Discovery & Identification Technologies for the Next Generation Internet

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Introduction

The digital industry is embracing the Next Generation Internet (NGI) - a new network of people, places, and things that puts human at the centre of attention, brings a plethora of personalised services within our reach and empowers us to be more efficient, creative, knowledgeable, and successful. One of the fundamental technical challenges of this new network is the "Discovery and Identification" of relevant, contextual and personalised information, services and experiences. Technology supporting this critical facet of NGI will need to access billions of heterogeneous data sources, stored or real-time, locally or globally, from personal and public terminals, mobile, wearable, Internet of Things, and cyber-physical systems. This technology will enable users to search a massive data space intuitively, often using natural languages, or other direct and indirect means intelligibly. This technology will understand users' intent, reflect on users' situational need and present relevant information services in a meaningful and personalised way. This report explores some of these experiences and reflects on the technical challenges that need to be addressed to uncover those experiences.

Envisioned User Experiences

We begin with four illustrative user experiences to draw upon a set of key research challenges for the discovery and identification technology of the NGI.

- Imagine, what if our Internet search experience turns into a human conversation in which intelligence, intuition and experience are combined to answer all your information need. You don't find information; you chat with your search application. Instead of

receiving a list of textual links, you get information as if your friend is answering your question in a humane way. What if you can search for an experience tailored to your personal choice and lifestyle from the Internet that is driven by experience instead of bits and bytes of data.

- Imagine, what if you can search the real world around and far from you in an engaging way. Imagine evolving in a purely digital world where you automatically discover sensors and services based on your credential, capabilities, etc. Imagine yourself in a new city, where you are guided to the nearest parking bay, which is safe and secure, guides you via the most cheerful path to the café. Imagine if you receive a real-time notification that your upcoming bus is overcrowded or the next entrance of the station is closed so that you can make informed decisions.

- Imagine, what if your search application is aware of your intention and activity, and discovers, filters, and presents information services just-in-time in a way that helps you to do things quicker, take informed decisions faster, and essentially help you to save time.

- Imagine, what if your search application eliminates linguistic boundaries, and turns into a multi-lingual experience sharing platform in which your questions are answered in a uniform and natural way combining multi-modal cross-language information.

- Imagine your personal data is protected and when someone receives them, they are processed in a way you decided.

Research Challenges

Experiences such as the ones mentioned above demand a radical transformation of today's Internet and the associative technologies. While, this report primarily aims at discussing the research challenges concerning the discovery and identification of information services, and experiences in that new Internet, our hope is that this discussion will instigate critical dialogues in the larger NGI working group. In the following, we discuss these challenges from three perspectives : system design, modelling, and data transparency.

Re-engineering The Physical Web

We are observing a metamorphosis of the world around us - as everything is becoming connected, the boundaries between the real and the digital are progressively blurring. This transformation will have a profound impact on how human will experience and interact with future information services, be it physical or digital. However, this transformation also challenges us in multiple fronts with respect to interaction some of these are mentioned below.

- Given the proliferation of the Internet of Things, it is natural that significant information sources of the NGI will be driven by connected objects of many forms and modality. This demands for a planet-scale IoT operating system that manages access and data heterogeneity of billions of sensors and devices in a unified manner, enabling their services to be discovered and accessed easily, and uniformly. To this end, it is important to look at the current industrial efforts, e.g., Google's Brillo, AllSeen Alliance's Alljoyn, etc. and streamline their best practices into a coherent architectural blueprint that will form the fabric of future connected objects, and their interactions. This is critical to ensure that we have a standardised mechanism to discover, filter and access connected objects' services. This calls for an open design approach at all levels - hardware, firmware, middleware, software, data, and services. Many of today's leading IoT solutions are proprietary, and tied to specific vendors. However, for truly unleashing the power of NGI, and in particular for the European Eco-system it is absolutely necessary to eliminate the silo-based approaches, and to develop an open semantics at all layers and associated eco-system around them for interoperable interactions within and across devices and their services.

- Given the physicality of IoT, it is natural that devices, and services will be spatially distributed. As such it is important to ensure that the discovery and identification technologies for the NGI address the locality aspect adequately, i.e., users will have a unified but contextualised search experience irrespective of the location and proximity of the devices and services. In addition, the granularity of such spatially-aware search needs to meet the human intuition and expectations, i.e., one should be able discover, filter, and rank devices, and services that are in their perceptual range, e.g., walking distance.

Processing Distributed and Real Time Streams

With the explosion of IoT, user generated content, and social-media data, the NGI will primarily be a massive-scale stream space with unprecedented velocity, variety and volume. Naturally, this live stream space – which is different than today's static Big Data – demands a brand new processing approach at all stages – capture, store, discover, filter and presentation

- One of the key challenges of NGI is the management of live streams. This management aspect includes discovering, fusing and filtering multiple relevant and often ephemeral streams that are relevant to an individual's need or to a service. These streams, in most cases, will be spatially distributed, and the query might demand ad-hoc fusion or aggregation of multiple streams partially or wholly. These challenges demand a fresh system approach towards the discovery and identification technology of NGI tailored to live and stored stream processing.

- Related to the previous aspect, it is important to consider how to obtain a particular piece of data – live or static given the availability of multiple mechanisms. For example, the distance to the car ahead can be measured by infra-red, sonar, differential GPS, etc. Therefore, it is essential to understand and develop Quality guaranteeing aggregation methods.

- The streams are temporal by nature. As such, data quality degrades with time in different manners. As such discovery and identification technologies will need to be aware of this phenomenon and should provide clear information on prediction or aggregation uncertainties.

- Most of the streams are ephemeral and personal. As such, we need to carefully assess whether it is necessary to move them to a central location to be processed. We need to device techniques for distributed processing of data where the minimum amount of data is moved toward each other for the only purpose of adding value and in respect of privacy and confidentiality rules.

Understanding Users and The World Around Them

The IoT, mobile and wearable allow us to see the world through the lens of an array of low-power sensors – cameras, microphones, accelerometers, etc. Collectively these sensors aim to create better understandings of humans' activities, and where, when, how they interact. The hope is that this understanding will allow the creation of contextual digital services and experiences that will fundamentally change the way we live and work. Indeed, context-aware discovery and identification will be a hallmark for NGI. Here are set of challenges that we need to address to realise the vision of a contextual Internet.

- The context of a user query is an important aspect to take into account: who is making the query, where is the query made, or when is it made may determine different levels of response. Besides, such situational context will also determine the access rights and relevant privacy and security dynamics (more on this later).

- Understanding users' will require inference on raw sensory data to produce rich and meaningful information. This demands advancement in the machine learning models in many fronts, and in particular development on contextual models operating on multi-modal sensory data that can shape the personalised response of users' queries.

- Given the cognitive resources of human are limited, it is essential to reduce information overload and deliver the minimum amount of information and service in a given context. Indeed, the better a service understands the context of a user, the easier it will be to deliver the minimum and right amount of information.

- Related to the previous challenges, it is equally important to consider the intelligibility and transparency of these contextual models in the design time so that these models do not only provide rich inferences but also offer explanation on how and why these models have reached to these inferences.

Language and Modality Independent Search Experience

A vast proportion of the traffic of the NGI will be governed by multi-modal content in addition to static text produced in many different languages. Despite phenomenal progress in language

translation and machine intelligence research powered by Deep Learning, today's Internet is still unilingual and unimodal. Although, current practice promotes content annotation with meta-data to overcome this limitation, but we need a fresh approach to accommodate multi-modality and multi-lingual content aggregation.

- Ideally, searching should be done in any language and modality, be it text, image, sound, smell, etc. It is important to consider how to aggregate, process, and filter these queries breaking the linguistic and modality boundaries.

- Related to the previous challenge, it is essential that search responses cluster answers gathered from different sources with different languages or modalities to offer a summarised view.

- The search experience should reflect users' needs contextually, and should offer the responses in a conversational form. The popular mobile application Quartz is a good example of such experience for the manually curated news. However, it is important to scale this experience to all aspects of NGI, and demands significant research in NLP, semantic and data visualisation technologies.

Data Ownership and Access

The dynamics of NGI in combination with IoT naturally means this envisioned technology will substantially shape our experience with new, useful, exciting, and sometimes entertaining information services. As discussed above, the common facets of many of these experiences are that they collect data that is produced *by* or *about* people. This increase in data volume and complexity raises the important issue of potential privacy and information exposure indeed, the importance of people's personal data has become almost a political issue – with concerns that large corporations will exploit people's personal data to gain competitive differentiation. As such it is of utmost importance that NGI workgroup and associated technologies like the one discussed here understand and accommodate policies that protect personal data.

- We need to carefully assess how to manage the access control for every single data and service units preferably at individual scale. Technology that can capture and process data

with personalised privacy rules needs to be developed, and should become a key foundation of NGI.

- Data tracking should help people know where their data is and who is doing what with them. In addition, verification of data is important and demands extensive research to understand and devise user centred techniques to verify that a certain piece of information is exact and accurate and that it has not modified or tampered in any form.

- The regulation of access rights on users' data should involve data owners and collectives. The autonomy of data gathering devices and data aggregation processes has to be limited by the consent given by data owners. Techniques that guarantee the respect to this limiting factor have to be developed.

Algorithmic Systems Transparency

We need to carefully address transparency and accountability for Internet services and technologies when dealing with data mining, discovery, recommender systems or predictive/prescriptive analytics for computer-aided decisions.

The algorithmic systems (data and algorithms) transparency is essential for digital trust and appropriation of emerging technologies and new generation Internet services. Today, there is an important informational dissymmetry between the on-line platforms owners and the citizens who are the users. Services consumers have little control over how companies and governments use their data. An important shift deals with the control of data use and the intelligibility of algorithms (explaining how a specific algorithm works), not only on the Internet but also on other connected services.

- The scientific challenges for "accountable-by-design" methods for research community are very important all over the world and need to explored further in depth. New workshops are emerging in such topics for example: "Fairness, Accountability and Transparency in Machine Learning" 2016[1]. Responsible-by-design methods required checking that the

[1] http://www.fatml.org/schedule/2016

properties of ethical, fairness, transparency, intelligibility, loyalty and equity have been taken into account at early stages of algorithmic conception of digital services. DARPA has launched the "Explainable AI" initiative in August 2016[2] (XAI). Data Transparency Lab have been founded and launched early 2015 by MIT, Mozilla and Telefonica[3]. At the DTL'2016, a new initiative was presented[4] called "Corporate Accountability Index".

- The federal Trade Commission (USA) pointed out the importance of mastering Big Data Technologies as they impact people lives[5] and could be tools for inclusion or exclusion. The national artificial intelligence research and development strategic plan of the USA[6] pointed out the priority of "Understand and Address the Ethical, Legal, and Societal Implications of AI" including the accountability and transparency among seven other strategic priorities.

- On December 2016, the French government announced the launch of a national scientific platform (TransAlgo) to foster research and development on responsible and transparent data management and analytics. Much interest is gathered from other European countries about this initiative.

To tackle these issues, Europe should address Big Data technologies accuracy and reliability including data vulnerabilities and provenance together with algorithmic accuracy. Facing machine learning multiple bias sources is challenging from research and technical points of view, as robustness to diversion, corruption and diversion is needed. Efforts should be dedicated developing technical trustworthiness measures and responsible-by-design methods.

[2] http://www.darpa.mil/program/explainable-artificial-intelligence
[3] http://www.datatransparencylab.org
[4] https://rankingdigitalrights.org/
[5] https://www.ftc.gov/system/files/documents/reports/big-data-tool-inclusion-or-exclusion-understanding-issues/160106big-data-rpt.pdf
[6] https://www.nitrd.gov/PUBS/national_ai_rd_strategic_plan.pdf