequently), leaving considerable number of people idle for hours or days, or forcing them to revert to old ways of doing things, which may not be entirely possible either. Incidences, however, as the collapse of the server for monitoring traffic control at the Heathrow airport for a few hours the year 2004 can give an indication of the severe problems facing large technological systems in which risks become compressed and transferred at a comprehensive level. The control of technology by means of technology has however been a widespread practice long before the current impressive social and economic involvement of ICT. Industrial production, medicine, environmental monitoring, transportation monitoring represent salient examples of fields where a variety of technologies have been deployed to control other technologies (Perrow, 1984; Simon, 1977). Information and communication technologies cannot thus be credited that controlling strategy, though ICT-based systems accentuate some of these tendencies by virtue of being often deployed as a meta-technology, monitoring the operations of other technological systems.

A different technological landscape with a different kind of problems is gradually been formed by the very *connectivity* or *interoperability* contemporary technologies of information and communication are currently able of constructing. Perhaps more than complexity, associated with the concatenation of technologies into an encompassing order (first, second and third order technologies), connectivity and interoperability straightforwardly challenge technological control accomplished through functional simplification and closure. Traditional technologies remain always functionally incompatible, e.g., rail, air or road traffic systems. Under these conditions functional complementarity (rather than interoperability) is accomplished by letting one system to take over at the operational boundaries of the other. Traditional technologies seldom intercept or merge functionally, as they have been constructed by recourse to different principles and preoccupations. In some cases, i.e. subway and rail traffic, such a functional merging may be an issue of appropriate standards. Very

[3] Wo aber Kontrolle ist/Wachst das Risiko auch (But where there is control/Risk grows as well).

often however (e.g., air and rail traffic) the self-contained nature of different technological systems reflects widely different social and techno-scientific projects.

Now, ICT-based systems and technologies may too remain uncoupled or brought to bear upon one another through gateways and other similar techniques that translate data inputs back and forth from the one system to the other but leave the systems intact. Furthermore, technological path dependencies and lock-ins accentuate the need of backward compatible innovations, a process that is prone to create independent, self-reinforcing technological trajectories and fragmentation of ICT and ICT-based systems. Hanseth (2000, 2004) elevates the problem of *backward compatibility* into a major inter-operational issue in large-scale and heterogeneous ensembles of ICT-based systems. In addition, a variety of social (e.g., exclusion) and institutional (e.g., firewalls) segmentations are imposed upon the internet, making it a highly fragmented terrain (Sassen, 2004; Woolgar, 2002). The incompatibilities, divisions and segmentations that underlie both the internet and other large information infrastructures suggest that it is perhaps naïve to think of them as unified socio-technical platforms along which information, events, benevolent and malevolent acts can smoothly propagate (Ciborra, 2000; Leigh-Star & Ruhleder, 1994).

It would be perhaps fruitful at this point to distinguish between unification and interoperability. It is beyond any doubt that despite various institutional, social and technical barriers, the internet contains extended zones of interoperability. This is far from being accidental. Connectivity is the 'essence' of the internet and interoperability its technical modality (Dreyfus, 2001). It is crucial to understand that, by virtue of being software codes, ICT-based systems and technologies can potentially be made interoperable even if they are not. No matter how cumbersome it may be, functional compatibility is always a possibility in software code. By contrast, there is no way to merge together functionalities, say, of rail and air traffic technologies. Once transformed into a software code, a product or technology can traverse its previously narrow confines and become an object of communication and exchange along a vast variety of technical and social settings, even though such communication and exchange may require additional technical developments or modifications. Music and film 'piracy' and cracking of software codes by hackers provide evidence of the standing interoperable possibilities of ICT-based systems and technologies.

The implications of these developments for the traditional strategies of technological control accomplished through functional simplification and closure are indeed far-reaching. Connectivity and interoperability straightforwardly violate the controlling strategies of functional simplification and closure making the interception of functionalities and the exchange of data and information across ICT-based systems an essential principle of the new technologies. Needless to say, the understanding of the internet is a highly complex phenomenon and we cannot do justice to its complexity here. But we can still venture to claim, as we have done in this text, that the diffusion and socio-economic embeddedness of the internet challenges the traditional forms of technological control and, by extension, the governability of complex sociotechnical systems. In one way or another, the development and diffusion of the internet takes technology out of the controlled order associated with functional simplification and closure into the messy realm of everyday encounters. This is a major development whose implications for the governance of complex systems are yet to be appreciated.

5. Organizational implications: some concluding remarks

In this paper I sought to place the understanding of the expanding organizational and economic involvement of ICT and the diffusion of the internet against the background of the traditional strategies of technological control. An implicit assumption behind that venture is that current developments can be better appreciated against the background of their similarities and differences to the standard forms by means of which technology has been implicated in the construction of predictable worlds and the regulation of human affairs.

The influence of information and communication technologies on organization forms and practices has often been assumed rather than analytically examined in an adequate fashion. New organizational forms, most notably networks, have often been associated with the pervasive character of ICT (e.g., Castells, 1996, 2000, 2001; DiMaggio, 2001). That association has however remained rather vague. It has generally been attributed to the transactional infrastructure of ICT (i.e. cross-boundary instant interactivity) and the forms of data exchange and communication it enables. The detailed analysis of how ICT reframes and reshuffles the processes, procedures and structures of control in complex systems has never been seriously pursued. Perhaps, as suggested in the introduction, the ghost of technological reductionism has steered attention away from the detailed study of the organizational implications of technologies. However, even though technologies are not causal forces they are indispensable means for the construction of social reality.

What I have consequently sought to do in this article is to open up that field and examine in some detail the specific ways by which contemporary technologies of information and communication reframe the traditional strategies of technological control, which, following Luhmann (1993), I have identified with functional simplification and closure. These developments cannot but have important organizational implications. Functional simplification and closure have been associated with centralized steering practices and management through rigidly segmented, sequentially ordered and hierarchical organizational patterns (Perrow, 1967, 1984; Zuboff, 1988). The normative content of traditional technological control is epitomized by the adequate separation of the technical system from the social relations of organizations (Luhmann, 1993). Such a separation has been an essential prerequisite for constructing *highly selective and regulated activity corridors*, along which the social system of organizational roles and positions has been allowed to interact with the secluded order of technical sequences. As I have sought to demonstrate in this article, such a project has always been subject to severe limitations yet it has provided the normative orientation and the grid upon which clearly defined organizational roles and job assignments have been premised and steering mechanisms developed.

The stratified social topology of traditional organization forms, the elaborate systems of formal rules, standard operating procedures, clear-cut job assignments and narrow competent profiles have all been associated with functional simplification and closure. Far from being a causal claim (hence the choice of the word 'associated') such a statement attributes to these generic technological strategies an important role in the construction and maintenance of the still dominant hierarchical organizational practices and forms (Kallinikos, 2004a). Now the interoperability (actual and potential) of ICT-based artefacts and the connectivity of the internet undermine some of the premises upon which functional simplification and closure have been predicated. The strictly regulated activity corridors by which the social system in organizations was allowed to bear upon the operations of the technical system are partly undermined by the messiness of the internet. The introduction of new players, some of them uninvited, into the game blurs responsibilities and weakens the patterns of accountability within and across organizations. Boundary drawing and regulation of cross-boundary traffic have always been crucial controlling practices that are now partly undermined or reframed by the patterns of connectivity the internet helps establish. Connectivity is, however, on the verge of becoming a worn-out concept. I have thus been at pains to show in this text why this is the case. The software-based constitution of information and communication technologies furnishes the common platform upon which most software-based systems, and the products or services they construct, can be rendered compatible with one another and ultimately interoperable.

The analysis performed here even suggests some important implications for the management of risk that is becoming increasingly a major issue in contemporary societies. For all its difficulties, technical risk analysis, based on the calculation of probabilities of unexpected events, safeguarded, and still does so, the operations of technological systems governed by the principles of functional simplification and closure (Rehn, 1998). Probabilities are always inferences about future events, whose validity is based on the availability of data that describes crucial parameters of a well demarcated system. When such a system is no longer identifiable, technical risk analysis becomes increasingly difficult to apply.

Information and communication technologies and the pervasive character of the internet thus help establish some preconditions for organizational practices and forms alternative to those that have dominated our age. But these possibilities (for they are as yet largely possibilities) for distributed work patterns, greater individual involvement, flat hierarchies and the like can be forged into alternative forms of organization only through social struggles. Important technological developments take place against the background of established social relations and there is more than a random chance that powerful social and economic elites will seek to shape these developments to accommodate their own interests (Introna & Nissenbaum, 2000; Lessig, 2001; Rifkin, 2000). These struggles however cannot be left untouched by the current technological developments as the battle over copyright, open source software development and peer-to-peer networks show (Lessig, 2001). It is my contention that some of the claims presented in this paper may help clarify part of the complex picture that keeps emerging for some time now.

A final note of caution. This paper makes claims about the possible influence of contemporary technologies of information and communication on organizations and society irrespective of context. Some people may find that claim too strong (see, e.g., Orlikowski, 2000; Suchman, 1996; Woolgar, 2002). I have sought to support it with several comments spread throughout this text. Let me just suggest here that the context itself cannot be given ontological primacy over all other aspects of social life and treated as the ultimate explanatory factor (Dilley, 1999). The context itself must be explained and the claims developed in this paper may help understand some of the forces that participate in the construction of local contexts and the diffusion of similar practices across populations of organizations (Powell & DiMaggio, 1991; Scott, 1995). Situated studies of technology may help illuminate one or the other aspect of the technical, organizational and social complexity into a which a particular technology finds itself embedded. But they can also overlook and unwittingly hide the forms through which processes of the sort analyzed here reach down to the local level participating in the constitution of local practices. In any case, the comprehensive character of current technological changes is such that it invites theoretical reflection of the wider social and institutional context into which they could be placed and their implications evaluated. This paper has attempted to respond to such an invitation.

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