Master Thesis Title: **Timing In Persuasive Designs**

TIMING IN PERSUASIVE DESIGNS

Designing Information Systems that can Sense & Seize *Kairos*

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Prayson W. Daniel

Aalborg University

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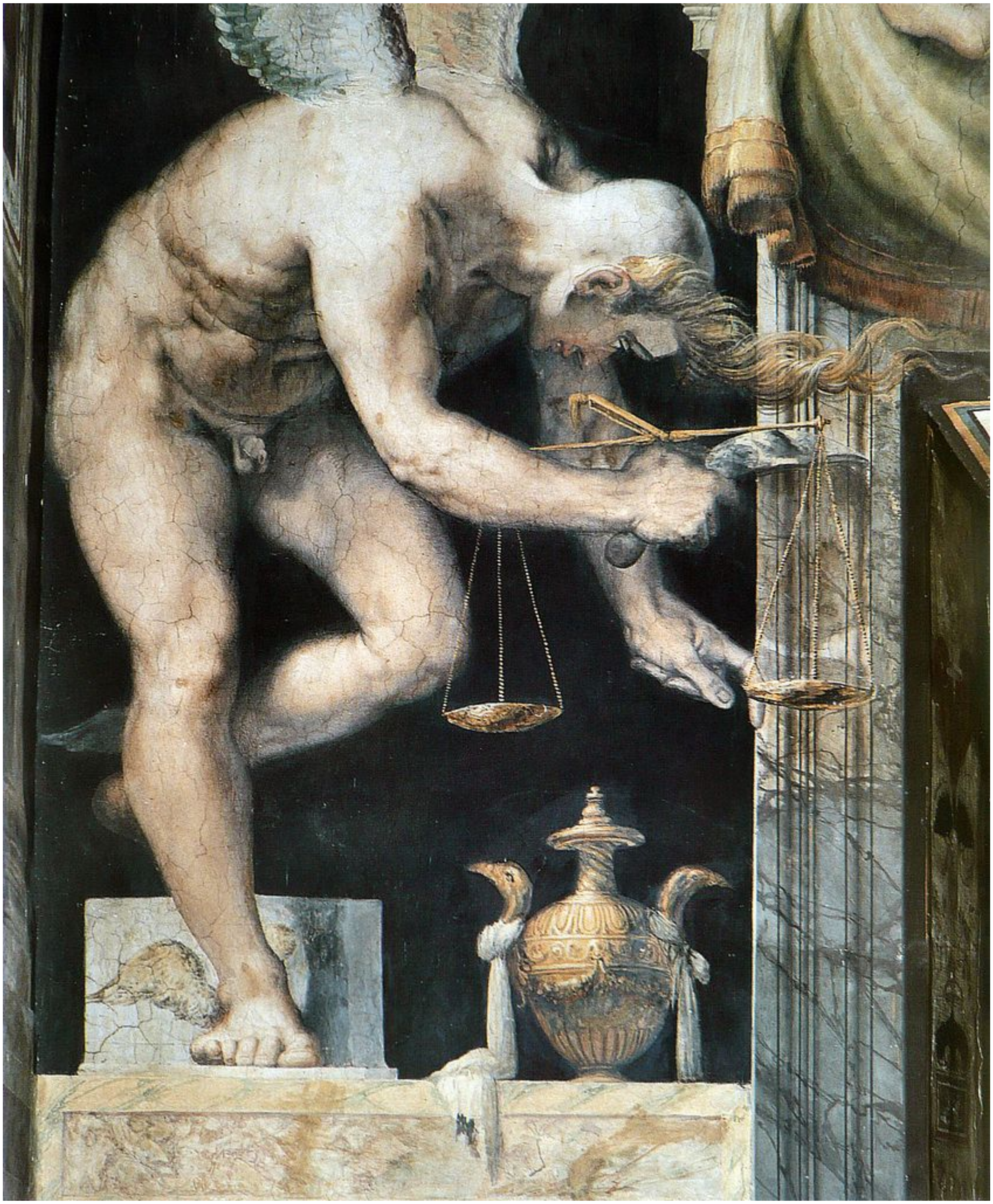
Contact Information:

Author: Prayson W. Daniel

E-mail: praysonwilfred@gmail.com



Francesco Salviati, Kairos (Sala dell'Udenzia invernale), 1552-1554, Rome, Palazzo Ricci

Cursu uolucri, pendens in nouacula,

caluus, comosa fronte, nudo corpore,

quem si occuparis, teneas, elapsum semel

non ipse possit Iuppiter reprehendere,

occasionem rerum significat breuem.

Effectus impediret ne segnis mora,

finxere antiqui talem effigiem Temporis.

- Phaedrus Babrius[1]

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[1]Babrius (1965) *Aesop's Fables* 5.8; Laura Gibbs' English translation of the fable:

"Running swiftly, balancing on the razor's edge, bald but with a lock of hair on his forehead, he wears no clothes; if you grasp him from the front, you might be able to hold him, but once he has moved on not even Jupiter himself can pull him back: this is a symbol of Opportunity, the brief moment in which things are possible." (Gibbs 2002)

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ABSTRACT

Fine-tuned just-in-time persuasive messaging influence user's decision making. For ICT to seize just-in-time moment, it must first *sense* such a moment. Sensing *kairos* in ICT pauses is one of the strategic and significant challenges facing persuasive technology. The author argued that the concepts of Bayesian network and nature of time can aid in designing information systems that are time sensitive and predict user's possible next action. ICT that utilizes the ideas of A-and B-perspectives of time, branching timeline, and Bayesian network are by elasticity of inventiveness a solution towards solving the challenge of *sensing* and seizing kairos in ICT.

KEYWORDS: Bayesian network, kairos, A.N. Prior, branching time, persuasive designs, suggestion technology

TIMING IN PERSUASIVE DESIGNS

In ancient Greek, timing, or more correctly, “opportunity”, was personified by the youngest and most beautiful son of Zeus, Kairos. Covered with long forelock on his forehead, Kairos’ forelock could be seized as he swiftly passed by. He, on the other hand, was bald behind. This meant that once Kairos had passed by, he could not be seized. In *Descriptions 6, On the Statue of Opportunity at Sicyon*, Callistratus provided us with an extraordinary descriptions of Kairos statue. He wrote:

> [H]e stood poised on the tips of his toes on a sphere, and his feet were winged. His hair did not grow in the customary way, but its locks, creeping down over the eyebrows, let the curl fall upon his cheeks, while the back of the head of Opportunity was without tresses, showing only the first indications of sprouting hair. […] the wings on his feet […] suggested his swiftness, and that borne by the seasons, he goes rolling on through all eternity, […] the lock of hair on his forehead indicated that while he is easy to catch as he approaches, yet, when he has once passed by, the moment for action has likewise expired, and that, if opportunity has been neglected, it cannot be recovered. (Callistratus, LCL 256: 397-399)

Kairos, thus, represents, as Ernst Panofsky stated, “the brief, decisive moment which marks a turning-point in the life of human beings or in the development of the universe” (Panofsky 1962, p.71). Timing is critical in interactive information technologies, *viz.,* technologies that are deliberately design to change their users’ beliefs, desires, and intentions, namely the information, motivational, and deliberative states of the users. In persuasive technologies, as B.J. Fogg noted, "*must* identify the right time to make the suggestion" (Fogg 2003, p. 43 emp. added), since seizing the opportune moment and context to present a fined-tuned suggestion, as documented by Campbell et al., (1994, pp.43-49), Fogg (ibid, pp.41-59; 183-208), Kreuter and Strecher (1996, pp.97-105), Skinner et al., (1994: pp.43-49) and Walji (2006, pp.7-89), increases the user's probability to performed desired course of action.

For information system to seize the opportune moment, it must sense the presence of such moment. Sensing *kairos* pauses is one of the strategic and significant challenges facing persuasive technology. W. IJsselsteijn et al. stated the challenge as following:

> [W]hen applying context-sensing and inferences for just-in-time persuasive messaging, the benefits that such interventions will bring are crucially dependent on the quality and relevance of the machine sensing and inference algorithms. As the physical world and human behaviour are both highly complex and ambiguous, this is by no stretch of the imagination a solved problem. Most problematic will be attempts at inferring some internal human intent, requiring levels of intelligence even a human would find difficult to attain (2006, p.3)

Acknowledging the challenge above, in their paper titled 'It might be Kairos', presented at the third international conference on Persuasive Technology, at the University of Oulu, in Finland

2008, Aagaard, Moltsen and Øhrstrøm[2] provided Bayesian network as tool to solve this challenge. This thesis advances AMØ's solution as it selectively explored concepts of "just in time", "time window", "being early/late" in philosophy of time, and Bayesian network ways of sensing and seizing such moments.

The central argument of this thesis is that the concepts of Bayesian network and nature of time can aid in designing information systems that are time sensitive and predict user's possible next action. ICT that utilizes the ideas of A-and B- perspectives of time, branching timeline, and Bayesian network are by elasticity of inventiveness a solution towards solving the challenge of *sensing* and seizing kairos in ICT. Seizing such moment would aid in machine-to-machine[3] contextualization of tailored suggestion that will increase the user's probability to performed the desired course of action.

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[2] herefter AMØ

[3] Machine-to-machine(M2M) is a label of technologies that exchange data without human assistance or supervising. Sensing kairos, as argued below would enable systems to form contextualized suggestions.

With the passage of time, the psychology of people stays the same, but the tools and objects in the world change. Cultures change. Technologies change. The principles of design still hold, but the way they get applied needs to be modified to account for new activities, new technologies, new methods of communication and interaction.

– Don A. Norman[4]

GENESIS: WHERE THE JOURNEY BEGAN

In his best-selling book that aims to offer practical principles to guide designers to design "products that fit the needs and capabilities of people" (Norman 2013 p.218), *The Design of Everyday Thing*, UX guru, Don A. Norman, captured one of system problems that befell my sister-law, as summarized in a paragraph below, and how such incident encouraged me to investigate how such problems could be solved. Norman wrote, "if the system lets you make the error, it is badly designed. And if the system induces you to make the error, it is really badly designed" (ibid, p. 167)

[4] 2013, pp.xvii-xviii

The sky was blue, the grass was green, and the air was warm. It was a perfect day and time for both my sister-law's family and ours to meet at swimming hall for a swim and family-time together in early July 2013. We had agreed to meet at the swimming hall at 10:00 a.m. Since both families had children under a year-old, this was a perfect time for such activity, since it gave our families a few hours to swim before the babies' noon napping time, 11:45 p.m. Sarah, my sister-law, was standing at a bus-stop were two buses (1A and 133), heading towards the swimming hall, departed. According to Rejseplanen App (a mobile journey planner for Denmark public transportation application), bus 133 was scheduled to arrive 2 minutes before 1A. Since bus 1A arrival bus-stop is closer to the swimming hall compared to 133, Sarah chose not to board on 133 but wait 2 minutes for 1A because of her desire for a short walk towards the swimming hall, as the buses arrived. The scheduled 1A, which Sarah was waiting for, never showed up. If she knew that the scheduled 1A was delayed or canceled, she would have chosen otherwise. She would have boarded 133 because her *greates*t desire[5] was to be at the swimming hall on time.

In this scenario an intervening change of information, within just-in-time time window, would have brought about change in the way Sarah would have viewed the world, her beliefs, (and her desires), which would in turn assist, or more correctly "influence", Sarah to make an informed decision. Due to lack of just-in-time suggestive technology, Rejseplanen App (2013 edition) induced Sarah to make an error in her choice of bus.

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[5] Her desire to be on time is greater than her desire for a short walk

Norman correctly stated that: "[i]t is the duty of machines and those who design them to understand people. It is not our duty to understand the arbitrary, meaningless dictates of machines" (2013, p.6). Is it possible that Rejseplanen App, or other systems, could be designed in such a way that their users' intentions were sensed and seized? Is it possible to design a system that could infer what Sarah's intentions were and in such time window offered the persuasive message, needed information in this case, that would have assisted her decision making? These are bewildering questions that began this exodus quest.

EXODUS: INTRODUCING RESEARCH QUESTIONS

The rise of mobile devices that unremittingly receive and transmit data through cellular data, wireless fibers (Wi-Fi), Global Positioning Systems (GPS) networks, and Bluetooth (iBeacons[6]) , has enabled data gathering and analysis of both approximate system locations and time-spent (and frequency) in each of the recorded locations. Using Bayesian machine learning algorithm, collected data are used in persuasive systems to *(a)* first form a pretty accurate deduction of at which of the recorded locations is the system-user's home, office, favorite locations *et cetera*,

[6] Gathering of location data via Bluetooth Low Energy wireless technology that allow system to compute their location on a micro-local scale.

based on the frequency and time of day spent in each location, and then *(b)* utilized such deductions to form personalized suggestive services.

Apple iOS systems, for example, has multiple application that utilize geo-location data to offer external triggers. Here I looked at two. Traffic Condition and Location-Based App Suggestion application. Traffic Conditions application use temporal geo-location data to form predicative traffic routing, while Location-Based App Suggestion compute and suggest the most likely mobile application the user might want to use (see Table 1 Apple iOS's Applications) given his or her location and time. In both applications, Apple iOS systems have somewhat managed to sense a broad "*time windows*". It is broad, because they, as shown below, fail to *sense* "being (too) early/late" moments and machine-to-machine collaboration.

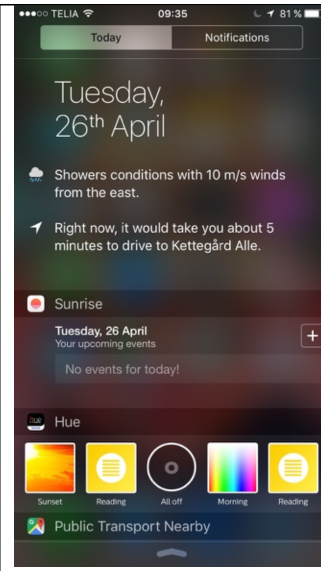
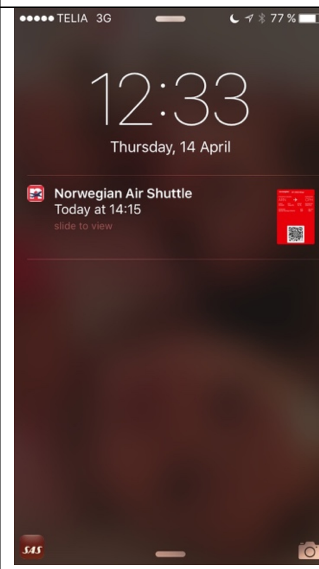
<table>
<tr>
<td>I: John is a father of two. His children go to a daycare located at Kattegård Alle. He frequently makes short stay at Kattegård Alle every weekday between 7:00-8:30 a.m. Given that it is Tuesday morning, and John is at home, the probability that he drops his children off at daycare between 7:00-8:30 a.m. is very high. Apple iOS's Traffic Conditions offered suggestive message (center of the screenshot), of traffic routing.</td>
<td>
</td>
</tr>
<tr>
<td>II: John received a flight notification of when his flight takes off from Norwegian Air App. He is located at Luntmakargatan 73, Stockholm. Given Norwegian flight data, John's Copenhagen home address, and his previous 2 days frequent-sleeping-hours-location being Rex Hotel, the probability that he will fly home from Stockholm Arlanda Airport at 14:15 is very high. Apple iOS's Location-Based App Suggestion, wrongly proposed SAS – Airline app(bottom left of screenshot), instead of Norwegian Airline app.</td>
<td>
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FIGURE 1 APPLE IOS'S APPLICATIONS

Limitations and failure to *seize* just-in-time moment is clear in second example (from the Location-Based App Suggestion application), while a further explanation in needed to show what might not be apparently clear failure in the first example (from Traffic Condition App.). In the first example, the system time is past 7:00-8:30. It is past 7:00-8:30's time *window* for suggestive tool to offer persuasive triggers[7]. What could have been a persuasive trigger is now digital noise[8].

Limitations of information systems that exploits system-users' location or (and) period of time data to sense and seize *kairos* moments for performing certain activity, such as sending suggesting persuasive messages, is echoed through many available applications. The reason behind such a limitation is that locations and period of time data is not enough background data for computing the probability "just in time"- moments, all-inclusive time window for forwarding certain persuasive clues/external triggers[9]. Fogg is, thus, correct in maintaining that "[t]iming involves many elements in the environment (ranging from the physical setting to the social context) as well as the transient disposition of the person being persuaded (such as mood, feelings of self-worth, and feelings of connectedness to others)" (Fogg 2003, p.43).

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[7] A simple temporal logic condition, such as "Always: a suggestion is active to the user only if location has not been visited or the suggestion is offered not T ago, $HG(s \supset (\sim Po \vee \sim P(T)e))$ where s: the suggestion is active; o: the location is (NOW) visited; e: the suggestion is offered; T= *past* frequent-Visited Period window, could solve this issue.

[8] Digital noise is a term I coined to mean scattered digital tools that degrades the persuasiveness of digital technology quality.

[9] Fogg 2003 & Eyal 2014 pp. 57-84

Fogg went further to offer an illustration, which I will be referring as “McDonald Problems”, on how difficult it is for ICT to sense and seize *kairos*. His illustration presented two major problems, *(i)* the problem of sensing and seizing *kairos* and *(ii)* the ethics of digitally stalking users (data gathering and analysis of users’ digital footprints) to ensure tailored-seizing of time windows (offering of fine-tuned persuasive suggestion in anticipation of a reward), which this thesis aimed to resolve:

> To illustrate the difficulty of creating opportune moments of persuasion, consider a concept that two students in my Stanford lab24 explored, using Global Positioning System (GPS) technology to identify a person’s location. Theoretically, by using GPS you could create a suggestion technology to persuade a person to do something when she is at a specific location.
>
> The students created a prototype of a stuffed bear that McDonald’s could give away to children or sell at a low price. Whenever the bear came near a McDonald’s, it would begin singing a jingle about French fries—how delicious they are and how much he likes to eat them.
>
> The toy was never implemented, but you can imagine how kids could be cued by the bear’s song and then nag the parent driving the car to stop by McDonald’s. You could also imagine how the technology might backfire, if the parent is in a hurry, in a bad mood, or doesn’t have the money to spend on fast food. The point

> is, while the geography may be opportune for persuasion, the technology doesn't have the ability to identify other aspects of an opportune moment: the parent's state of mind, financial situation, whether the family has already eaten, and other variables. (Fogg 2003, p.43)

Could systems designed to sense user's current state of affairs using temporal logic[10] and compute user's maximum intention likelihood solve the "McDonald Problems"? Would machine-to-machine exchange of user's data raging from geolocation and period of time to user's economic status, calendar events, and family consumption expenditure (market value of user's goods and services) support in somewhat accurate computing that it may be opportune moment for persuasion?

Aagaard, Moltsen and Øhrstrøm have suggested Bayesian Network as a solution to how information systems could sense that it might be *kairos*. This thesis is intended to develop and enhance their solution as it offers affirmative answers to the above questions. It is possible to design information architecture that incorporate tensed sequence of events and fine-tuned data mining for naïve Bayesian network computational analysis to sense the maximum likelihood of not only present or future *kairos,* but also maximum likelihood of "being late", namely passed time window. This thesis presents a conceptual model that will endow persuasive technology with "the

[10] See Appendix 1 for applications of Temporal Logic in ICT

ability to identify other aspects of an opportune moment: [such as] the parent's state of mind, financial situation, whether the family has already eaten, and other variables" (ibid., 43)

Two fundamental tenets that cry out for investigation in order to understanding how such information architecture could be design are nature of time and Bayesian theorem. The third and forth parts of this thesis is first reserved for a selective exploration of the nature of time acquaint us with ideas such as "time window", "beings (too) early/late" and "branching timeline", and their application in designing of information technologies that are time-sensitive, and second, a concise history of the genesis of Bayesian theorem, what it is, and its application in designing information systems that capable of computing the probability of concurring events. Before exploring the nature of time and Bayesian theorem, and their application to information technology, a momentary exploration of what persuasive technology is is required. In the introductory part of this thesis, I introduced terms, like "persuasive technology", "persuasive trigger", "suggestive technology", and "tailoring", without defining what they are. Next second section is, thus, set apart for sole purpose of introducing the idea of persuasive designs.

METHODOLOGY & LIMITATIONS

This thesis makes use of Toulmin's model of argumentation in making a conceptual case for application of Bayesian theorem/network, and nature of time concepts in designing information systems that can sense and seize opportune moment. The ideas in this thesis reflect preliminary theoretical considerations regarding timing in persuasive design. It is, thus, guided by tried theories rather than empirical data. This is a crystal clear limitation of the claims presented.

With this disclaimer, the author wish to make it clear that he is aware of it but hold that the case presented contains valuable propositions that will contribute to answering the challenge of information and communication technologies(ICT) sensing and seizing opportune moments.

> *Today, products that are both mobile and connected are few, and the products that do exist are limited in what applications they run. But this will change. In the future we're likely to see a wide range of devices and applications, including those designed to motivate and persuade. Although examples of mobile persuasion are few today, many will emerge in the coming years, especially as mobile phone systems allow people and companiesto easily create and deploy applications. While mobile persuasion in the service of mobile commerce will receive lots of attention and funding, a clear win for individuals is using mobile technology to help people achieve their own goals. The kairos and convenience factors make mobile persuasion one of the most promising frontiers in persuasive technology*
>
> – BJ Fogg 2003[11]

BOOKS OF KINGS: BJ FOGG & THE DAWN OF PERSUASIVE TECHNOLOGY

"CAPT-ology" was a term coined by a young Stanford researcher B. J. Fogg in 1997 to explain the concept and research field of the computer as a persuasive technology. Fogg noted that we tend to interact with information systems as if they were, somewhat, conscious beings. This was so because information systems functioned, according to Fogg, "as tools, as media, and as social actors" (1998, p. 226). Were there are two conscious beings, there exist also some aspects of

[11] Fogg 2003, p207

persuasion[12]. The psychology of human-computer interaction (HCI) presented, as Fogg noted, an opportunity for a systematic study of computer functions as persuasive beings (Fogg 1997; 1998). Captology, thus, as the concept and research field of how to systematically design information systems with the intention of persuasion, was born. Fogg wrote:

> I coined the term “captology”— an acronym based on the phrase “computers as persuasive technologies.” Briefly stated, captology focuses on the *design, research, and analysis of interactive computing products created for the purpose of changing people’s attitudes or behaviors* (Fogg 2003, p.5)

According to Fogg, a persuasive information system is “an interactive technology that changes a person’s attitudes or behaviors” (Fogg 1998, p.225) Trailing Fogg and more elaborative definition is given by Oinas-Kukkonen and Harjumaa. Persuasive technology is “computerized software or information systems designed to reinforce, change or shape attitudes or behaviors or both without using coercion or deception” (Oinas-Kukkonen & Harjumaa 2008, p. 202). To easily comprehend interactivity of technology as persuasive technology, Fogg clarified the roles of information systems as tools, as media, and as social actors, in what he called “The Functional Triad”.

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[12] Fogg defined persuasion as (i) ”an attempt to shape, reinforce, or change behaviors, feelings, or thoughts about an issue, object, or action”(Fogg 1998, p. 225), (ii) ”an attempt to change attitudes or behaviors or both (without using coercion or deception)” (Fogg 2003, p. 15)

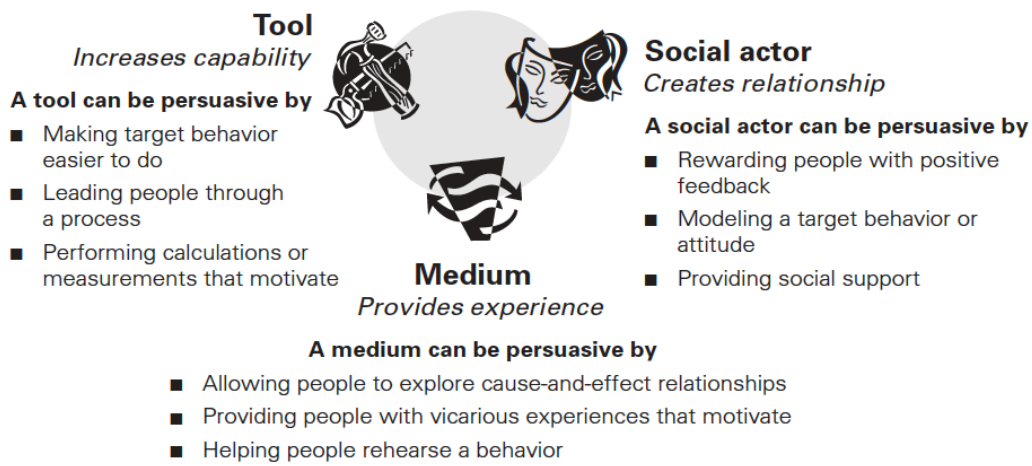

FIGURE 2: FOGG'S FUNCTIONAL TRIAD (2003, P.25)

As a "Tool", persuasive information systems are designed to make the user's desired outcome easier to achieve. Principles such as reduction, tunneling, tailoring, suggestion, self-monitoring, surveillance and condition are applied in persuasive designs to enable users to easily and efficiently accomplish simple and complex tasks. According to Fogg, the pervasive affordances of information system as a tool are reduction of "barriers (time, effort, cost)", increase of "self-efficacy", provision of "information for better decision making", and conversion of "mental models" (Fogg 1998, p. 227).

As a "Medium", persuasive information systems are designed to enable users to observe or experience or both immediate link between cause and effect of particular course of action (Fogg 2003, p. 63). Principles such as simulation and rehearsal are applied to enable users to virtually experience and rehearse states of affairs that are rewarding or (and) motivating for behavioral change. Persuasive affordances of information as medium are provision of "first-hand learning, insight, visualization, [and determination]", promotion of "cause/effect relationship" cognition, and motivation "through experience [and] sensation".

The National Academies of Science, Engineering & Medicine provides an interactive visualization that allow users to understand the cause and effect relationship of energy consumption. The used simulation first-hand learning experience.

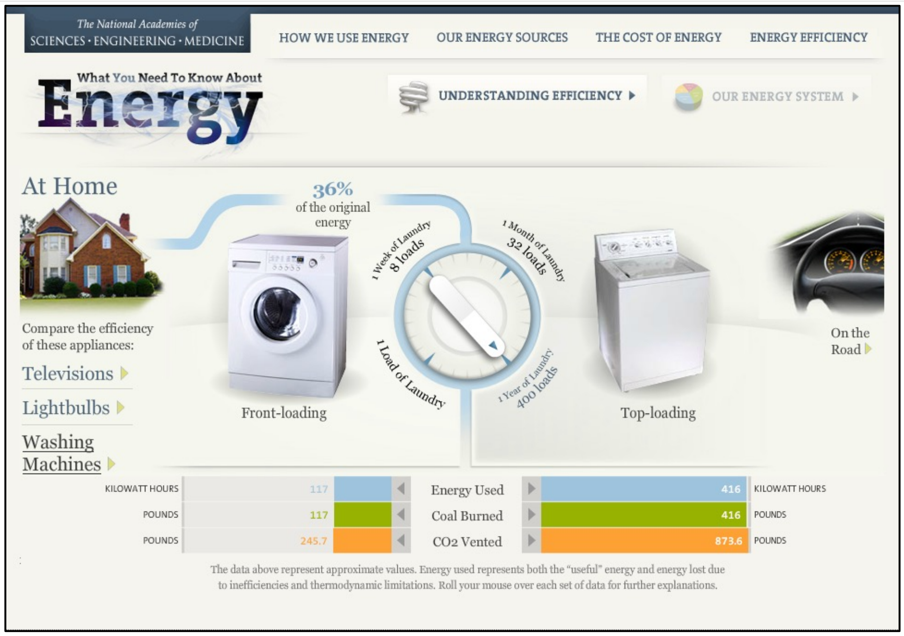

FIGURE 3: HOW WE USE ENERGY COPYRIGHT © 2016, THE NATIONAL ACADEMY SCIENCES

As a "Social Actor", persuasive information systems are designed change the user's behavior or attitude or both through providing social encouragement such as digital rewards, positive feedback, cheering, crowd/cooperation endorsement or praise, to "invoke social responses from users" (Fogg 1999, p.28 cf. 2003, pp. 89-91) Persuasive affordances of information as social actor are establishment of "social norms", invocation of "social rules and dynamic" and provision of "social support or sanction".

A MINOR CRITICISM ON FOGG'S MEDIUM & SOCIAL ACTOR

It appears that Fogg commits a categorical error in understanding information systems as medium and social actor. For example, he confuses category of substance, what a medium is, with category of action, what a medium does, which is information systems production digital simulation. What persuades is not medium or social actor *per se* as it is but what it does, namely mediation of designers' or collective systems users' intentions. We are thus must likely to respond to digital technologies as if they were somewhat equivalent to corporeal persons because they mediate through simulation other corporeal persons' social-like connections.

Fogg's Functional Triad, Principle and Examples Summarize Table

Role	Principle	Function	Example
Tool	▪ Reduction ▪ Tunneling ▪ Tailoring ▪ Suggestion ▪ Self-monitoring ▪ Surveillance	▪ Simplification of complex process ▪ Predetermination of processes ▪ Customization of users' data ▪ Opportune recommendation ▪ Elimination of tedium self-track ▪ Motivation of crowd stimulus	▪ Amazon's 1-Click Purchase ▪ Amazon's Checkout Steps ▪ Netflix's User Profile ▪ Frequently Bought Together ▪ Facebook Profile Page ▪ Facebook News Feed Page
Medium	▪ Simulation ▪ Rehearsal	▪ Observation of cause-effect ▪ Capability of rehearsing activities	▪ Nike+ Dashboard ▪ Microsoft Flight Simulator
Social Actor	▪ Praise ▪ Rewards ▪ Liking ▪ Completion ▪ Recognition	▪ Positive Feedback Motivation ▪ Digital Rewards Motivation ▪ Social Endorsement Motivation ▪ Social Comparison Motivation ▪ Social Acceptance Motivation	▪ Nike+ Cheer Feature ▪ Nike+ Trophies ▪ Reddit Up/Down Voting ▪ Nike+ Friends ▪ Facebook Like Button

FIGURE 4: *FOGG'S FUNCTIONAL TRIAD EXPLAINED*

PERSUASIVE TECHNOLOGY & BEHAVIOR MODELS

Fogg introduced what he called Fogg Behavior Model (FBM) as a systematical guide for persuasive technology designers to follow, monitor, and encourage targeted factors underlining behavioural change (Fogg 2009a-d). According to Fogg, behavior is a product of motivation, ability, and trigger. When motivation, ability, and trigger elements "converge at the same moment", or in other words, "present at the same instant" (Fogg 2009a), there and then behavior change will emerge.

When motivational elements, such as sensation (pleasure/pain), anticipation (hope/fear) and belonging (social rejection/acceptance), are high, according to Fogg, it is possible to get users to perform difficult tasks. While, when it is low, users can only perform easy tasks. The ability to perform a task decreases with the complexity of the task given. Following Fogg, "to increase a user's ability, designers of persuasive experiences must make the behavior easier to do" (2009a, n.p.). Decreasing complexity, thus, is increasing ability. The element of triggers, such as facilitator (appropriate when motivation is high, and ability low), signal (appropriate when motivation and ability are high), and spark (appropriate when motivation is low, and ability high), are used, matching on user's contextual situation, to initiate what users ought to do next.

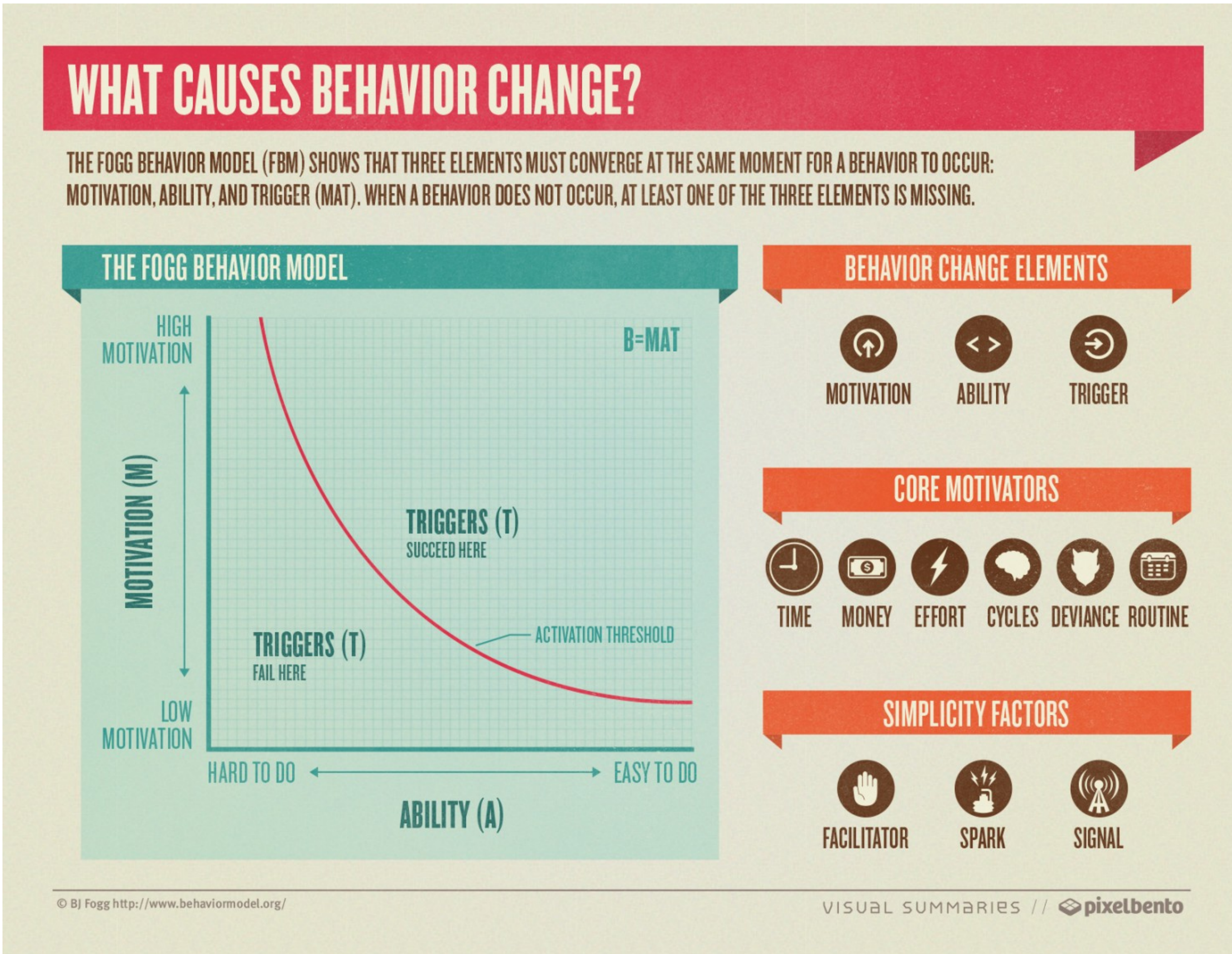

FIGURE 5: JEREMY BECHMAN'S INFOGRAPH OF FBH

Similar to FBM is Eyal's "The Hook Model" (HM). HM, wrote Eyal, "explains the rationale behind the design of many successful habit-forming products and services" (2013, p. 22) Unlike FBM, attitude or behavior change happens in a continuous process that spirals from triggers (both external and internal), activation, variable reward, and investment stages. Triggers are suggestive technology, e.g. notification, that alert users to take the next step. Users tend to respond toward

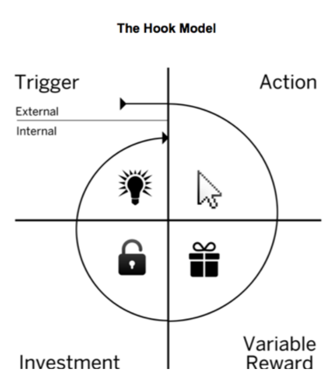

FIGURE 6 EYAL'S THE HOOK MODEL

suggestive technology, acting in a way that anticipates a fulfilling rewarding experience. When reward experience was fulfilling yet promising more, users to to invest their time into the circle of anticipating another trigger, action, reward, investment spiral loop (Eyal 2013).

SUGGESTIVE TRIGGER AND TIMING (KAIROS)

Triggers are cue for users to take action either by placing information within user's external environment (e.g. play, new mail, or buy now icons) or through associating the user's internal stored memory (e.g. positive/negative emotions, routines, demography) or both (Eyal 2013). Fogg's suggestion technology, "an interactive computing product that suggests a behavior at the most opportune moment" (Fogg 2003, p. 41 emp. removed), and conditioning technology, "computerized system that uses principles of operant conditioning to change behaviors" (*ibid.,* emp. removed) play the role of triggers as they call for user's to take the next action.

Knowing the right moments to offer tailored triggers is essential since, as Fogg pointed out, a "computing technology will have greater persuasive power if it offers suggestions at opportune moments" (*ibid.,* p. 41). He equally noted that "[i]ntervening at the right time and place via networked mobile technology increases the chances of getting results" (*ibid*., p. 183)

Contemplating Sarah's predicament with Rejseplanen App, we can see how a tailored trigger, such as a suggestive message, sent before the departure of bus 133, would have assisted her decision making. It would have persuaded Sarah to take the next step at that optimal time and place. In order to understand optimal time, we are to understand the nature of time, and how it can be applied in persuasive technology.

NATURE OF TIME & PERSUASIVE DESIGNS

What is the relationship between the past, the present, and the future? Does the past, somehow, determine the present, and does the present determine the future? In a pool of many unanswered issues about the nature of time, exploration of these two, I believe, would assist in the quest to solving the problem of designing information systems that can sense and seize kairos moments.

The concept of time, according to Martin Heidegger, is “our guide” in understanding “the basic question of the reality of history and nature [which] is the basic question of the reality of a particular domain of being” (Heidegger 1992, p.8) Sherover equally noted that “time was seen as the frame for the reality of the encountered world and thereby, by implication, as a key to the comprehension of its meaning and significance” (2001, p.549). Likewise, José Angel Sánche Asiain wrote:

> The concept of time is perhaps one of the most integrating in human knowledge. It appears in many fields, including philosophy, biology and, most prominently, in physics, where it plays a central role. It has interested Man of all Ages, and the

> finest minds from Saint-Augustine to Kant and Einstein have paid attention to its meaning, and the mystique shrouding its most notorious property: that of flowing only forward, its irreversibility. (Asiain 1994, p. xiii)

Given the importance of the concept of time, its is easy to assume that we know what “time” is. We do not. Two millennia have come and past, and we are nowhere near finding a definition that does justice to the concept of “time”. Demonstrating that this is the case, I would explore two definitions that are reechoed over and over again: (i) the concept of time in relationship to motion/change and (ii) the concept of time in relationship to human experience.

When it comes to (i), Aristotle was very aware that the concept of time could not be fully understood in terms of “motion and a kind of change”. Time was nevertheless dependent of existence of change in states of affairs. He wrote:

> [Time is not change in motion] But neither does time exist without change; for when the state of our own minds does not change at all, or we have not noticed its changing, we do not realize that time has elapsed, any more than those who are fabled to sleep among the heroes in Sardinia do when they are awakened; for they connect the earlier 'now' with the later and make them one, cutting out the interval because of their failure to notice it. So, just as, if the 'now' were not different but

> one and the same, there would not have been time, so too when its difference escapes our notice the interval does not seem to be time. If, then, the non-realization of the existence of time happens to us when we do not distinguish any change, but the soul seems to stay in one indivisible state, and when we perceive and distinguish we say time has elapsed, evidently time is not independent of movement and change. It is evident, then, that time is neither movement nor independent of movement (*Physics* Book IV.11)

Augustine, following Aristotelian understanding of time, popularized this idea. He explained that "times are made by the alteration of things" (Confession 12.8) and where there is no change of events, "there are no times" (ibid., 11.4). This understanding of time is reechoed countless time and places ever since (McTaggart 1927, p.13; Prior 1962; Chersky 2003, p.1078; Arnold III 2008, p.164).

The main objection that applies to Aristotelian-like understanding of time, is that we cannot make sense of movement or change without assuming *a priori* the concept of time. Movement is understood as the difference between initial state of being (I_0) to another given state of being (I_1), *viz.,* the motion/change of (I_0) to (I_1). The problem is the concept of "initial-to-X" makes no sense without first assuming we know what time is. Thus defining the concept of time in terms of change/motion is a tautology. Broad pointed out this circularity as follows:

> The circularity becomes specially glaring when put in the following way; The changes of things are change *in* Time; but the change of events or of moments from future, through present, to past, is a change *of* Time. We can hardly expect to reduce changes of Time to changes in Time, since Time would then need another Time to change in, and so on to infinity (1923, pp.64-65)

Defining concept of time in relationship to human experience does not escape the objection either. Heidegger, for example, does no better in his attempt to understand the concept of time when he contended that:

> Time is not something which is found outside somewhere as a framework for world events. Time is even less something which whirs away inside in consciousness. It is rather that which makes possible the being-ahead-of-itself-in-already-being-involved-in, that is, which makes possible the being of care" (Heidegger 1992, pp. 319–320).

Even though, for argument sake, we grant that time is neither something interior or exterior, the definition fails because we cannot make sense of "being-ahead-of-itself-in-already-being-involved-in" without first assuming the concept of time. As McTaggart also noted, "time cannot be explained without assuming time" (McTaggart 1908, p.470). Going through selected works of twenty-eight philosophers, viz., Heraclitus, Plato, Aristotle, Plotinus, Augustine, Locke, Leibniz, Kant, Hegel, R.H. Lotze, Bergson, Samuel Alexander, McTaggart, Russell, Hans Reichenback, Whitehead, William James, Peirce, Josiah Royce, George Santayan, Dewey, Piaget, Husserl, Eugéne Minkowski, Heidegger, Robin George Collingwoord and Richard McKeonon, on the nature of time, in Sherover's annotated anthology, The Human Experience of Time: The Development of Its Philosophic Meaning (2001), I found no definition of the concept of time that is either not circular or does no justice to it.

Although we intuitively know what "time" is (Hendricks 2001 p.26), defining or attempting to explain what it is, has turn out to be one of the greatest challenge in the history of western philosophy (Goudsmit & Claiborne 1980; Sherover 2001). Hasle and Øhrstrøm sum up well: "Nobody has yet presented a satisfactory definition of time. Every attempt to tell what time is can be understood as an accentuation of some aspects of time at the expense of others" (Hasle & Øhrstrøm 1995, p. 3)

According to Hasle and Øhrstrøm, we not only have no definition of what time is, but we cannot have definition of what it is since the concept of time is "unique and *sui generis*" (1995, p.3). We can, thus, safely resound both Aristotle's frustration, *viz.,* "[a]s to what time is or what is its nature, the traditional accounts give us as little light as the preliminary problems which we have worked through" (*Physics* Book IV.10) and throw of a towel into the ring as we admit that together with Augustine that, "If no one asks me [What, then, is time?], I know: if I wish to explain it to one that asketh, I know not" (*Confession* 11.14).

If we do not have a definition of time, how are we, then, going to know what *just-in-time* means? How are we to define the parameters of "time window", "early/late" or "waiting for something" of occurrence particular events that might be need for creation of information systems that are time-sensitive? The answers to these questions lies in the dialogue between the two understanding of time. The A- and B- theories time.

THE A- AND B- THEORIES OF TIME

Even though we lack satisfactory understanding of the concept of time, how we understanding the relationship of series of events present us with a guide to understand the concept of *kairos*, and how information architecture could be design to be *just-in-time* sensitive.

In *Physics* Book IV.10-11, Aristotle began his exploration of the concept of time by investigating the ontology of time. He understood "now" as the defining moment that sets apart the past and the future. Aristotle believed that "now" could be understood either as "always remain one and the same" or "always other and other". He wrote:

(1) If it is always different and different, and if none of the parts in time which are other and other are simultaneous (unless the one contains and the other is contained, as the shorter time is by the longer), and if the 'now' which is not, but formerly was, must have ceased-to-be at some time, the 'nows' too cannot be simultaneous with one another, but the prior 'now' must always have ceased-to-be. But the prior 'now' cannot have ceased-to-be in itself (since it then existed); yet it cannot have ceased-to-be in another 'now'. For we may lay it down that one 'now' cannot be next to another, any more than point to point. If then it did not cease-to-be in the next 'now' but in another, it would exist simultaneously with the innumerable 'nows' between the two-which is impossible.

Yes, but (2) neither is it possible for the 'now' to remain always the same. No determinate divisible thing has a single termination, whether it is continuously extended in one or in more than one dimension: but the 'now' is a termination, and it is possible to cut off a determinate time. Further, if coincidence in time (i.e. being neither prior nor posterior) means to be 'in one and the same "now"', then, if both what is before and what is after are in this same 'now', things which happened ten thousand years ago would be simultaneous with what has happened to-day, and nothing would be before or after anything else. (*Physics* Book IV.10)

Aristotle initiated the debate that would captivate the philosophy of time and later divide philosophers generally into two camps, the A- theorists (holding tensed/dynamic understanding of time) and the B-theorists (holding tenseless/static understanding of time). Below, I divided philosophers into these two camps:

I. The B- theorists, such as Russell (1915, 193813), Grünbaum (196714, 1969, 1973), Smart (196315, 1968, 1987), Ayer (1965), DC. Williams (1951, 1966), Goodman (1966), Quine (196016, 1976), Lewis (1970, 1979, 2004), Frege (198417), Saunders (2002), among many others[18], who hold that there exists no *genuine*[19] "coming into being", series of events are

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[13] Mostly on chapter 54

[14] chapter 1

[15] chapter 7

[16] chapter 36

[17] A clear defense is on p. 370

[18] Mellor (1981, 1989, 1998); Horwich (1987); Le Pidevin (1991); Oaklander (1991); Savitt (2000); and Sider (2001)

[19] B-Theorist hold that A-theory is mind dependent (or *mental time* as Russell would said), while B-theory is not (it is *physical time*. Thus we may experience temporal becoming subjectively as rational creature in space-time but from outside, there is not such temporal becoming. Russell, for example wrote: "In a world in which there was no experience there would be no past, present, or future, but there might well be earlier and later" (Russell 1915, p. 212) Similarly Grünbaum wrote: "the coming into being (or becoming) of an event is no more than the entry of its effect(s) into the

to be understand as located in earlier, simultaneous or later than others. As Ayer noted " events are not in themselves either past, present or future. In themselves they stand in relations of temporal precedence which do not vary with time. [...] What varies is only the point of reference which is taken to constitute the present, [...] the point of reference, by which we orient ourselves in time, the point of reference which is implied by our use of tenses, is continuously shifted" (1965, p. 170). Similarly, Grünbaum stated:

> what qualifies a physical event at a time *t* as belonging to the present or as now is *not* some physical attribute of the event or some relation it sustains to other *purely physical events*. Instead what is *necessary* so to qualify the event is that at the time t at least one human or other *mind-possessing* organism M is conceptually aware of experiencing the event at that time (1969, p. 155 emp. original)

The notions of such as “passing present” and “act of becoming”, among other similar A-series notions, are to DC Williams fundamentally deceptive (Williams 1951, pp 460-461 cf Gödel 1951, p.557). “Events”, Smart summarized B-series, “do not come into existence; they occur or happen. ‘To happen’ is not at all equivalent to ‘to come into existence’” (Smart 1949, p. 486) Mellor went even further when he stated that “There is no flow of time. The tensed view

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immediate awareness of a sentient organism (man)."(1973, pp. 326-326) of time is self-contradictory and therefore untrue" (Mellor 1981 p.69) Mellor, here, is resounding McTaggart's squabble with A-series. McTaggart wrote:

> [E]very event has them all [A- properties of past, present and future attribute]. If M is past, it has been present and future. If it is future, it will be present and past. If it is present, it has been future and will be past. Thus all the three incompatible terms are predicable of each event, which is obviously inconsistent with their being incompatible, and inconsistent with their producing change (1908, p. 468)

II. The A- theorists, on the other hand, such as Broad (1923, 1938), Reichenbach (1956), Whitrow (1980), Sellars (1962), Geach (1965, 1972), Capek (1966, 1976), Prior (1967, 1968, 1970, 2003), Gale[20] (1968), Chisholm (1900a, 1990b, 1981), Craig (2000; 2001), among others[21], who hold that the "now", or the "present" is an authentic feature in the world at each location, where series of events run from the past to the present and from the present to the future. In other words, there exists genuine "coming into being".

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[20] Gale came to reject A-theory in his later works

[21] Hinckfuss (1975); Schlesinger (1980, 1994); Adams (1986); Lucas (1989); Smith (1993); McCall (1994); Bigelow (1996); Lowe (1998) and Merricks (1999).

Reichenbach, representing the majority of A-theorists[22], stated that "the concept of *becoming* acquires a meaning in physics: The present, which separates the future from the past, is the moment when that which was undetermined becomes determined, and 'becoming' means the same as 'becoming determined'" (1956, p.269) Prior to Reichenbach, A.N. Prior stated that we experience "coming to pass of one thing after another, and not just a timeless tapestry with everything stuck there for good and all" (Prior 1996, p.48). Thinking Prior's thoughts after him is Craig[23]. He contended:

> For we experience that world [the existing external world], not as a static tableau, but as a continual flux, as a tensed world. We do not experience a world of things and events related merely by the tenseless relations earlier

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[22] Reichenbach citation is almost *like* a paraphrase of what Broad wrote in 1923: "We are naturally tempted to regard the history of the world as existing eternally in certain order of events. Along this, and in a fixed direction, we imagine the characteristic of presentness as moving, somewhat like the spot of light from a policeman's bull's-eye traversing the fronts of the houses in a street. What is illuminated is the present, what has been illuminated is the past, and what has not yet been illuminated is the future" (Broad 1923, p.59)

[23] For Craig, experience is "a defeater-defeater that overwhelms any B-theoretic arguments against the reality of tense" (2000, p. 138) Prior wrote: "what we know when we know that the 1960 final examinations are over can't be just a timeless relation between dates because this isn't the thing we're pleased about when we're pleased that the examinations are over." (Prior 2003, p.42)

> than, simultaneous with, and later than, but a world of events and things which are past, present, or future (Craig 2001, p. 159)

From Prior's "It was the case that p, and it is not the cast that p" (1962, p.8), it appears that there is a passage of time in change of state p to not-p. Even though terms like "passage of time" or "Time does fly" are metaphorical, according to Prior, they are factually true. Events, such as John's birthday, "become more past at the rate of a year per year, an hour per hour, a second per second" (ibid. p. 2) The flow or passage of time is events relative move from distance-past to past, and from past to present; and from distant-future to future, and from future to present. Le Poidevin would say;

> We are not only aware of [the flow of time] when we reflect on our memories of what has happened. We just see time passing in front of us, in the movement of a second hand around a clock, or the falling of sand through n hourglass, or indeed any motion or change at all (Le Poidevin 2007, p. 76)

Čapek would have added that:

> If true reality is timeless, where does the illusion of succession come from? If time has no genuine reality, why does it appear to be real?
>
> No solution can be found which would not introduce surreptitiously the reality of time somewhere. If the illusory reality of time is nothing but a gradual rising of the curtain of ignorance which separates our mind from

> the complete and timeless insight, then at least this process of rising is still a process which unfolds itself gradually without being given at once; but by conceding this, we admit the reality of time either in our mind or between our mind and the allegedly timeless reality (Čapek 1961, p.164 *cf.* 166)

> Furthermore, A-theorist such as McCall understood temporal series of events as independent of human experience. Series of event, according to McCall, "defines a separation of the universe into past and future that is ontological rather than epistemological" (1976, p. 343) Tooley concurred, with McCall assessment: "Time, understood as involving the coming into existence of events, is a totally object feature of the world that is not dependent in any way upon the experiences of humans, or other conscious (or self-conscious) being" (1997, p.377)

A- and B- theories[24] terminology had their genesis in J. McT. E. McTaggart's legendary essay, titled '*The Unreality of Time'* in 1908, that attempted to prove the unreality of time. McTaggart did not believe that things that exist could be temporal. If they were not temporal, then time was unreal. In his pursuit to demonstrate this, McTaggart distinguished two different ways of understanding the relationship of series of events, the A- and B- series. The A- series is "the series of positions running from the far past through the near past to the present, and then from the present

[24] It is Gale that first christianed McTaggart A- and B- series, A- and B- theories.

to the near future and the far future", while the B- series is "the series of positions which runs from earlier to later" (McTaggart 1908, p. 458) McTaggart expounded this distinction in his work, '*The Nature of Existence*' (1927). He expounded first order understanding of time, which B-series, as follows:

> Positions in time, as time appears to us *primá facie,* are distinguished in two ways. Each position is Earlier than some and Later than some of the other position. To constitute such a series there is required a transitive asymmetrical relation, and a collection of terms such that, of any two of them, either the first is in the relation to the second, or the second is in this relation to the first. We may take here either the relation of "earlier than" or the relation of "later than," both of which, of course, are transitive and asymmetrical. If we take the first, then the terms have to be such that, of any two of them, either the first is earlier than the second, or the second is earlier than the first. (1927, pp.9-10)

With that in place, McTaggart introduced his enigma. Since he held that A-series (which position events as "either Past, Present or Future") is essential for time, and thus A- series is necessary for the B- series, as McTaggart admits, "there can be no *B* series when there is no *A series,* since without an *A* series there is no time" (ibid., p. 13), then it appears that we encounter a clear contradiction[25]. He wrote: “The distinctions of the former class [B-series] are permanent, while those of the latter [A-series] are not. If *M* is ever earlier than *N,* it is always earlier. But an event, which is now present, was future, and will be past” (ibid., p.10). We, thus, have temporal series of events necessary for atemporal series event. A passage/dynamic of time necessary for static, ever-present static tableau. This contradiction led McTaggart to a conclusion, that is not shared by either defender of A-or B- theory, that time is unreal. He wrote:

> The reality of the *A* series, then, leads to a contradiction, and must be rejected. And, since we have seen that change and time require the *A* series, the reality of change and time must be rejected. And so must the reality of the *B* series, since that requires time. Nothing is really present, past, or future. Nothing is really earlier or later than anything else or temporally simultaneous with it. Nothing really changes. And nothing is really in time. Whenever we perceive anything in time – which is the only way in which, in our present experience, we do perceive things – we are perceiving it more or less as it really is not (McTaggart 1927, p. 22)

Surveying the literature above, it is difficult to show which view of time is correct. This thesis assumes Priorean position, namely “[w]e can describe most of what happens in time by talking

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[25] Grünbaum would disagree with McTaggart here. Grünbaum believed that: ”the tempral relations of earlier (before) and later (after) can obtain between two physical events independently of the transient now and of any minds. On the other hand, the classification of events into past, present, and future, which is inherent to becoming, requires reference to the adverbial attribute now as well as to the relations of earlier and later”(1967 p. 375)

about events being earlier and later than one another, and it is possible to construct a formal calculus expressing the logical features of this earlier-later relation between events. But this earlier-later calculus is only a convenient but indirect way of expressing truths that are not really about 'events' but about *things*, and about what these things are doing, have done and will do" (Prior 1996a, p.45) The direct way of expressing truth that are really about 'events' is that of distinction between past, present, and future (Prior 1996b, p.47).

Hasle and Øhrstrøm, are thus correct when they stated that "Both the A-theory and the B- theory are internally consistent theories. They can both profitably be used for describing a range of temporal phenomena, and indeed, from a formal point of view each of the theories can be 'absorbed' within the other, under certain premises" (Hasle & Øhrstrøm 1995, p. 255). Information systems designed to be *just-in-time* sensitive must take both A- and B- theories of time in consideration. As I argued below, information system that is design to compute maximal likelihood of events as the unfold in A- series, given a whole time-line relationship, as in B- series, would not only be able to sense it might *now* be kairos, but also the probability of *future* kairos moments.

A- AND B- THEORIES IN TIME-SENSITIVE INFORMATION SYSTEMS

In the first example, Apple iOS's Traffic Condition suggestive technology, we noted down a clear limitation of Apple's persuasive technology. Traffic Condition system does not have mechanism to sense that it is past John's time window to drop his two children off. As a result, as digital tool that was designed to assist its user have a good experience, turned out to be a digital noise.

John's recurrent behavior could be placed under B- theorem. The 7:00-8:30 is the "time window" to which series of events prior to 7:00-8:30 are grouped under "earlier than", time window, and those after, "later than" time window. The order of when to forward persuasive external triggers could be placed under A- theorem. Since John experience a passage of time, e.g. waking up at 5:45 a.m., dropping his children off at daycare at 7:30 a.m., and working at his office at 9:00 a.m., persuasive information systems equipped with A- and B- theorem-like mechanism has the ability to offer time-sensitive external triggers.

The traffic routing suggestion toward daycare, for example, could be set to be offered from 5:00, to *either* at the end of 7:00-8:30 time window *or* presence of temporal geo-location data, that recorded that John had already visited that location on that day. This will eliminate digital noise.

In passage above I introduce another concept of "either-or" system response. The suggestive external trigger was to self-terminate on either of the two conditions, closed time window or incoming geolocation data.

Human beings are complex creatures. The occurrence of chain of events, though having certain patterns, occasionally varies. To illustrate this, let's continue with John's case. Imagine that John's children were having holiday, or John was ill, etc. on that particular day. Information systems that are designed to be time-sensitive, and has multiple data inputs, as John's calendar, doctor appointments, etc., will be able to take into account temporal expect of their users to form more conditions, other than geo-location data.

The idea that the occurrence of chain of events may take different time-lines than the expected, information systems that will be capable of sensing *kairo*s moments must have the ability to adopt to changing time-lines. In order to understand how information systems can be designed to adopt to changing time-lines, we will have to dive back into the philosophical dialogue on nature of time.

A BRIEF HISTORICAL BACKGROUND OF BRANCHING-TIME IDEA

McTaggart's classifications of time in A- and B- series resuscitates the classical problem of determinism. If the past, present and future, as Smart wrote, "are all equally real" (Smart 1968, p. 255) then whatever happens, happens necessarily. To illustrate this point, let's consider John's illustration. Imagine a set of series of events E, namely John woke up at 5:45 a.m., dropped his children at daycare at 7:30 a.m., and started working at his office at 9:00 a.m., on date D_0, say 23rd of May 2016. If now is 9:01 a.m. 23rd of May 2016, We can deduce the following premises from A-theorem:

i. Prior to D_0, it will be that case that John will perform E.

ii. Now, it has been the case that John performed E.

(i) and (ii) capture the A- theorem of time. John experience the passage of time from E moving from future to present, and present to past. Observing E from B- theorem of time, we can deduce:

iii. Prior to $D_{0,}$ there are events that are earlier-than E (e.g. John sleeping).

iv. Now, there are events that are simultaneous with E.

v. Posterior to $D_{0,}$ there are events that are later-than E (e.g. John going to pick up his children).

Though John experienced passage of time, the temporal becoming of one event after another in E, as in (i) and (ii) from the A- theorem understanding of time, from the B-theorem, which switches the "past" with "earlier than", the "present/now" with "simultaneous with", and the "future" with "later than", series of events in E are simply eternally-present. Paraphrasing de Beauregard, from B-theory of time, everything, "past", "present" and "future" events, is written (de Beauregard 1981, p.430). If this is the case, then we can deduce:

vi. It has always been the case that John perform E.

vii. It will always be the case that John perform E.

viii. Necessarily, John perform E.

If B-theorem is true, then it appears that John is determined to performed E. John cannot do otherwise than perform E. He does not possess the libertarian freedom over his action. Hence resuscitation of the classical problem of determinism.

Applying Priorean position (Prior 1996a, p.45) one of the solutions that could solve the challenge is understanding time not as linear series, as Kripke noted[26] (Kripke 1958), but as branching series. Let S, W, D, O, and G stand for John **s**leeping, John **w**oke up at 5:45 a.m., **d**ropped his children at daycare at 7:30 a.m., started **w**orking at his office at 9:00 a.m., and John **g**oing to pickup his children. Using John's example, we can represent the series of events in a branching timeline (Figure 7).

This modal presents us with a branching time were there exits multiple possible "pasts/earlier-than-s", "presents/simultaneous-with-s", and "futures/later-than-s". There exists, at each present moment, alternative possible unfolding of future events. The possible alternative that is actualized becomes actual-past/present (marked with darker arrowed lines in Fig. A). Since at every now-moment, there exist two possible future unfolding of events, the future thus is open. If this is the case, we can deduce:

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[26] On Spetember 3rd 1958, a then 17 years old Saul Kripke wrote a letter to Prior, pointing out Prior's error. Kripke wrote: " "I have been reading your book Time and Modality with considerable interest. The interpretations and discussions of modality contained in your lectures are indeed very fruitful and interesting. There is, however an error in the book which ought to be pointed out, if you have not learned of it already […]in an indetermined system, we perhaps should not regard time as a linear series, as you have done. Given the present moment, there are several possibilities for what the next moment may be like – and for each possible next moment, there are several possibilities for the next moment after that. Thus the situation takes the form, not of a linear sequence, but of a 'tree'" (Kripke 1958)

ix. It is possibly the case that John will perform E.

(ix) presents a way to understand positions of events without committing oneself to determinism. Such a modal is useful in information systems, because Bayesian network computation present as with the likelihood of the occurrence a particular event, e.g. John dropping his children off at daycare, given background data. Assuming indeterminism is true, we can use Bayesian network to compute what John might do (the probability distribution of alternative events, example of W and ¬W), given prior background information, e.g. probability of S >>1. A branching time-sensitive systems, would, thus, be persuasive information systems, that adopts indeterministic unfolding of series of events.

Going back to John's case, the suggestive external trigger, that offered John the best traffic routing towards daycare, could be set to be terminated either at the close of time window *or* presence of other conditions, such as temporal geolocation data of John's already visited daycare that location on that day.

With branching-timeline, different incoming data or in John's case, conditions, can be accounted for. For example, incoming data such as John's children were having holiday, or John was ill, etc. would warranty a different branching timeline than the S, W, D, O, and G. Since, given such background data the probability of D >> 0. The most likely flow of events then would be S, W, and ¬D, …. B-theoretical perspective is used form a priori probability in Bayesian network, as I showed below, while A-theoretical perspective would be used to form posteriori probability.

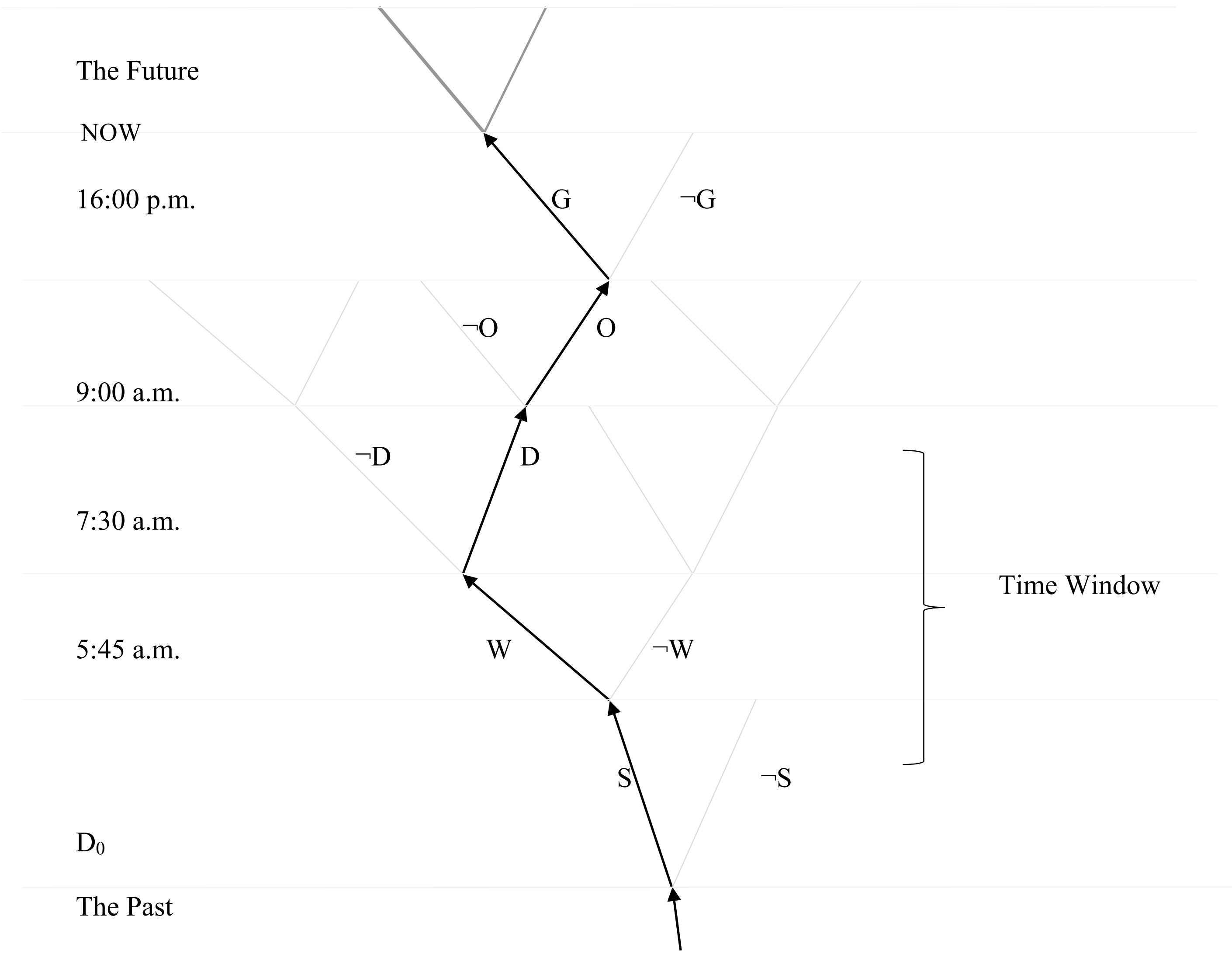

FIGURE 7 PRIOR'S PEIRCEAN SYSTEM

As Øhrstrøm et al., noted "[i]f we want to design a system which can convince the user to behave in a certain manner, then communication of such a persuasive system must be based on an A-theoretical perspective" (Øhrstrøm et al., 2010, p.136)

In this case, viz., probability of D >> 0, the suggestive external trigger, which usually offers John the best traffic routing towards daycare, at 7:00-8:30 time window could be set not to do so. It could suggest, for example, traffic routing to John's doctor's position, if the received sensed data is John's doctor appointment at 7:15, or traffic routing to the airport, if sensed data is John's family flight tickets to their holiday trip. In short, information systems, such as suggestive external trigger, would be able to sense and adopts into its users indeterministic temporal unfolding of events.

When we talk about suggestive triggers, that are able *to sense* and adopts into its users indeterministic temporal unfolding of events, we are talking about information technology's ability to sense the *opportune moment*. What is the opportune moment?

Kronos means the time measured objectively, impersonally, and mathematically by the motion of unconscious matter through space. For instance, one day of kronos is always exactly twenty-four hours long, the time it takes for the earth to rotate. Kairos, on the other hand, is human time, lived time, experienced time, the time measured by human consciousness and purposive reaching-out into a future that is not yet but is planned for. Only kairos knows anything of goals and values.

- *Peter Kreeft*[27]

KAIROS & PERSUASIVE DESIGN

Kierkegaard's *Øjeblikket* & Kairos

Kierkegaard also classified, in *Begrebet Angest*[28] (1844), time into '*det timelige*", the temporal A-series-like, and *'det evige'*, the eternal, B-series-like. The temporal time is the time with an infinite succession of events or people who supersede one another. This infinite succession of events could be brought to a halt by dividing time into, what Kierkegaard called, "*nærværenede, forbigangen og tilkommende*" (Kierkegaard 1844, p. 79), which is the present/Now, the past, and the future.

[27] Kreeft 1994, n.p.

[28] "The Concept of Anxiety" in English

This division of time applied not in temporal succession of events in itself, but time with respect to *'det evige'*.

The eternal is the ever-present moment that set aside the temporal succession, according to Kierkegaard, to become infinitely and maximally *complete* present moment. In the eternal, thus, there cannot be quantities succession of events. Nothing to come in to being, or go out of being. There is only qualitative moment were the future and the past co-exists '*i øjeblikket'*. The eternal, nevertheless, discloses time as temporal succession of events. Were the temporal and the eternal touch each other, there there is "*i øjeblikket*", the fullness of time. Kierkegaard wrote:

> Øieblikket er hiint Tvetydige, hvori Tiden og Evigheden berøre hinanden, og hermed er Begrebet *Timelighed* sat, hvor Tiden bestandig afskærer Evigheden og Evigheden bestandig gjennemtrænger Tiden. Først nu faaer hiin omtalte Inddeling sin Betydning: den nærværende Tid, den forbigangne Tid, den tilkommende Tid […] Det Begreb hvorom alt dreier sig i Christendommen, det, der gjorde Alt nyt, er Tidens Fylde, men Tidens Fylde er Øieblikket som det Evige, og dog er dette Evige tillige det Tilkommende og det Forbigangne. (1844, p.127, 129 cf 1980, pp. 89-90)

According to Kierkegaard, where everything is made right again, in other words, the point to which what was fraudulent is transformed to flawlessness, there exists the *fullness of time* (kairos). This fullness of time is the *øjeblikket* as the eternal, but yet the eternal that which is also the future and the past. Kierkegaard position of every-present eternal moment is almost a duplication of Saint Augustine statement in Book 11 of his *Confessions*. Augustine wrote that "in the Eternal nothing passeth, but the whole is present; whereas no time is all at once present: and that all time past, is driven on by time to come, and all to come followeth upon the past; and all past and to come, is created, and flows out of that which is ever present" (*Confessions* 11.11)

In *Works of Love,* Kierkegaard explained the relationship between '*det evige'* and the future, which is helpful to understand the passage above. He wrote,

> The eternal is, but when the eternal touches the temporal or is in the temporal, they do not meet each other in the present, because in that case the present would itself be the eternal. The present, the moment ["i *øjeblikket*"], is over so quickly that it actually does not exist; it is only the boundary and therefore is past, whereas the past is what was present. Therefore, when the eternal is in the temporal, it is in the future or in possibility. The past is the actual, the future is the possible; eternally, the eternal is the eternal; in time, the eternal is the possible, the future. (1995, pp. 248-249)

Following Kierkegaard, the *i øjeblikket* is the designation of time, but fullness of time where the eternity touches the temporal. This is the concept of a magical moment where chronological time "stops". A window of time where there is a complete presence of factors that briefly transforms quantitative moment into qualitative. A time in time where there is a brief moment of endless possibilities. *I øjeblikket* is *Kairos*.

KAIROS: THE CONCEPT OF TIME IN TIME

In the prologue, I introduced the Kairos who was the. This section will take the subject a bit deeper by exploring the concept of quantitative and qualitative time. It seeks to answer what is *Kairos* and how ICT could sense and seize it.

Contrasting *Kairos*, the youngest and most beautiful son of Zeus; a god of swiftly passing opportunity as introduced in the prologue of this thesis, is Kronos. Kronos was one of the oldest primeval deities. According to Cicero, Kronos was understood as a "being who maintains the course and revolution of the seasons and periods of time" (Cicero 1933 pp 184-185). In Hesiod's *Theogony* (Hesiod 2007 pp.40-41), Kronos is depicted as devouring his sons. As the saga moved more from literal to figurative, this scene was understood to signify how the passage of time consumes mortals (Panofsky 1962, pp.69-91).

Kronos is a god of temporal succession of events. He is the chronological quantities time. As time passes, there exist Kierkegaard's "i øjeblikket". "In the midst of the ordinary time (*kronos*)," wrote Mark Freier, "extraordinary time (*kairos)* happens" (Freier 2006, n.p.) In one part of the Jewish wisdom literature, understood to be written by one of King David's sons, we encounter the idea of proper time for every moment. We read in Ecclesiastes 3.1-8:

To every thing there is a season, and a time to every purpose under the heaven:

A time to be born, and a time to die;

A time to plant, and a time to pluck up that which is planted;

A time to kill, and a time to heal;

A time to break down, and a time to build up;

A time to weep, and a time to laugh;

A time to mourn, and a time to dance;

A time to cast away stones, and a time to gather stones together;

A time to embrace, and a time to refrain from embracing;

A time to seek, and a time to lose;

A time to keep, and a time to cast away;

A time to rend, and a time to sew;

A time to keep silence, and a time to speak;

A time to love, and a time to hate;

A time for war, and a time for peace (JPS Tanakh 1917[29]).

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[29] The Holly Scriptures According to The Masoretic Text: Jewish Publication Society 1917.

We are told that in a linear time there are opportune moment. In other words, in quantitative chronological succession of events (*kronos)*, there are qualitative influential moments (*kairos).* It is, as Kinneavy wrote, "the right or opportune time to do something, or the right measure in doing something" (Knneavy 2002, p.58 c*f* Smith 1986, p.4; Benedikt 2002, p. 227). Paul Tillich magnificently explained that:

> Time is an empty form only for abstract, objective reflection, a form that can receive any kind of content; but to him who is conscious of an ongoing creative life it is laden with tensions, with possibilities and impossibilities. Not everything is possible at every time, not everything is true at every time, nor is everything demanded at every moment (Tillich 1957, p. 33)

We now know that *Kairos* is "qualitative" time. The fullness of time to persuade person to take the next action (Eyal 2013). Is it possible to understand qualitative time in terms of the presence of quantitative factors?

AMØ- BAYES NET SOLUTION & KAIROS SENSING INFORMATION SYSTEMS

In their paper titled 'It might be Kairos', Aagaard, Moltsen and Øhrstrøm (AMØ) presented a model for Bayesian computation of quantified "level of Kairos". Following in Fogg's footsteps, AMØ used *factors,* that potentially induce the presence of opportune moment, as a way to quantify "level of Kairos".

The factors are such as geolocation, period of time, user's archetypal routine, present endeavor, and daily objectives, according to Fogg (2003, p.188) and AMØ (Øhrstrøm et al., 2008). Fogg argued that if it is possible for mobile information systems to be aware of their "user's goals, routine, current location, and current task, [… them such] systems will be able to determine when the user would be most open to persuasion in the form of a reminder, suggestion, or simulated experience" (Fogg 2003, p.188).

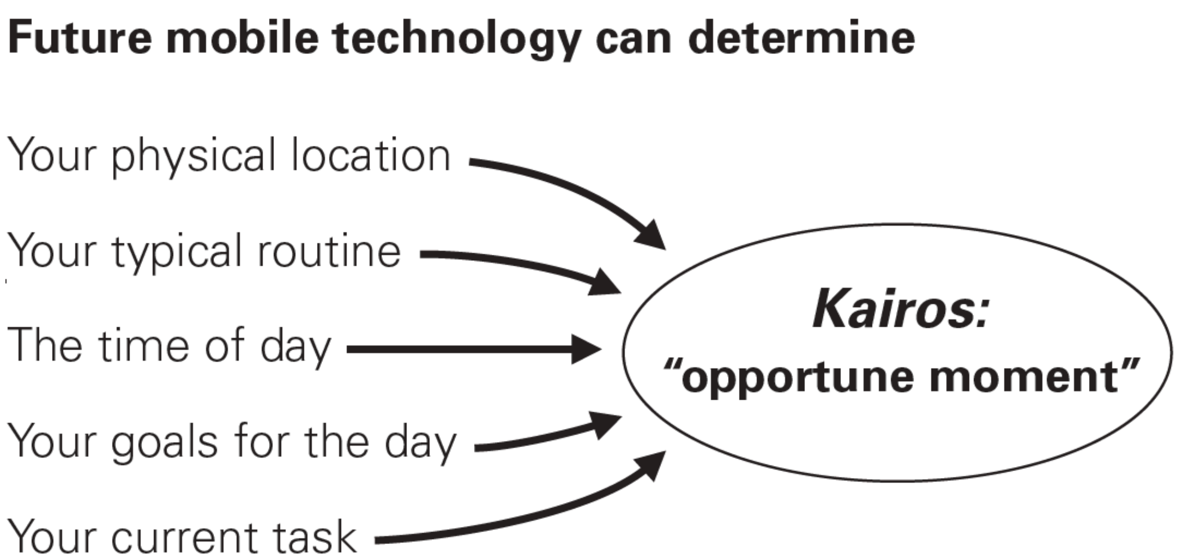

FIGURE 8:FOGG'S KAIROS MODEL 2003

According to AMØ, the evidential primacy of factors depends on user's contextual backgrounds. AMØ noted that:

> Depending on what kind of Persuasive goal we have and which users we are targeting, the factors value as evidence for Kairos change. E.g. when aiming to change a personal habit like smoking, the location bears little evidence, that the user is persuasiable. Time_of_the_day bears a lot evidence. In other examples it is opposite: location or other factors are strong evidence that we have a Kairos moment (Øhrstrøm et al., 2008)

Unlike Fogg Model, that only has input factors, which are used in sensing that it might be Kairos, AMØ introduced two output "*identifiers* of Kairos", Behavior and Physical_Measures, that would assist in evaluating levels of Kairos. The data collected concerns the user's interaction with technology, and his or her physical state (e.g. vital signs)

Bayesian network[30], according to AMØ model, is a network with random variables (such as kairos itself, factors or(and) identifiers that provides background data that it might be Kairos) of a "domain and their causal dependencies", and compute presence level of Kairos. An a priori

[30] A Bayesian network "is a graphical model for probabilistic relationships among a set of variables."(p.1)

expected probability, given user's data can be given to each variable's state. To illustrate this, AMØ introduced a prototype mobile application, "MightyKairos", based on Bayes net that was designed to assist the antropophobic autistic child, Pete, to avoid crowded places as he moves from one location to another.

Since the persuasive goal in this situation is Pete's safety and good experience during his movement from one location to another, factors, which serve as evidence for Kairos presence are location, and Time_of_day, Type_of_day, among other factors. A Bayesian net for sensing Pete's Kairos moment would thus look like Figure 6.

Kairos								
Location	Home	Neigh borhood	Downtown	School	Home	Neigh borhood	Downtown	School
Time _of_day	Rush-hour	Rushhour	Rushhour	Rushhour	Not_ Rushhour	Not_ Rushhour	Not_ Rushhour	Not_ Rushhour
True	0.01	0.6	0.8	0.1	0.99	0.1	0.2	0.9
False	0.99	0.4	0.2	0.90	0.01	0.9	0.8	0.1

FIGURE 9: AMØ'S BAYESIAN NETWORK FOR IDENTIFYING KAIROS FOR ANTHROPOPHOBIA

MightyKairos has to alert Pete of his coming state of affairs. For example, if Pete is located at Downtown, and the time of day is rush-hour, MightyKairos sensing the probability of 0.8, offers an alert to Pete.

The more background data from factors and(or) identifiers we have in a Bayesian network, the more accurate its predications turn out to be. For example, the probability of it is rush-hours given that the location is downtown and type_of_day is Sunday would be lower than a normal weekday. In MightyKairos' case identifiers, such as Physical_Measures variable that consists of states (e.g. body temperature, pulse rate, and respiration rate) would be significant in providing evidence to the effect of being in a Kairos.

Continuing with John's case illustration, Apple iOS uses typical_routine- factor-like to tailor John's suggestive traffic routing. The problem was that it was *past* John's 'dropping his children off at daycare' time window. If Apple's suggestive technology could *sense* John's geolocation, time_of_the_day, and current_task, it's suggestive messages, a traffic routing toward daycare, would have been terminated, or superseded with another traffic routing toward John's work.

A STEP FORWARD: BAYESIAN NETWORKS AND BAYESIAN LEARNING ALGORITHM

Causal probabilistic relationship among variables, that is useful for indicating or(and) determining the presence of Kairos, can be deduced from supervised or unsupervised machine learning of the expected probability variables state in Bayesian network. The deduced causal relationships would be used to form predictions relative to the presences of incoming data.

In order to understand Bayesian probability, Bayesian machine learning, a concise introduction to Bayesian approach to probability and statistics is required. The next segment of this thesis selectively explores Bayesian theorem's nativity, and how it's application in computer science.

NUMBERS: HERE COMES BAYES THEOREM

Richard Price's (1723-1790) critique of "*On Miracle*" among other celebrated essays by David Hume (1711-1776), first published in 1748[31], introduced Thomas Bayes' (1702-1761) ideas of probability calculus into a larger audience. Rewarding few years back, John Locke (1632-1704), in his work *Essay Concerning Human Understanding* (1690), wrestled with the problem of how, when it came to two major and at odds sources of credibility, a person was to apportion his or her belief. The Bayesian apparatus, a distribution of parameter values, where each value of a given source has weight according to its posterior distribution, provides assistance in aiding a belief-holder apportion his or her belief when it comes to two major and at odds sources.

Clarifying the paragraph above, it would be in this thesis benefit to briefly explain how the Bayesian apparatus could be utilized in an attempt to apportion one's beliefs. I selected this

[31] *Philosophical Essays Concerning Human Understanding* (1748). This collection was later retitled as *Enquiries Concerning Human Understanding*

historical debate because it relates to how, given background information, we can deduce the probability of the occurrence enquired event.

In its historical context, Bayesian apparatus was used by Price rebut Hume case against miracles. Hume's central case against miracles, as I understood it to be, was typical of the eighteenth–century's criticism against the credibility of eyewitness testimony in establishing the truthfulness of the resurrection of Jesus of Nazareth. He presented his 'proof'[32] as follows:

> A miracle is a violation of the laws of nature; and as a firm and unalterable experience has established these laws, the proof against a miracle, from the very nature of the fact, is as entire as any argument from experience can possibly be imagined. (1748, p. 114)

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[32] Hume defined "proof" as "such arguments from experience as leave no room for doubt or opposition" (1748, p. 56, fn. 1)

Hume went further to advanced his 'general maxim':

> That no testimony is sufficient to establish a miracle, unless the testimony be of such a kind, that its falsehood would be more miraculous, than the fact, which it endeavours to establish[33]. (ibid., 115-116).

Using Bayes' probability calculus, Hume appears to argue, *quo* his proof, that the probability of a state of affair, such as 'a dead man returning to life', that violate a generally established law, the records of undeviating past experience[34], namely, 'no dead men return to life', is zero. For Hume, the probability of the state of affairs that aligns with undeviating past experiences is one. This is, of cause problematic, as Price noted that "[i]t must be remembered, that the greatest uniformity and frequency of experience will not offer a proper proof, that an event will happen in a future trial. […] or even render it so much as probable that it will always happen in all future trials." (Prince 1768, pp. 392-393)[35]

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[33]Hume informed as that "If the falsehood of his[witness] testimony would be more miraculous than the event which the event which he relates; *then and not till then*, can he pretend to commend my belief or opinion" (ibid., 115-116)

[34] Hume explained: "There must, therefore, be a uniform experience against every miraculous event, otherwise the event would not merit that appellation. And as uniform experience amounts to a proof, there is here a direct and full proof, from the very nature of the fact, against the existence of any miracle" (ibid., 143–44).

[35] Original essays were published by Price in 1767, pages references above are from the 2nd ed. I768, London: A.

John Earman correctly noted that the advent of probability in seventeenth and eighteenth century brought about a change in the way theologians and philosophers approached old problems (Earman 2000, p. 26). Instead of queries that aimed for “all-or-nothing”, for example, “did Jesus of Nazareth rise from the dead?”, their approach changed to probing the degree of likelihood, “how likely is it that Jesus of Nazareth rose from the dead?”. Earman outlined three creeds of Bayesianism:

> First, epistemology is most fruitfully discussed not in terms of all-or-nothing belief but in terms of degrees of belief. Second, rational degrees of belief should be regimented according to the probability calculus. […] Third, when an agent has a learning experience and the content of the experience is fully captured by a proposition E, then the agent’s degree of belief function Pr_{new} after the learning experience is related to her degree of belief function Pr_{old} before the learning experience by the rule of conditionalization: $Pr_{new}(\cdot) = Pr_{old}(\cdot/E)$, where the conditional probability Pr(Y/X) is defined by Pr(Y&X)/Pr(X) when $Pr(X) \neq 0$. If Pr_{old} reflects previously acquired knowledge K, that is, $Pr_{old}(\cdot) = Pr_{oldold}(\cdot/K)$, then $Pr_{new}(\cdot) = Pr_{oldold}(\cdot/K\&E)$. (ibid. 26)

Millar and T. Cadell.

Let H, K, and E respectively represent the hypothesis on trial, the background knowledge/information, and the new evidence/data. The Bayes' theorem of the degrees of belief H given agent's given K and E, *viz*., *posterior* probability of H, is computed by dividing both prior probability $\Pr(H|K)$ and probability of new evidence given the hypothesis on trial and background knowledge by probability of new evidence given background information (Earman 2000, p.27).

$$\Pr(H|E\&K) = \frac{\Pr(H|K)\times\Pr(E|K\&H)}{\Pr(E|K)}$$

Earman further explained that:

> $\Pr(E|K\&H)$ is called the *likelihood* of H: it is a measure of how well H explains E. $\Pr(E|K)$ us variously called the *prior likelihood* or the *expectancy* of E: Using the principle of total probability [the above equation] can be recast in a form that is useful in many applications:

$$\Pr(H|E\&K) = \frac{\Pr(H|K)\times\Pr(E|K\&H)}{\Pr(H|K)\times\Pr(E|K\&H) + \Pr(\neg H|K)\times\Pr(E|\neg H\&K)}$$

$$= \frac{1}{1+\left[\frac{1-\Pr(H|K)}{\Pr(H|K)}\right]\left\{\frac{\Pr(E|\neg H\&K)}{\Pr(E|H\&K)}\right\}}$$

> For Bayesians, the explanation of the truisms of confirmation and induction are most often to be traced to an application of [the former and the latter equations] (ibid. p. 27)

With Bayes theorem, it becomes apparently clear that Hume's 'general maxim' is incorrect. Consider a cloud of witnesses c_1-c_n, independently witnessing the occurrence of miracle R. When computing, for example, the probability of these multiple witnesses, it appears that their testimony is sufficient to establish that it's more likely than not that R occurred without the negation of their testimony be more miraculous.

To show why that is so, let *L* be a generally established law deduced from records of undeviating past experience, c(E) be the testimony of C to the occurrence of event R (which violates L). According Earman, Hume's maxim, is:

$$\Pr(R|c(R)\&L) > \Pr\left(c_1(R)\&\ldots\&c_n(R)\,\middle|\,(R\vee\neg R)\&L\right) > .5$$

As it appears, following Earman (ibid. pp.54-55), Hume's general maxim is, though correct, a useless tool to establish that there is no c(R)s testimonies that can establish the credibility of R. The posterior probability of multiple testimonies could be computed as follows:

$$\Pr\big(c_1(R)\&\ldots\&c_n(R)\,\big|\,(R\vee\neg R\big)\&L = \Pr\big(c_1(R)\,\big|\,(R\vee\neg R\big)\&L)\times\ldots\times\Pr\big(c_n(R)\,\big|\,(R\vee\neg R\big)\&L)$$

Granting that there exists a uniform complete choice on both sides of the equality, then:

$$\Pr\big(c_1(R)\&\ldots\&c_n(R)\,\big|\,(R\vee\neg R\big)\&L) = \frac{1}{1+\left[\frac{\Pr(\neg R\,|\,L)}{\Pr(R\,|\,L)}\right]\left(\frac{\Pr(c_1(R)\,|\,\neg R\&L)}{\Pr(c_1(R)\,|\,R\&L)}\right)^n}$$

Using Bayesian analysis, it is clear that even if $\Pr\big(c_1\ (R)\,\big|\,\neg R\&L\big)\gg 1$, when $\Pr\big(c_1\ (R)\,\big|\,R\&L\big) > \Pr\big(c_1\ (R)\,\big|\,\neg R\&L\big)$ the *posterior* probability of R $\gg 1$. Apportion distribution of belief in R parameter values increases with increase in background data, such as $c_1(R)\ \ldots\ c_n(R)$, in favour of R (Earman 2000, p.55).

PERSUASIVE SYSTEMS, FOGG'S MCDONALD PROBLEM & BAYESIAN THEOREM

Fogg pointed out possible flaws of information system that sensed *kairos* through computing its user's geolocation to nearest McDonald. Fogg maintained that "while the geography may be opportune for persuasion, the technology doesn't have the ability to identify other aspects of an opportune moment: the parent's state of mind, financial situation, whether the family has already eaten, and other variables" (Fogg 2003, p.43).

Using Bayesian theorem, we can take into account some of the aspects that would sense the degree of *kairos* likelihood. We can compute the likelihood the presence of *kairos* moments (N) given background data (M, mined from *factors* and *identifiers*) as Pr(N|M). Since Pr(N&M) = Pr(N|M) $\Pr(M) = \Pr(\mathrm{M}|\mathrm{N}) \Pr(\mathrm{N})$ then

$$\Pr(\mathrm{N}|\mathrm{M}) = \frac{\Pr(\mathrm{M}|\mathrm{N}) \Pr(\mathrm{N})}{\Pr(\mathrm{M})}$$

To illustrate this, consider the McDonald Problem. Let W, X, Y, and Z respectively stand for known data: there is no important calendar event within next 2 hours, finance within family f consumption expenditure, it has been N day(s) above McDonald f-visits average, f location-to-

McDonald-and-time[36] is within the past records, the probability that f visits McDonald given background data $\Pr(\mathrm{M} \mid (\mathrm{W\&X\&Y\&Z})$ is

$$\left(\frac{\Pr(\mathrm{M})}{\Pr(\neg\mathrm{M})} \times \frac{\Pr(\mathrm{W} \mid \mathrm{M})}{\Pr(\mathrm{W} \mid \neg\mathrm{M})} \times \frac{\Pr(\mathrm{X} \mid \mathrm{M})}{\Pr(\mathrm{X} \mid \neg\mathrm{M})} \times \frac{\Pr(\mathrm{Y} \mid \mathrm{M})}{\Pr(\mathrm{Y} \mid \neg\mathrm{M})} \times \frac{\Pr(\mathrm{Z} \mid \mathrm{M})}{\Pr(\mathrm{Z} \mid \neg\mathrm{M})}\right) \times \Pr(\neg\mathrm{M} \mid (\mathrm{W\&X\&Y\&Z}))$$

If

$$\frac{\Pr((\mathrm{W\&X\&Y\&Z}) \mid \mathrm{M})}{\Pr((\mathrm{W\&X\&Y\&Z}) \mid \neg\mathrm{M})} \gg 1$$

then M (it is the case that *f* visits McDonald), is most likely state of affair given the background recorded data (W&X&Y&Z) over ¬M. When, and only when, M is most likely state of affair, then a tailored persuasive message, e.g. a personalized discount just for *f*, could be forward to *f*.

[36] Temporal logic could be utilized to test whether or not f has already eaten. Using geolocation and their respective timestamp, Bluetooth, and other input data, it is possible to calculate the probability that f has eaten or not. See footnote 7 for similar issue and calculation.

BAYESIAN NETWORK AND BAYESIAN MACHINE LEARNING

Heckerman defined Bayesian network as "a graphical model that efficiently encodes the joint probability distribution (physical [machine learning of networks from data] or Bayesian [machine learning from prior knowledge alone]) for a large set of variables" (Heckerman 1995, p.11). Given continuous incoming of user's data, it is possible to design a persuasive system that adopts to user's real time events, and at *opportune* moment trigger suggestion, notification, or alters. Such a system has to go beyond AMØ's model, that is based on prior knowledge alone. It need to have both Bayesian data input from both prior knowledge and incoming data that would "produce improved knowledge".

The updating of prior knowledge, given new information, is what is known as Bayesian learning. AMØ's Bayesian network, thus, need to be updated so as to enable computation of *posterior* probabilistic distribution, given new incoming data, to form "a collection of probabilistic classification/regression models, organized by conditional-independence relationships" (1995, p.17) Appendix 2 and 3, are set aside to present Bayesian computations in a more detailed manner.

THE USER EXPERIENCE: KAIROS, A- AND B- SERIES, AND BRANCHING TIME

As mentioned, persuasive designs are information systems that are designed with specific goals in mind, namely changing of user's attitude or behavior or both. The concept of branching time, and the distinction of A- and B- theories of time have a lot to offer. Consider, for example, architecting website or application navigational tool. As Øhrstrøm et al., noted that "the path-type breadcrumbs seen on top of some web pages or lists of recently viewed items within a web site may provide the user with tools to keep track of movements and associated thoughts. Gathering and displaying information about user movement can clearly be accomplished by applying a B-theoretical perspective. A trail of breadcrumbs thus marks a route, consisting of one page visit after another, and no more than the before-after relation is needed to account for this" (Øhrstrøm et al., 2010, p.135)

In a similar manner, persuasive information architectures can be designed in a way that leads users through their own determination towards designers predetermined and intended goal. Persuasive information system designer can tunnel users through their own determination into different sequences of events, as in A-series, but yet have designers' predetermined goal, as viewed in B-series. Information systems users tend to act according to certain present beliefs (what users implicitly[37] or explicitly believes to be true) and desires (what users believes would either bring about pleasure and contentment or avert displeasure/discomfort and pain) (Heider 1958; Jones & Davis 1965; Shaver 1985; Adams 1986; Malle & Knobe 1997; Wyatt 2002; Botti & Iyengar 2004; Malle & Hodges 2005). As Marc Lewis wrote:

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[37] Works of cognitive scientists suggest that we hold unconscious beliefs that affects our behavior. Atran (2002), Barrett (2004; 2011; 2012), Bering (2006; 2010; 2011), Boyer (2001, 2008), McCauley (2000; 2011), Pyysiäinen (2003; 2009); Norenzayan & Gervais (2013); Banerjee & Bloom (2013); Lindeman et al., (2014)

> The neural circuitry of desire governs anticipation, focused attention, and behaviour. So the most attractive goals will be pursued repeatedly, while other goals lose their appeal, and that *repetition* (rather than the drugs, booze, or gambling) will change the brain's wiring (Lewis 2015, p.11).

Persuasive technology tools, such as suggestion, notification, alters and condition, can be used in a way that modifies or reinforces system user's beliefs and desires. At opportune moments, persuasive systems can offer users with suggestive information of most attractive objectives, with the intention of navigating them towards an intended outcome. For example, a suggestive information or a notification sent to a traveler about changes in her transportation would assist her take a desired course of action.

Information systems that uses Bayesian network would be able to go beyond used of geolocation-dependence to perform tasks. For example, Philips Hue application (2016 edition), a technological system that is design to control smart wireless LED lights, has a serious fault in its Away and Home features senses users their location to either turn the lights on or off. Since Philip Hue uses only geolocation data, it fails to *sense* that it is daytime with bright natural light, and thus it should not turn the lights on at the return of its user. Another problem is that in the presence of two or more household users, say user A and user B, living in the some house, Philips Hue application fails to sense that if *only* A has left the household, it should not switch the lights off. There is nothing more annoying than having B's lights switch off, just because A left the house. Equipped with Bayesian network, Hue application would be able to resolve these blunders.

Rhetoric is the art which seeks to capture in opportune moments that which is appropriate and attempts to suggest that which is possible

- John Poulakos[38]

ACTS OF APOSTLES: APPLICATIONS

Concepts of nature of time, and Bayesian theorem have dozen applications in information architecture designs. In this section I explore applications of timing in Rejseplanen App(2016 edition), as selected persuasive design, and address some of ethical challenges raised by collection, analysis, and use of user's private digital data for the purpose of persuasion.

Rejseplanen App as Persuasive Technology & Some Recommended Modification

Since 2011, Rejseplanen App has gone into multiple updates which saw changes not only on user interface design (UI) but also in its design interactivity that maximized user experiences with the application.

[38] Poulakos 1983, p.36

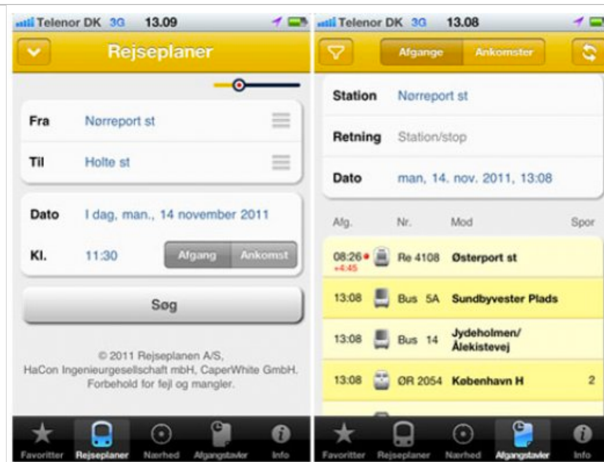
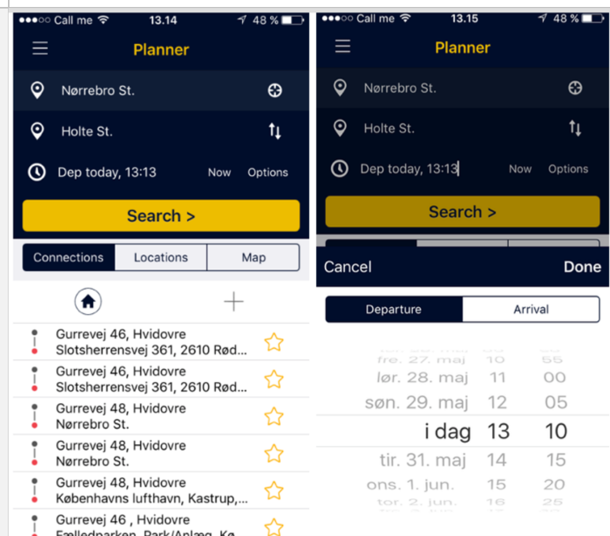
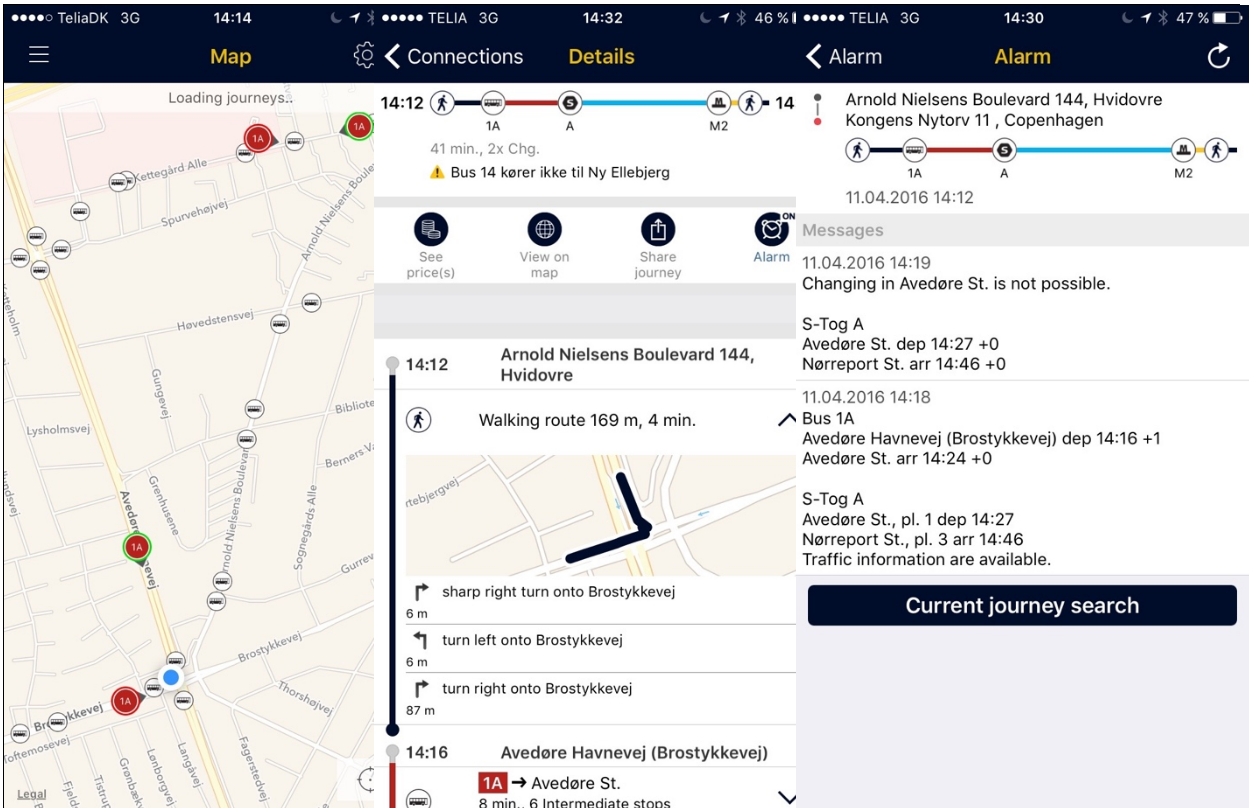
Rejseplanen App 2011 Caption: Rejseplanen – den perfekte guide på farten - Rikke Højgaard Eriksen 14. November 2011 b.dk	
Rejseplanen App 2016 Reduction, as persuasive tool, is present in Rejseplanen 2016. App. users possess ability to activate their geolocation data for the app. to sense their current location. The element of auto-predictive filling when beginning to type a departure or arrival station, also, plays as reduction tool.	

FIGURE 10 REJSEPLANEN EVOLUTION

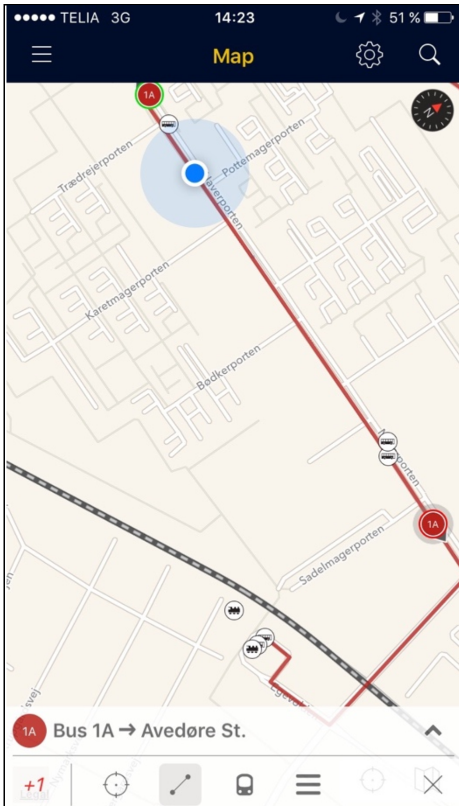
The concept of A- and B- perspectives of time, and Branching time are equally present in Rejseplanen App. 2016 edition. Map feature is packed with persuasive technologies tools and media. Rejseplanen Map feature enable users to both view how their journey is unfolding, as in A-series perspective, and a bird eye-view, as in B-series, of their total journey. This feature functions as ‘medium’, since it offers real-time simulation of public transportations location. Application’s users can experience the cause/effect of, for example, their bus or train waiting and the approaching of such public transportation. This feature can thus assist users to form visualized data-centric informed decision-making.

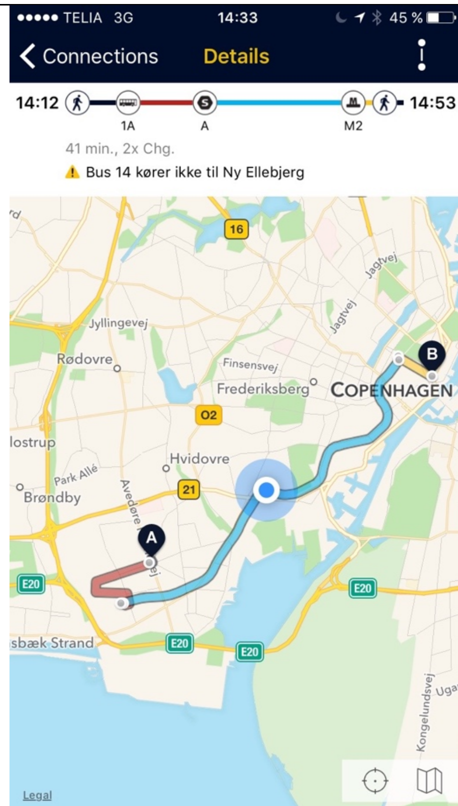


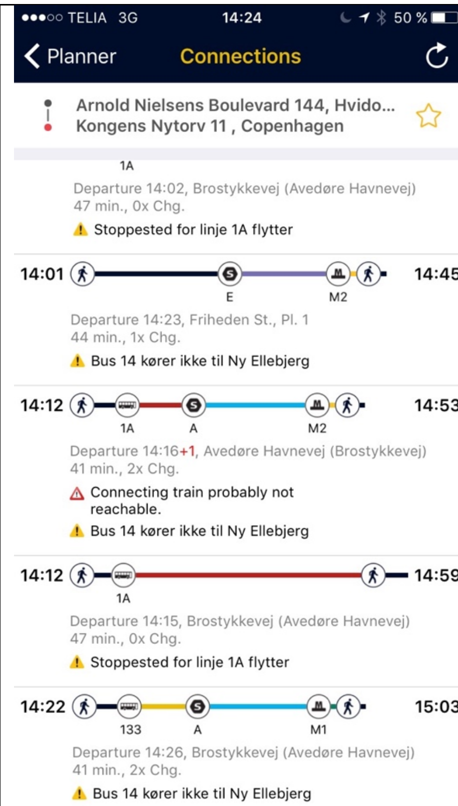
Simulation of real-time buses and trains movements.	Tunneling users from one step to another.	Suggestive message, namely an alert, that a traveler is most likely not able to make connection.

FIGURE 11REJSEPLANEN PERSUASIVE FEATURES I

Rejseplanen App. offers the ability to subscribe to tailored route updates. Notification alert, suggestive messages, are sent to subscribed users to notify them about their journey. This feature, I believe, should be available to travelers whose planed journeys are expected to experiencing unplanned outcome, even if they have not subscribed to their route updates.







A-series unfolding of events. Rejseplanen users can follow her actual location.	B- series ever-present of events. Rejseplanen users can see the whole series of events.	Branching timeline: Users can observe the unfolding of events in different branching timelines.

FIGURE 12 REJSEPLANEN PERSUASIVE FEATURE II

There is, of course, room for improvement. Rejseplanen still lacks the ability to sense users *kairos* moments. It does not include Bayesian network that would form prediction of what travelers intend to do. If equipped with Bayesian network that self-updates through learning user's typical_routine, current_task, type_of_day, and goal_of_day, among other relevant factors, it could offer users with suggestive suitable routes, and departure times, for example, without users accessing the application. Imagine if a traveler T, who takes bus X to work every morning at 8:00. If T fail to catch X at 8:00 in the morning, T will be late to work. Consider that X is delayed 20 minutes on the typical day where T goes to work. A persuasive message sent to T to catch another bus or earlier bus would trigger T to behave differently.

Rejseplanen equipped with Bayesian network that sense travelers kairos moments and trigger suggestive notifications, would be available improvement. It would, for example, solve Sarah's problem, as presented in the introduction. Bayesian network that included Sarah's goal_of_day, possibly mined from Sarah's digital calendar, or(and) data generating activities, e.g. Sarah's digital footprints (such as text-messages, website visits, social media (Facebook, Instagram etc.). Equally, McDonalds App. that is geared with Bayesian network could at *opportune* moment sent a notification to adults with tailored offered.

Users data collection and analysis for the purpose of designing persuasive systems presents some ethical challenges. The next part is set aside to arise and address some of ethical issues related to designing information technologies that can sense and seize opportune moments.

As computer technology evolves and gets deployed
in new ways, certain issues persist – issues
of privacy, property rights, accountability, and
social values. At the same time, seemingly new
and unique issues emerge. The ethical issues can
be organized in at least three different ways:
according to the type of technology; according
to the sector in which the technology is used;
and according to ethical concepts or themes

- Deborah G. Johnson[39]

ETHICAL ISSUES & POSSIBLE SOLUTIONS

Johnson hits at the core in noting issues of privacy, digital property rights, accountability, and social value as ethical issues that need to be addressed. As proposed above, in order to make information technology that can sense and seize user's opportune moments, such a system would require Bayesian networking that learns from users incoming data to form data analysis for prediction and suggestive technology.

[39] Johnson (2004, p.65)

The ideas proposed in thesis appears to suggest digital “stalking”. Why would any reasonable person desire his or her private and public digital information, such Physical_Measures, geolocation, goal_of_the_day (calander), current_task, typical_routine, among other factors and identifiers of the presence of opportune moment, to be used for digital persuasion reasons? Does such information system threat user’s privacy and digital property rights? Who would be held accountable for the safe-keeping and proper use of user’s data?

The solutions I will propose, but not defend, in this paper are machine-to-machine (M2M) communications, end-to-end data encryption, and user’s digital autonomy over his or her private data, as solutions to such ethical questions.

To insure user’s privacy, M2M communication ought to be introduced. Pereira and Aguiar defined M2M communications as “mechanisms, algorithms and technologies that enable networked devices, wireless and/or wired, and services to exchange information or control data seamlessly, without explicit human intervention” (Pereira & Aguiar 2014, p.19583) It is without *explicit* human intervention in a sense that designers/human after lunching such ICT, have no access to user’s data.

M2M communication present another solution that would improve user’s experience. Exchange of information between Norwegian database and Apple iOS would have add Application Suggestive system utilized John’s current_activity and goal_of_day, to suggest Norwegian Airline app. instead of SAS App..

Ensure safe-keeping of data, introduction of *crytodata*, end-to-end data encryptions that will insure that user's data is secured from third parties' view. User's Bayesian network would take as input collection of encrypted data from data mining APIs and output encrypted data for persuasive information systems to use for purposes of persuasion. Given that its is M2M communication, encrypted data can remain as it is.

Answering the problem of digital property rights, persuasive information systems that uses user's private and public data must be designed to give users full-power over there digital footprints. A total off button that will discard all user's private and encrypted data ought to be available to ensure that user's have full power over persuasive system use of their data.

Of cause the solutions offered here do not address all the ethical issues raised in designing information systems that imports and analyze user's data for persuasion purposes. The aim of introducing them is to show that to every ethical issues raised, there exists a possible solution to address.

REVELATION: FUTURE RESEARCH & CONCLUSION

This paper calls for a number of future researches. Two of future researches that I would like to such further to form empirical data are (i) how Bayesian network that takes in both a priori knowledge and incoming data, for Bayesian machine learning, to form posteriori knowledge, would be more capable, if indeed it would, of sensing the presence of kairos than the one that only has priori knowledge, and (ii) how open are users to grant machine-to-machine exchange of their private digital data (question of ethics). But for now, I hope that problems answered introduced valuable propositions that will contribute to answering the challenge of information and communication technologies(ICT) sensing and seizing opportune moments.

As I conclude, the thesis argued that the concepts of Bayesian network and nature of time can aid in designing persuasive information systems that are time sensitive and predict user's possible next action. ICT that applies the ideas of A-and B- perspectives of time, branching timeline, and Bayesian network, are by elasticity of inventiveness a solution towards solving the challenge of *sensing* and seizing *kairos* in ICT.

It is indeed problematic to attempt design information system that can infer some internal human intention. What is less problematic is sensing parameters of a probability distribution of their intention. If we understand internal human intention no such much as 'optimal' particular setting of parameter but rather a distribution of parameter values weight distribution, then it is possible to begin the task of designing machines that will automatically help us achieve our daily goals.

APPENDIX 1

SELECTED AUTHOR'S PAPERS IN RELATIONSHIP TO NATURE OF TIME AND KAIROS

From 'The Role of Some of Metaphysical Concepts in Persuasive Designs,' pp.14-16, 18-19 Design of Information Architecture, 8th Semester paper

WHAT DOES 1600'S JESUITS' DEBATE HAVE TO DO WITH BRANCHING TIMELINES?

The controversy *de Auxiliis* (On Assisting Grace) was 16th century utmost intense theological controversy regarding the nature of predestination, grace, God's knowledge, and human liberty in Catholic theology[40]. What concerns us, out of this debate, is their understanding of God's knowledge of future contingents. Two figures from the Jesuits tradition, Louis de Molina (1535-1600) and Francisco Suárez (1548-1617), selected for the purpose of this essay, presented fascinating theological system that allegedly reconcile human liberty with God's grace and providence.

[40] The battle between the Dominican and the Jesuits.

Molinism, named after Molina, was one of the contending views that reconciled strong libertarian account of creaturely freedom, it presupposes, with God's grace and providence. If God's grace were understood to be intrinsically efficacious in saving fallen creatures, then, according to Molinism, it would violate creaturely freedom. Safe guarding both a strong view of God's providence and knowledge, and a strong view of libertarian creaturely freedom, Molina introduced the idea *scientia media* (middle knowledge), the knowledge that is in between God's *necessary knowledge*, *viz.,* God's inherent, and *a prior* to creation of actual world, knowledge of all necessary beings(i.e. *necessitas consequentie*, necessary truth), and God's *free knowledge, viz.,* God's *posterior* to creation of the actual world knowledge of which of the possible state of affairs He actualized(i.e. contingent truth). Molina explained that,

> *[M]iddle* knowledge, [is] by which, in virtue of the most profound and inscrutable comprehension of each faculty of free choice, He[God] saw in His own essence what each such faculty would do with its innate freedom were it to be placed in this or in that or, indeed, in infinitely many orders of things—even though it would really be able, if it so willed, to do the opposite.(Molina, *Concordia*, 4.52.9.)[41]

[41] Molina, *On Divine Foreknowledge*, p. 168. In some literature, Molina's work is cited this way: Molina, *Concordia*, 4.52.9. This specifies the major part of the *Concordia* (4), the disputation number (52), and the section number (9).

Stating Molina's idea in other words, God is believed, in this view, to know what every sentient being would freely do in every possible branching timeline that that being finds himself. For example, God, in this view, is believed to know what person *P* would do in every branching timeline *P* is in. God, thus, possesses super-comprehensionism, namely the knowledge of maximal counterfactuals of creaturely freedom[42].

Suárez discourses on grace in Rome (1582-1583) initially rejected Molina's idea of *scientia media*[43], but in around 1585 he endorsed it. He although customized Molinism to another view known as *congruism.* Suárez concurred with Molina's definition. He wrote,

> [C]oncerning de concurrence of God with free choice, we always suppose that God knows regarding any will, what it will do or would do, if it were constituted in this or that situation, and this is usually called the conditional knowledge of future contingents as are these*: if Peter were tempted her and now, he would sin.*(Suárez, 'Scientia Dei,' p. 291) [44]

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[42] William Lane Craig believes that "providence and prestination presuppose middle knowledge."(*Problem of Divine Foreknowledge and Future Contingents 2000*, p. 183)

[43] 'De scientia conditionalium,' in Un Tratado inedito de Suarez sobre la ciencia media, ed. Severion Gonzalez Rivas, S. J. [Miscelànea Comilla 9], pp. 81-132 (Madrid, 1948[1585])

[44] Suárez, 'Scientia Dei,' p. 291: In *libris quos de concursu Dei cum libero arbitrio nuper scripsimus, saepe supposuimus cognoscere Deum de quacumque voluntate, quid actura sit, vel esset, si in hac vel illa occasione constitueretur; et vocari solet haec scientia futrorum contingentium conditionatorum, qualia sunt haec: Si Petrus hic et nunc tentaretur, peccaret.*

Molina and Suárez disagreed on who is to be said to have actualized the desired state of affairs, namely who is that brings about that God's given grace became efficacious. Is it God, or the fallen creature, or both? To make this point clearer, consider that in branching timeline *C*, induced by grace *G*, Peter freely educes salvific act A. Both Molina and Suárez agreed that God would place Peter in *C* with *G*, certainly knowing that Peter will educe *A*. They also equally agreed that *G* is not intrinsically efficacious, and, thus, does not causally predetermine *A* (and, thus, creaturely liberty is intact).

Molina and Suárez, nevertheless, disagreed whether or not it is Peter's liberty alone that extrinsically bring about that *G* is efficacious in *C* given *A*. Molina would hold that God, who certainly know that Peter would freely educe *A*, would place Peter in *C* with induced *G,* without absolutely determined prior to Peter's free act. It is Peter's liberty alone that renders *G* efficacious. Suárez held different view. He believes that God would place Peter in *C* with induced *G* (or another congruous grace *g*), which will absolutely guarantee that Peter would freely educe *A*. God *via scientia media* know which grace other than *G* would guarantee that Peter would freely educe *A*, if Peter were to choose other than *A* in *C*. In this view, it is not Peter's liberty alone that renders *G* (or other than *G*) efficacious, but also God who *a prior* predetermined to confer a congruous grace.

[…]

How designers go about designing a persuasive technological system that, if successive, would bring about the desired states of affairs, depends on the underlining metaphysical foundation of their collective conception of the world. The questions of ontology, epistemology, explanation-and-prediction, axiology and praxeology that form our worldviews are inescapable.

In designing a persuasive system that actualization desired states of affairs, namely bringing about change or enforcement of desired attitude or (and) behavior without infringing user's freedom will, would have to deal with explanation-and-prediction (theory of past and future causality), axiology (theory of values) and praxeology (theory of duties). These theories depend on the underlining theory of being, ontology, to which this essay would not cover.

Designing a persuasive system that intentionally attempt to influence a change in its user's attitudes or behaviors or both without using coercion or deception (Fogg 2003, p.15) requires a certain understanding of the nature of freedom of will, namely how do we make our choices, and when is our choices said to be free. Designers also have to talk a further step into the theory of duties. The questions of the right or the wrong methods of swaying products' users must be addressed by trustworthy designers.

EXPLANATION-AND-PREDICTION, AXIOLOGY AND PRAXEOLOGY IN DESIGNING

According to Molina, "[t]hat agent is called free which, when all the requisites for acting are posited, can act or not act, or can so do one thing that it can also do the contrary." (Molina 1953, p. 14) This is a classical definition of libertarian freedom. If this view, as it appears, is true, it is impossible to probabilistically calculate which choice an individual would take. Until the point of decision, the probabilities of both options are equal.

Thus, as it appears, namely freedom of will is the liberty of an agent *P* acting *A* or not acting *~A* at a particular moment *M*, we have no idea what makes *P*, say, choose *A* over *~A* at *M*. What could be factors that compels *P* to choose *A,* over *~A*? Jonathan Edwards (1703-1758) explained that, "in some sense, *the Will* [that by which the mind chooses any thing] *always follows the last dictate of the understanding*. But then the *understanding* must be taken in a large sense, as including the whole faculty of perception or apprehension, and not merely what is called *reason* or *judgment*." (Edwards 2008, p. 7 emp. orig.) According to Edwards the factors that compels *P* to choose *A*, over *~A* is *P*'s greatest motive/desire *D* at *M*. He wrote, "*It is that motive, which, as it stands in the view of the mind, is the strongest, that determines the Will*." (*ibid.* p. 5 emp. orig.)

This is a different metaphysical assumption. Unlike Molina's libertinism, that rejects a compatibility of predetermination with human liberty. Edward's model is that of classical compatibilist. If Edwards' assessment is correct, we could begin to have an idea, namely *D*, of what makes *P* choose *A*, over *~A*, at *M*. How *D* could be recognized would involve complicated array of elements both within and outside of *P.*

[…]

From 'Nativity of Temporal Logic and Its Applicability in Computer Science,' pp.11-13, Logic and Time III, 9th Semester paper.

3. APPLICATION OF TEMPORAL LOGIC IN COMPUTER SCIENCE

A simplified practical application of temporal logic in ICT is summarized well by E. A. Emerson and J. Y. Halpern when they wrote: “In practice, [Temporal logic, a formalism for reasoning about correctness properties of concurrent programs] has been found useful to have an until operator *p* U *q* which asserts that *q* is bound to happen, and until it does *p* will hold.” (Emerson & Halpern 1985, p. 1). But its story began with Amir Pnueli, in the late 1970’s, introduction Prior’s temporal logic in programming and system verification. His work, “The Temporal Logic of Programs” (1977) pioneered temporal logic in computer science. In his paper ‘The Temporal Semantics of Concurrent Programs’ (1981), Pnueli advocated formalized-temporal logic as a suitable apparatus for validating semantics of concurrent programs. He explained:

> Temporal Logic provides an excellent and natural tool for expressing these [class that contains the notion of termination and total correctness for sequential programs, and those of responsiveness, accessibility, liveness[sic] and eventual fairness] and other properties which depend on development in time. This, the temporal semantics of a program is given by a formula *W*(P) expressing the temporal properties of all its possible and legal execution sequences. Then in order to prove that a temporal property *R* holds for a program we only have to prove the validity of the implication. (1981, p. 48)

For Pnueli believed that temporal logic provides are tool to verify instant of time were there are more than one future outcome to consider. Specification (temporal logical statements) could be imputed in a system to see if it provides desired or erroneous outcomes.

Together with Mordechai Ben-Ari and Xohar Manna, Pnueli noted that the superiority of branching time over that of linear time. They argued that unlike linear time type of programs that studies a uniformly execution sequences of a program, branching time type of programs “considers for a give program the set of all *execution trees* generated by the program” (M. Ben-Ari et al. 1983, p.208)

Using temporal logic, E. M. Clarke, E. A. Emerson and A. P. Sistla, in steps of Pnueli and others, a *model checker* algorithm that determine whether a system meets finite-state concurrency and within a seconds the state of the system with hundreds of possible outcomes can be verified (Clarke et al. 1986)

With this, Prior predication of the usefulness of temporal logic, a sort of system that does “not depend on any serious metaphysical assumption that time is discrete; they are applicable in limited fields of discourse in which we are concerned only with what happens next in a sequence of discrete states” (1967, p. 67), in computer science, came true.

APPENDIX2

JUST-SO-FERRY PROBLEM ILLUSTRATION

Illustrating the power of Bayesian theorem, lets imagine Just-Ferry Table, as an example of a database that records names, modernity, arrival status, sailing period and route length taken by 6 different ferries.

Ferry_Name	Modern_Ferry	Arr_Status	Day_Time	Route
St. Mary	No	On Time	Morning	Long
St. Luke	Yes	Delay	Evening	Short
St. Mary	No	On Time	Evening	Short
St. Mary	No	On Time	Evening	Short
St. Mathew	Yes	Delay	Morning	Long
St. Mark	No	On Time	Evening	Short
St. Paul	Yes	Delay	Morning	Short
St. John	Yes	On Time	Evening	Long

Using Bayesian computation, the probability of a single attribute such "Ferry_Name" and "Route". The probability that St. Mary, for example, took a short/long route, can be computed as follows:

$$\Pr(\text{Short} \mid \text{St. Mary}) = \frac{\Pr(\text{St. Mary} \mid \text{Short})\Pr(\text{Short})}{\Pr(\text{St. Mary})}$$

$$\Pr(\text{Short} \mid \text{St. Mary}) = \frac{\left(\frac{2}{5}\right)\left(\frac{5}{8}\right)}{\left(\frac{3}{8}\right)} = 0.666\ldots$$

$$\Pr(\text{Long} \mid \text{St. Mary}) = \frac{\Pr(\text{St. Mary} \mid \text{Long})\Pr(\text{Long})}{\Pr(\text{St. Mary})}$$

$$\Pr(\text{Long} \mid \text{St. Mary}) = \frac{\left(\frac{1}{3}\right)\left(\frac{3}{8}\right)}{\left(\frac{3}{8}\right)} = 0.333\ldots$$

When considering multiple attributes, such as the probability that the ferry is St. Mary given that that an old ferry arrived on time, and its evening, naïve Bayesian classifiers, which assumes independent distribution of attributes, can be utilize as follows:

$$\Pr(\text{St. Mary} \mid \text{No \& On Time \& Evening})$$

$$= \frac{\Pr(\text{No} \mid \text{St. Mary})\Pr(\text{St. Mary})}{\Pr(\text{No})} \times \frac{\Pr(\text{On Time} \mid \text{St. Mary})\Pr(\text{St. Mary})}{\Pr(\text{On Time})}$$

$$\times \frac{\Pr(\text{Evening} \mid \text{St. Mary})\Pr(\text{St. Mary})}{\Pr(\text{Evening})}$$

$$\Pr(\text{St. Mary} \mid \text{No \& On Time \& Evening}) = \frac{\left(\frac{3}{4}\right)\left(\frac{3}{8}\right)}{\left(\frac{4}{8}\right)} \times \frac{\left(\frac{3}{5}\right)\left(\frac{3}{8}\right)}{\left(\frac{5}{8}\right)} \times \frac{\left(\frac{2}{3}\right)\left(\frac{3}{8}\right)}{\left(\frac{5}{8}\right)}$$

$$\Pr\left(\text{St. Mary} \mid \text{No \& On Time \& Evening}\right) = 0.054$$

The more background data we have, the more precise our predictable probability will be.

APPENDIX 3

NAÏVE BAYES CLASSIFIER IN COMPUTER SCIENCE

$$y_{MAP} = arg \max_{y \in Y} P(y|x) = arg \max_{y \in Y} \frac{P(y)P(x|y)}{P(x)} \approx arg \max_{y \in Y} P(y)P(y|x)$$

Appearing in Nong Ye's work, *Data Mining: Theories, Algorithms, and Examples* (2014 p. 32), the equation above calculates "the maximum a posterior (MAP) classification [target class] y of [data vector] x". Ye explained the equation as follows:

Y is the set of all target classes. The sign ≈ [in the equation above] is used because *P*(*x*) is the same for all *y* values and thus can be ignored when we compare $\frac{P(y)P(x|y)}{P(x)}$ for all *y* values. *P*(*x*) is the prior probability that we observe *x* without any knowledge about what the target class of *x* is. *P*(*y*) is the prior probability that we expect *y*, reflecting our prior knowledge about the data set of *x* and the likelihood of the target class *y* in the data set without referring to any specific *x*. $P(y|x)$ is the posterior probability of *y* given the observation of *x*. $arg \max_{y \in Y} P(y|x)$ compares the posterior probabilities of all target classes given *x* and chooses the target class *y* with the maximum posterior probability (Ye 2014, p.32)

Ye went further to point out that:

A classification y that maximizes $P(x|y)$ among all target classes is the maximum likelihood (ML) classification:

$$y_{ML} = arg \max_{y \in Y} P(x|y)$$

If P(y) = P(y') for any y ≠ y', $y \in Y$, y' $\in Y$, then

$$y_{MAP} \approx arg \max_{y \in Y} P(y)P(x|y) \approx arg \max_{y \in Y} P(x|y),$$

and thus

$$y_{MAP} = y_{ML}$$

[If we grant the assumption that data vector x values are independent of each other, since Naïve Bayes assumes independence of values, then]

$$y_{MAP} \approx arg \max_{y \in Y} P(y)P(x|y) = arg \max_{y \in Y} P(y) \prod_{i=1}^{p} P(x_i|y)$$

The naïve Bayes classifier estimates the probability terms in [above computation] in the following way:

$$P(y) = \frac{n_y}{n}$$

$$P(x_i|y) = \frac{n_{y\&x_i}}{n_y}$$

where

n is the total number of data points in the training data set

n_y is the number of data points with the target class *y*

$n_{y\&x_i}$ is the number of data points with the target class *y* the *i*the attribute variable taking the value of x_i (Ye 2014, p.32)

Computation for multiple classifier systems (Fumera & Roli 2005; Heckerman et al., 1995). Another valuable works is Heckerman et al.,(1995)

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