Alea Iacta Est: Now is the Time to Extract Value from Digital Data Streams

Introduction

A Digital Data Streams (DDS) is the continuous digital encoding and transmission of data describing a related class of events.[1] The notion is based on the concept of Digital Data Genesis (DDG),[2] the increasing availability of events directly in digital form as they manifest. Our involvement in DDS research started with a series of projects commissioned by the Advanced Practice Council (APC) of the Society for Information Management (SIM) – a sponsor of the *MIS Quarterly Executive*. APC members were interested in understanding how to extract value from external data streams. DDSs can be thought of as a recent evolution of computing, from batch processing, to online transactions processing, to the continuous processing of streaming data.[3] It follows that DDSs provide both tactical and strategic opportunities, and they may require new capabilities.

Tactics

Response time latency suggests that value creation potential decays as time goes by when three types of delays occur. Delays in extracting needed data from an event of interest (capture latency); delays in transforming data into usable information (analysis latency); and delays in making a decision to act upon this new information (decision latency). It follows that a firm can create new value by reducing response latency. Process-to-actuate tactics occur when a firm taps into one or

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[1] Piccoli, G., & Pigni, F. (2013). Harvesting external data: the potential of digital data streams. *MIS Quarterly Executive*, 12(1), 143-154

[2] Piccoli, G., & Watson, R. T. (2008). Profit from customer data by identifying strategic opportunities and adopting the 'Born Digital' approach. *MIS Quarterly Executive*, 7(3), 113-122.

[3] Pigni, F., Piccoli, G., & Watson, R.T. (2016). Digital Data Streams: Creating value from the real-time flow of big data. *California Management Review, 58*(3), 5-25.

more real-time DDSs to reduce analysis latency, decision latency or both. In High Frequency Trading (HFT), for example, the detected fluctuations in a share's price are processed through low latency algorithms, generating trade orders within milliseconds from a price change. For high frequency traders, profits largely depend on the rapid processing of new data and the actuation of trades based upon it.

A second value tactic is assimilate-to-analyze. It occurs when a firm extracts value by merging multiple data streams and static databases to generate new insights. The focus is on extraction of insights rather than immediate action. In warfare, for example, real-time data assimilation and analysis is fundamental to effectively coordinating any kind of battlefield operation. The Distributed Common Ground System-Army (DCGS-A),[4] is the United States Army's primary system designed to gather, process data and disseminate intelligence, surveillance and reconnaissance information about threats, weather and terrain to all echelons. The system integrates hundreds of intelligence-related data sources to generate insights for army intelligence professionals. Data are gathered, processed and disseminated to guide and support commanders' and forces' decision-making.

Tactical opportunities emerge when a new DDS can be tapped into by organizations, for either process-to-actuate or assimilate-to-analyze initiatives. But both approaches assume the availability of digital representations of events flowing in a DDS. Yet, not all events are created equal and not all events are easily streamed. Event streamability represents "the degree to which a class of events is amenable to encoding and channeling through a digital data stream".[5] Streamability is a function of both a given event's characteristics (e.g., detectability, measurability) and the state of the art in available information technologies (e.g., representation, reach, and monitoring capabilities). Many valuable data are today only in a potential state of value release, waiting to be unlocked by the application of new IT that can channel them into a DDS. Consider for example call centers seeking to ensure consistent high quality customer service. Today calls are taped and reviewed on a sample

[4] Distributed Common Ground System – Army, https://dcgsa.army.mil/

[5] Pigni, F., Piccoli, G., & Watson, R.T. (2016). Digital Data Streams: Creating value from the real-time flow of big data. *California Management Review, 58*(3), 5-25.

basis in order to improve customer service by training and coaching agents on best practices. Speech recognition technology, however, has evolved dramatically as of late, making it possible to measure customer satisfaction in real-time. In other words, the conversations between call center agents and customers can be though of as a DDS. This enables process-to-actuate tactics, where calls are evaluated for signs of distress in customers' voice, in real-time, and escalated to supervisors as needed. Interestingly, many DDSs already exist as byproduct of previous IT investments and can be leveraged without having to wait for new IT advances. For example, Google searches from mere byproduct of the activities of millions of users have become valuable sources of trends, flu predictions, and innovative services like the autocomplete feature of online forms.

Strategy

Embracing DDSs as a value creation resource enables firms to craft IT-dependent strategic initiatives[6] and new business models. Much of our work for the SIM APC concentrated at this level. To date we have categorized and analyzed 171 initiatives – by startups and incumbents – with scope ranging from business model improvements to outright DDS-enabled industry transformation. We identify five distinct DDS Value Creation Archetypes: generalized blueprints for DDS-enabled strategic initiatives.

- *DDS Generation*: firms create value by originating the data stream, recognizing (or stumbling upon) events with high streamability.
- *DDS Aggregation*: firms collect, accumulate, and repurpose DDSs to create value through information services and platforms.
- *Service*: firms merge and process DDSs to provide new services or to improve existing ones.
- *Efficiency*: firms merge and process DDSs to optimize internal operations.
- *Analytics*: firms merge and process DDSs to enhance decision making by producing superior insight, typically through dashboards, data mining and data visualization.

[6] Piccoli, G., and Ives, B. (2005). Review: IT-dependent strategic initiatives and sustained competitive advantage: a review and synthesis of the literature, *MIS Quarterly*, 29(4), 747-776.

Capabilities

Our review of firms making innovative use of DDSs suggests that organizations need a distinct set of resources and capabilities to create and extract value from a DDS. We propose the following categorization:

- *Mindset* is the organization's culture, strategy and willingness to invest in data driven initiatives. It represents the attitude to explore DDS value potential, the supportive cultural context for experimentation, along with a strategic focus for capturing DDS value.
- *Skillset* represents the capability to manage DDS strategic initiatives. Thus, acquiring and orchestrating all the resources, technical and complementary (e.g., domain knowledge) to the DDS initiative, and assembling them in the form of new products, processes, and decision-making routines.
- *Dataset* is the capability to identify, intercept, and access the DDSs that match organizational needs for value creation, including mastering the streamability factors cited earlier. Dataset goes beyond mere data governance by encompassing event streamability, data quality and structure, and ultimately value.
- *Toolset* is the capability to consistently adapt to the new hardware and software needed to intercept emerging DDSs and harvest their content. It comprises both technical competencies and resources that are necessary to tap into the DDS. The toolset dimension influences directly the ability of a firm to profit from the increasing streamability of events.

In the context of the DDS business data processing framework (Figure 1), organization can leverage a new set of tactics to envisage innovative strategic opportunities. While events are increasingly streaming, firms may extract value from a DDS by taking immediate action based on the content of a single stream – such as a grocery order to the available Instacart's shopper[7] – or integrating several streams in real-time to gain superior insights. Process-to-actuate and assimilate-to-analyze tactics are the mechanisms triggering the value propositions portrayed by the value archetypes. Mindset,

[7] Instacar is a startup that uses independent pickers and drivers to deliver groceries from existing grocery stores.

skillset, dataset and toolset are abilities managers need to develop with their organization in order to fully realize the potential of DDS initiatives.

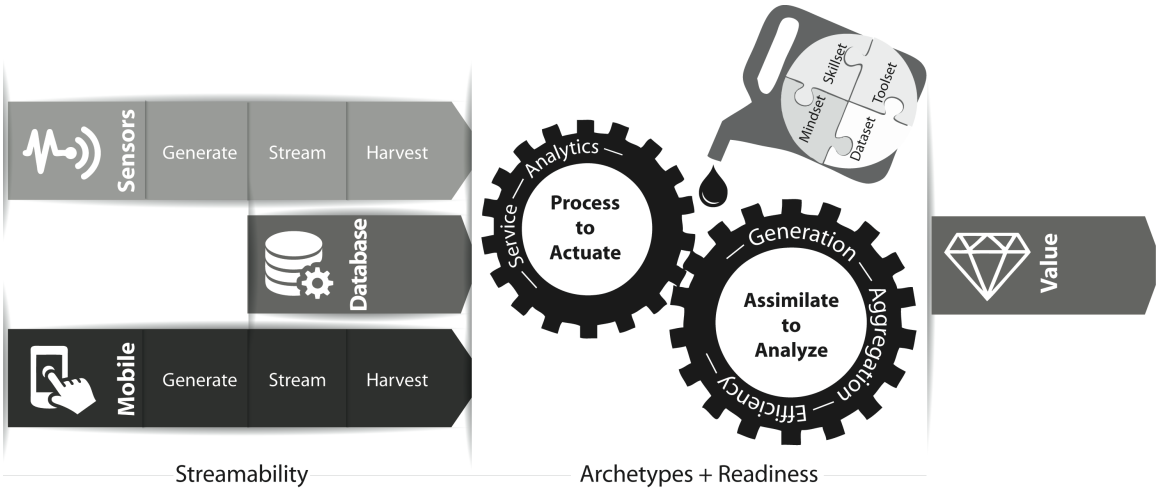

Figure 1: Integrative DDS Framework (adapted from Pigni et al. 2016)

The Future of DDS and DDS Research

The DDS landscape is in great ferment with an increasing realization that streaming data is not just one aspect of big data (i.e., velocity), but instead a source of value creation in its own right. While big data provides value through analytics almost exclusively, and therefore is a linear evolution of business intelligence, DDS value stems from both the assimilate-to-analyze and the process-to-actuate tactics. Vendors have realized this shift and now offer an array of solutions focused on both sets of opportunities. For example, IBM (e.g., InfoSphere Platform, SPSS, and Watson Explorer) and SAS (e.g., Data Loader, Factory Miner, Visual Analytics) are both offering solutions for assimilating and analyzing DDSs.[8] Cutting edge process-to-actuate tactics are realized by leveraging natural language processing (NLP), voice recognition and machine learning. Platforms such as Google Cloud Machine Learning, IBM Watson, Microsoft Azure Machine Learning strive to fulfill the promise of autonomous systems "taking action" (e.g., automatic translations, real-time "mistyping" corrections, message replies, product recommendation,

[8] Beyer, M.A., Thoo, E., Zaidi, E., Greenwald, R. (2016) *Magic Quadrant for Data Integration Tools*, Gartner, ID G00303221 ; Kart, L., Herschel, G., Linden, A., Hare, J. (2016) *Magic Quadrant for Advanced Analytics Platforms*, Gartner, ID G00275788

customer tickets routing). Hadoop and Spark are the open source building blocks of cost effective and scalable solutions for massive, real-time data processing. Additionally, Apache UIMA (Unstructured Information Management Architecture) is a forefront platform for content analysis and NLP on which message-based process-to-actuate tactics are realized. Smartphones, cars, appliances, and smart devices leverage process-to-actuate tactics to create customer value. The business applications are probably less visible or obvious. For example, insurance companies inform customers about an incoming hailstorm,[9] banks shut down credit cards when abnormal purchases hint of an ongoing fraud, personalized advertisers push offers based on inferred customer profiles, and anticipatory shipping is set to revolutionize retail logistics with products packaged and shipped when an imminent order is predicted – not actually placed.[10] It is clear, from these examples, that DDSs call for a paradigm shift in the use of information systems for value creation. The CEO of Flowthings, Eric Alterman, recently put it best: "Once you look at data as streams, the idea of parking that in a database, even in-memory, it's the wrong metaphor. Streams are data in motion and you keep it in motion until it does its jobs and comes to rest."[11]

Looking forward on the basis of our previous work, we see the evolution of value creation from DDS developing along the following vectors:

- The Internet of Things (IoT): Blake Ives and his colleagues suggest in this issue[12] the real-time DDSs that stem from IoT devices offer "as great an opportunity for business model innovation as the rise of the commercial Internet was in 1993." Their suggestion rests on the notion that, as computing capabilities move out of dedicated devices (i.e., computers) and into everyday objects, the IoT promise to bring the seamlessness of the information world to the physical world. Nick Franklin, the former Executive Vice President of Next Generation Experience at Walt Disney Parks and Resorts worldwide, captured this sentiment perfectly when he stated: "What people call the Internet of Things is just a technological underpinning that misses the point. This is about the experiential Internet. The guest doesn't need to know how it happened."

[9] Hail Hero hail warning system, Budget Direct, https://www.budgetdirect.com.au/existing-customers/hail-hero.html

[10] Walorska, A. M. (2015). Turning Data Into Experiences. Pro-active Experiences and their Significance for Customers and Business. *Procedia Manufacturing*, *3*, 3406–3411. http://doi.org/10.1016/j.promfg.2015.07.53

[11] Higginbotham, S. (2016, August 12). Two startups break through the computing fog. Retrieved from https://medium.com/@gigastacey/two-startups-break-through-the-computing-fog-e256ff26c42a

[12] Ives, …. (2016)

- Conversational Interfaces: Conversational interfaces promise to bring to the mainstream Mark Weiser's prediction that "the most profound technologies are those that disappear. They weave themselves into the fabric of everyday life until they are indistinguishable from it."[13] Weiser coined the term "ubiquitous computing" when he was head of the Computer Science Laboratory at the Xerox Palo Alto Research Center. It was a vision of human computer interaction that would be seamless. That vision seems close at hand with the evolution of cloud-enabled natural language interfaces (e.g., Amazon Echo, IBM's Watson Conversation) and chat bots and assistants (e.g., Nuance Nina). As we have become used to "talking" to one another via text message, Whatsapp or Skype, we have created the precondition for "seamlessly" interacting with computers. This is an interesting shift, reminiscent of the emergence of IT-enabled self-service. As websites began to spring up to enable a widening array of commerce online – from purchasing books on Amazon, to booking tickets on Expedia, individuals started to appreciate the value of IT-enabled self-service, and designers began to hone in on customer experience design principles. While many dot-coms imploded in the early 2000s, IT-enabled self-service trickled into everyday activities – from checking out a book at the library, to checking in for a plane ride. We believe that conversational interfaces represent a similar shift. They are not simply a new user interface. When framed as a set of purposeful DDSs, conversational interfaces represent a new frontier for value creation, a new platform on which to build a new wave of business models.
- Artificial Intelligence and Cognitive Computing: The ultimate concretization of a process-to-actuate tactic is leaving business decisions totally up to algorithms. As Muller and his colleagues[14] note in this issue the more that the organizations they studied explored the opportunity to have algorithms react autonomously to detected events, the more they were concerned by the extent they should, or shouldn't, let technology control their service operations. Algorithms can now learn and discover pattern in data, and use this newly acquired knowledge to act autonomously. The major players, IBM, Google, Microsoft, have open sourced cognitive APIs to foster the development of more "intelligent" applications and services. Software that seeks to infer new knowledge, to discover events, to derive the

[13] Weiser, M. (1991). The computer for the 21st century. *Scientific American*, 265(3), 94–104. (p. 94)

[14] Mulller et al (2016)…

context in which events are occurring, increasingly scrutinizes DDSs autonomously. While today's applications are predominantly using streams from web searches, online commentaries, Wikipedia, and social networks, IoT devices are set to breathe new life into AI-enabled process-to-actuate tactics. The synergies from local, device generated DDS and those from external sources including apps, remote sensors, or the web raised business expectations. While the "Era of AI" is solidly rooted in DDS, most advances in the process and actuate space will require the integration of various sources, APIs, services and technological components, with the added hurdle to find where and if the new insight will actually be valuable.

- Health awareness and analytics: Citizens and physicians have traditionally relied extensively on sparse measures to assess healthiness. Only the very ill are intensively measured, but now with smart watches and pedometers, individuals can generate real-time DDSs of vital signs and their physical activities continually. As non-intrusive sensors for other vital signs, such as blood pressure, are embedded in smart watches, we foresee the emergence of the FitGbytes[15] as a fashionable wearable recording gigabytes of data about a person over a year. Combine these data with a person's genome data and compare them with millions of other individuals and today's health analytics will soon look remarkably primitive.

The prior trends create fertile ground for academics to answer new theoretical and applied research questions about value creation with DDS. We provide a tentative list, by no means conclusive, to stimulate discussion.

- While the concept of streamability is intuitively appealing, it is not yet understood. Yet, if we can develop a "theory of streamability" it would be very useful in guiding the search for opportunity for new DDS generation. Such a theory would require us to understand under what conditions events are likely to stream. Streamability depends on the inherent characteristics of an event and the advances in information technology and knowledge necessary to generate the digital representations of those events. Over time the miniaturization of sensors, the continued increase of available computational power, and new algorithms have pushed the frontier of streamabilty.

[15] The Fitbit was a popular device introduced in the middle of second decade of the 21st century to measure electronically the number of steps a person took each day.

However, we are still far from a world were managers don't wander haplessly: "I wish I had access to data on [important issue/decision]". What are the classes of events that are amenable to streaming? What are the characteristics of events that act as obstacles to streamability? What technological changes are likely to remove such obstacles? What are the psychological, organizational, social, or political obstacles to streamability? These are some of the questions awaiting solid answers.

- While a single DDS may carry a limited number of events, combining streams, and aggregating events will provide the additional opportunity to identify patterns, or more complex events bearing greater insight, and potential actions. This is the what Complex Event Processing (CEP) principles suggest. Indeed, CEP technologies are becoming foundational in a broader set of applications[16] for processing IoT increasing data volumes and types of event inputs, combine event processing techniques, and provide predictive insight. But how can managers identify the valuable events in DDS? How should they prioritize the different input streams? And how do we evaluate the performance of these increasingly complex systems? Are these systems best suited for internal firm operations or will customers accept them as well?
- Increasingly, customer interactions are captured in DDSs enabling new levels of automation (e.g., self-service, chat bots) radically transforming customer service as we know it. Conversational interfaces are a clear opportunity to impact customer experience and engagement. A virtual assistant can react and adapt in real-time to the context of the conversation, providing solutions, acting promptly, and even "persuading" customers. Far from being consolidated, designing conversational interfaces is clearly different than developing an app, and is an open – and multidisciplinary - research topic. What are the key design elements of effective conversational interfaces? What is the role of contextual information in the conversation? This is an interesting shift, reminiscent of the emergence of IT-enabled self-service. The recent launch of Apple AirPods signals the mainstreaming of conversational interfaces, and manager must start planning for how they will foster customer relationships in this new environment.

[16] Luckham, D. (2012). *Event Processing for Business: Organizing the Real-time Enterprise.* Hoboken, New Jersey: John Wiley & Sons, Inc.

- Every information processing paradigm brought a new set of skills and resources. DDSs require organization to equip for a different journey with increasingly complex projects, leveraging new set of skills. The chronic shortage of data scientists[17] well depicts this trend. However, the DDS opportunity demands an eclectic set of competences in sensor design and optimization, circuit design, machine learning, security engineering, and connected device frameworks. This last information processing paradigm is blurring IT barriers, challenging the nature of IT capabilities and their role in firm success. What would be the role of IT capabilities, when firm's resources, products and services become all IT-related?
- In the DDS paradigm where digital events have a relevant business value, part of the competitive battle will be played in securing DDS access. Weather, asset geolocation, heartbeat, financial transactions, credit card purchases, are possibly "rare" DDS on which firms could build competitive advantage. With the acquisition of the Weather Company IBM secured both the data and the know-how of a fundamental business variable: weather. IBM chose the "buy" approach, but in other cases DDSs may not yet stream, requiring the design of new platforms or devices. While virtual networks benefit of nearly unlimited economies of scale, physical networks, like in the old days of the telephone, are different. Firms engaging in DDS initiatives become part of an ecosystem.[18] Thus, they face the dilemma of collaborating to reduce costs versus relenting control of their data. Moreover, increased DDS processing requires interoperable systems, standard protocols, and practices. How will standards impact the success of DDS initiatives? How will DDS ecosystems organize for interoperability and standardization?

The DDS landscape is evolving rapidly and questions, both theoretical and practical, abound. There is a great opportunity for practicing managers and academics to partners in seeking answers.

Introduction to the Special Issue

[17] Noyes, K. (2016, January 21). Why "data scientist" is this year's hottest job. *Computerworld*, Retrieved from http://www.computerworld.com/article/3025440/data-analytics/why-data-scientist-is-this-years-hottest-job.html

[18] Jernigan, S., Ransbotham, S., & Kiron, D. (2016). *Data Sharing and Analytics Drive Success With IoT - Creating Business Value With the Internet of Things* (2016 Global Executive Study). MIT Sloan Management Review.

This special issue began forming in December 2014 when we were asked to create a call for papers for the Pre-ICIS 2015 MISQE Academic Workshop on Digital Data Streaming (DDS). The workshop stimulated interest in this emerging area of inquiry and eleven full-length papers were submitted to the special issue. After several rounds of reviews four submissions were accepted. The articles cover a wide variety of perspectives on the DDS phenomenon, and they all share a focus on value creation and the objective of offering tangible managerial guidelines.

The first article by Blake Ives, Biagio Palese and Joquin Rodriguez posits that the changes driven by the Internet of Things (IoT) will likely be far more profound than those engendered by previous mobile devices. Taking the perspective that harnessing the business value of IoT is predicated on the ability to leverage the DDSs that IoT devices generate, the authors focus on the customer service domain. They organize their analysis of 191 IoT initiatives using the Customer Service Life Cycle (CSLC) as the guiding framework. The analysis shows how companies are creating services and applications that impact a narrow range of functionalities, focus on one or two phases of the CSLC. Moreover, they tend to deploy IoT investments incrementally in those areas where they had focused prior customer service efforts. In line with the spirit of the *MISQ Executive,* the authors leverage their insights to offer guidelines to managers considering IoT investments.

The second article, by Oliver Müller, Iris Junglas, Stefan Debortoli, and Jan vom Brocke investigates how three organizations - Florida State University (FSU), Hilti Corporation, and Inventx Corporation - leveraged the DDS stemming from customer service request to improve their service process. The authors show how these organizations successfully deployed text analytics solutions, and obtained tangible benefits. Their article contributes to the DDS literature by exploring the central role of domain knowledge in interpreting text analytics and actuating the gained additional insights. The lessons derived from the cases demonstrate how to evolve a DDS initiative from the tactical to the strategic level, by challenging and developing organizations' mindset, skillset, dataset and toolset. The authors distill their insight into a four-step procedural roadmap to support firms in leveraging textual DDS for competitive advantage.

The third article, by Abhijith Anand, Rajiv Sharma, and Tim Coltman outlines four steps to success for CIOs focused on creating value for their organizations. These steps are (1) engage top and line management to explore and evaluate DDS-based innovations; (2) engage line managers and specialist digital data

support teams to understand the potential business value of DDS-based innovations; (3) invest in maturing the DDS platform; (4) make resource allocation processes progressively more agile. The authors take an investment perspective to DDS and explain how organizations should manage this class of investments. They help move DDS research beyond highlighting the dimensions of the opportunity and attempt to systematize its management toward higher efficiency and effectiveness of DDS investments. In line with the thrust of the special issue they show that advances in information technology should be judged very pragmatically on their potential to create value through new information systems offerings. They highlight that execution of these steps requires agile resource allocation, because there is an interaction between a DDS platform's maturity and top management commitment.

The fourth article, by Matthias Herterich, Falk Uebernickel and Walter Brenner analyzes the path taken by two major German global corporations – Siemens and Thyssenkrupp. The authors follow the journey of these organizations as their understanding of digital data streaming deepens and they discover how to enhance value creation thought the introduction of a range of information systems designed to extract value from available DDSs. The authors uncover the learning path in the conversion of a new DDS to a portfolio of value creating information systems. These paths are generalized into models for minimizing risk when learning about the possibilities enabled by a new information technology – as they start with internal projects and gradually ripple out to partnering in value co-creation. This article advances the DDS literature by adding the experience of established companies to our understanding of DDS opportunities. More importantly they demonstrate how to plan a journey for systematically learning and exploiting DSS, while controlling risk.

As with any special issue, there is a lot of effort by many participants. We thank the discussant at the workshop, the reviewers, all the authors of accepted and non-accepted papers. With this special issue we mark an important point. We sit at the edge of a paradigm shift of a magnitude comparable to the democratization of the Internet in 1993. With the advent of the commercial Internet, we deployed digital technology to "digitize" reality, to model and manipulate its representation. Free of the constraints of "atoms" and distance, we quickly developed an impressive industry fostering productivity, increasing firms' responsiveness, improving customer service, and interconnecting people and objects. Now, we are experiencing an extensive and global intertwining of the digital and physical worlds – as in the famous

Escher illusion (Figure 2) physical has digital representations and digital has physical actuations. Sensor networks and sensitized objects, are populating the environment with autonomous cars, smart cities, and smart phones. Smart devices, virtual assistances, AI do more than just observe us, they will directly act upon our reality and direct our actions. For example, smart phones remind you to stand every hour and when to take a mini-meditation break, among a host of other suggestions. The Internet of Things (IoT), in many ways, understates the profoundness of next paradigm shift. We are moving towards an Internet of People (IoP), where collection of interacting smart devices powered by DDSs transform citizens' everyday life to create a sustainable, resilient, and healthier society. Digital data streams are an essential seed innovation of this transformation.

Figure 2: M.C. Escher *Reptiles*, lithography, 1943