Common Knowledge Based Social Media Modeling

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Abstract

The Purpose of this paper is to create and test a model for social media interactions based on common knowledge operators. Methodology and theoretical approach of this paper is based on the elements of Game Theory and more precisely – common knowledge. In general, social media campaign effectiveness is measured using various goals, such as engagement or traffic conversion rate. These goals help companies achieve higher conversion rates. In this paper social media is overviewed, its most recent applications in marketing are discussed and a common knowledge based model is presented.

Keywords: Social media marketing, common knowledge, Online Marketing, Advertising

Introduction

Social media has been a widely discussed topic in the past few years. Many scientists and marketers tend to comment on the importance of social media. Prior to this paper a research has been done and published on how social media transformed the way bars and clubs conduct marketing campaigns in Lithuania. Even textbook authors devote entire chapters to social media. Internet Technology once considered the future of marketing became its present. It provides marketers with interactive media communication capabilities to enhance existing relationships with consumers. Even though social media could be considered the most potentially powerful tool in business, there is a lack of approach towards social media other than one that provides traditional pros/contras or potential benefits. This paper is a scientific approach on social media from the perspective of the mathematical logics, more precisely, common knowledge.

Social Media Overview

Social media combines social user blogs, multimedia sites, collaborative websites and most interestingly – microblogs, such as Facebook or Tvitter. Social Media is "media that is published, created and shared by people on the Internet, such as blogs, images, videos, and more"(Stokes & Blake, 2008). It also contains of various tools and platforms that allow Internet users to collaborate on content, exchange of views and experiences, and connect for business or pleasure(Strauss, Frost, & Ansary, 2009). The social network "type of website models, where agents become part of a wider virtual community" (Stokes & Blake, 2008). For this reason, social media can be called as communication set for agents to share information, and social network - an environment or a set of worlds, which combines information of various agents: each possessing some information which is known publicly and some – which is known privately.

Conventional approach states that people are actively involved in their use of the media to meet their needs. When used correctly, social media can empower successful two-way communication with customers, or empower information sharing capabilities between the agents in the same group(Mangold & Faulds, 2009). If we consider a well-known Muddy kids example (Halpern, Van Der Meyden, & Vardi, 2004), a father could be easily replaced by a blogpost or a Tweet and we could still get the same results. For this reason, with the application of substitution axiom it will be shown in this paper that common knowledge could be used as a language toolset to model agent information sharing in social networks.

Social media platforms have potentially unlimited application, in many cases the provided value extends beyond e-commerce which strongly focuses on communicating sales to the fans or to the potential target group. One possible application is research. You could create several book-covers for your newly written book and instead on trusting yourself or your designer, you could show the covers to the potential readers. They could help you choose the cover that they would like the most.

A similar experiment was conducted by the author – before launching a new professional blog the several design templates were presented to the students on social media sites and the one that received the most likes and comments got to be the face of a professional blog. One of the key social media elements was just presented – engagement with the audience. Just like it is not enough simply to open a corner store (one would need prior research and then promotion), creation of online presence doesn't guarantee that the business will gain value from it. Correct social media implementation requires adoption, community building and absorptive capacity (Culnan, McHugh, & Zubillaga, 2010).

One of the reasons, why social media was chosen for this research, is its transitivity. Concept of transitivity states that if an agent 1 knows some sort of information, than agent 1 knows that he knows this information. With social media agents who post information, submit it to special forms before submission, and agents who consume that information, receive it in special newsfeeds. If such post is written on a blog, than this information is public two-way conversation between agents(Wright & Hinson, 2009). Knowledge logics share several modal operators – distributed knowledge operator, knowledge operator, everyone knows operator and knowledge is common operator. All these operators have great potential for social media analysis, for example close group posts could be analyzed from perspective of distributed knowledge, when public announcements could be analyzed with the involvement of common knowledge operator. These public announcements can analyzed to estimate not only what the brands broadcast to their target group, but also how certain agents react both to the information that they receive from the brands and the information that other agents broadcast back by commenting or relying to the messages. All this information has a potential to reach any agent within the group. It is recommended that businesses should not try to hide any negative comments made about their product or service(Qualman, 2012). He advocates using these negative comments as a way to reach out and converse with unsatisfied consumers and to constructively improve their products and services. Social media has created a newfound transparency and businesses must consisted what to communicate because of the ease with which an offensive message can be recorded and shared (Qualman, 2012).

Marketing Applications of Social Media

Recent research shows that consumers' level of engagement in a company's social media activity is positively related to perceptions of corporate reputation. Engagement could range from not being active on social media and not knowing social media activities, to following the brand on one of its social media channels. Part of the positive association between engagement and reputation might be the result of emotional contagion e the tendency to feel and be influenced by others' emotions (Barsade, 2002). In general, majority of word of mouth communication on social media sites about brands is positive. Agents, who choose to follow the brands in social media are exposed to both content placed by the brand and the responses to these posts, and to the questions, complaints and remarks posted mainly by customers and often followed by a response of the brand. Previous studies have shown that witnessing a company responding to customer complaints in social media affects the evaluation of this company. It is also stated that the consumer's intensity of social media use is positively related to the engagement in a company's social media activities.

The higher one's intensity of social media use, the more likely one will become a "friend" or "follower" of a company and to become engaged in their online activities (Leung & Bai, 2013). Looking at the differences, indicated in research between customers and noncustomers, it should be noted that customers, and non-customers have different antecedents and motives to follow and become engaged in a company's social media activities. Whereas for noncustomers general company interest or just curiosity may play an important role, for customers social media platforms also prove their worth as channels for customer service, direct feedback and product/company updates (Webster, 2012). Furthermore, customers that have personal experience with a company, are more involved with it and know more about it, resulting from information seeking behavior before a purchase, and also after a purchase. Previous research by scientists shows that customers have more positive perceptions of the company's reputation than non-customers, regardless their intensity of social media use and engagement in the company's social media activities. Research shows, that the differences between costumers and non-customers together show a rather different picture for both groups with regard to social media engagement and corporate reputation. The higher reach of the company's social media activities among customers is likely the result of both being encompassed by the company's attempts to motivate customers to use their social media channels, and the higher persuasiveness of these appeals because of the higher instrumentality of these channels.

Additionally, customer support in social media may have important side effects for non-customers, who now witness customers being supported on Twitter or Facebook, which may strengthen their perception of the level of customer orientation of the company. Non-customers experience the candid way employees of the company respond with a conversational human voice to several types of online feedback, like questions, compliments, and complaints (Kelleher & Miller, 2006). In earlier studies, a conversational human voice was shown to be of added value for brand evaluation (Kelleher & Miller, 2006), and candidness in online dialogues showed to enhance trust and familiarity(Lee, Hwang, & Lee, 2006). Together, this may influence the perception of corporate reputation. The relationship between social media engagement and corporate reputation is more pronounced among non-customers. This suggests that companies should actively focus their social media activities on non-customers for a number of reasons. First, the largest part of a company's target markets consists of noncustomers. Companies need to continuously explore opportunities to sell to new customers since at some point existing customers may fall away. In the short term, firms may not see market performance effects from their social media activities focused on non-customers. Nevertheless, in the longer term it may come to new supplier selection e online engaged non-customers may turn more easily into customers, since corporate reputation is an important aspect in purchase intentions(Keh & Xie, 2009). This stresses the need for companies to keep in touch with non-customers. Social media platforms can offer an "early warning system", which, at a relatively low expense, is alsouseful for ideation and co-creation (Hoyer, Chandy, Dorotic, Krafft, & Singh, 2010). Engaged non-customers with a positive perception of the company's reputation may come to play an important role as online "ambassador" and influencer (Shamma & Hassan, 2009). To further show how customers and noncustomers could be engaged by different medias common knowledge concept is introduced and social media case, based on common knowledge, is modeled.

Common Knowledge

Common knowledge has been widely uses to model behavior of different agents in fields of economics and game theory. Agents (also possibly known as people or companies) are presumed to possess different levels of information. To define this knowledge, a modal operator $K(i)$ is used. Conventional expression $K_i\varphi$ stands for "agent *i*knowsφ, where φ stands for the peace of information that agent *i*knows. If we have an environment (world) in which there are two agents, then $K_1\varphi$means that agent 1 knows φ. If agent two has exactly the same information: e.g. both of them know only that it rains outside, then $K_2\varphi$. If those two agents posses different information: e.g. agent 1 knows that it rains outside, and agent 2 knows that today is Friday, then the information of agent 2 should be defined using different formula. If this case $K_2\psi$ stands for agent 2 knows ψ. $K_2K_1\varphi$stands for "agent 2 knows that agent 1 knows φ. And $K_1K_2\varphi$ stands for "agent 1 knows that agent 2 knows φ. If the group of agents consists only of two agents then if φ is true and $K_1\varphi$and $K_2\varphi$, then every agent knows φ, which could be defined by a modal operator E. $E\varphi$stands for "everyone knows φ". If φ is true and everyone in this group knows that everyone knows φ, then the information on φ is a matter of common knowledge. And it can be defined as $C\varphi$. This language contains a set of propositional symbols $P, P_1, P_2,\ldots, Q, Q_1, Q_2, ,\ldots$ the set of logical connectives $\supset,\wedge,\vee,\neg$; finite set of agent constants $i, i_1, i_2,\ldots$; multiple knowledge modality $K(i)$, where i is an agent constant; everyone knows operator E; common knowledge operator C.

A formula of RCL is defined inductively as follows: every propositional symbol is a formula; if A, B are formulas, then $(A \supset B)$, $(A \wedge B)$, $(A \vee B)$, $\neg(A)$ are formulas; if i is an agent, A is a formula, then $K(i)A$ is a formula; if A is a formula, then $E(A)$ and $C(A)$ are formulas. The operator $K(i)$ behaves as modality of multi-modal logic K_n. In the language of common knowledge, it is assumed that there is perfect communication between agents. In other words, if $K_2\varphi$, then φ is true and $K_1\varphi$. The operator C and E behave as modalities of modal logic $S5$. In addition these operators satisfy the following powerful properties: $C(A) = A \wedge E(C(A))$ (fixed point) and $A \wedge C(A \supset E(A)) \supset C(A)$ (induction). Formal semantics of the formulas $K(i), E(A), C(A)$ are defined as in the reflective common knowledge logic.

Modeling Social Media Analysis

As it was previously mentioned, from the perspective of logics, Facebook is an environment or a set of worlds, which consists of various agents. Let us say that all of these agents combined form a group *F*, which consists of the total amount of all possible groups of agents within this social network. Despite this fact, all of the agents form smaller individual groups: *G1, G2, G3…Gn*. Same agent can be a member of more than one group, thus this can be expressed in this way: $K_1^{G1,G2,G3}$, meaning that agent 1 is a member of *G1, G2, G3.*

Each agent possesses certain information which the agent can choose to share with the group. The whole sequence follows: Agent 1 knowsφ, then agent 1 shares information aboutφ, members of the group accessFacebook and find out aboutφ. In general this can be formulized into following:

$$\varphi \to K_1\varphi \wedge S_1\varphi \to \cdots K_2\varphi \wedge K_3\varphi \ldots \wedge K_n\varphi$$

In this case, moment of sharing looks like crucial for the whole sequence to stand, but in general as the agents exist in the world of complete information, we can see that

$$\varphi \to K_1\varphi \to \cdots K_2\varphi \wedge K_3\varphi \ldots \wedge K_n\varphi$$

There are several parameters in common knowledge, which all can be identified in social networks, particularly in Facebook. A primary element to consider is transitivity, which states that if any agent within a group possesses information, then all this knowledge is transferred to all the agents within the group. In other words, social media serves as a gateway for the complete group information.

Let us assume that there are three agents in the group G, and all of them are Facebook friends. Agent 1 possesses information $\psi 1$, but has not posted this information on the social network so far. Agent 2 has information $\psi 2$ and agent 3 has information $\psi 3$. If asked – agent 2 and agent 3 could not tell that the agent 1 possesses information $\psi 1$. The same would be in the other cases as well. It is an indicator that at this point of the game, neither of the agents contain information about the other agents.

If Agent 1 chooses to share $\psi 1$ on Facebook, all of the agents will get instant access to this information on their computers or smartphones. Therefore, at this point we can state that

$$K_1\psi 1 \wedge K_2\psi 1 \wedge K_3\psi 1$$

If we take a different case, when agent 1 personally informs each of the other agents of $\psi 1$, we will have a distributed knowledge scenario, where

$$K_1\psi 1 \wedge K_2\psi 1 \wedge K_3\psi 1$$

But

$$K_1\psi 1 \wedge K_2\psi 1 \wedge K_3\psi 1 \wedge \neg K_3K_2\psi 1 \wedge \neg K_2K_3\psi 1$$

Despite the fact that agent 1, agent 2 agent 3 know $\psi 1$, it's not that everyone knows that everyone knows that everyone knows $\psi 1$ before all of them interact together stating their knowledge. In general, if we let $E^k\psi 1$ represent the fact that everyone knows that everyone knows . . . (k times) $\psi 1$, and let $C\psi 1$ represent the fact that p is common knowledge, then it turns out that Facebook post actually converts the agents' state of knowledge from $E^{k-1}\psi 1$ p to $C\psi 1$. With this extra knowledge, information about $\psi 1$ becomes common knowledge.

Given this example, one might think that common knowledge arose because all the agents knew that they all could use social network. For common knowledge this is not enough. Suppose the agents do not trust each other, and each agent secretly log the traffic of the other agents. Thanks to these logs, all the agents know that each agent has used social media, but they still do not have common knowledge. Common knowledge arose here because of the public nature of social media. Public post of $\psi 1$ puts the agents in a special situation, one with the property that all the agents know both that $\psi 1$ is true and that they are in this situation. Under such circumstances $\psi 1$ is common knowledge. Note that the common knowledge does not arise because the agents somehow deduce each of the facts$E^k\psi 1$ one by one. (If this were the case, then arguably it would take an infinite amount of time to attain common knowledge.) Rather, the common knowledge arises all at once, as a result of the agents being in a special situation(Halpern et al., 2004).

As we apply several essential axioms to transfer knowledge between agents (such as axiom of transitivity or truth), each agent knows that he knows what he knows and each agent knows that if agent knowsφ, then φ is true. Therefore, each agent knows all the logical consequences of his knowledge. Distribution axiom states that if an agent knows$\varphi$and knows that φ implies ψ, then both φ and $\varphi \Rightarrow \psi$ are true at all worlds he considers possible. Thusψmust be true at all worlds that the agent considers possible, so he must also know ψ. It follows that $\vdash (K_i\varphi \wedge K_i(\varphi \Rightarrow \psi)) \Rightarrow K_i\psi$. Distribution axiom allows us to distribute the $K_i$operator over implication. It seems to suggest that our agents are quite powerful reasoners. Further evidence that our definition of knowledge assumes rather powerful agents comes from the fact that agents know all the formulas that are valid in a given structure. If φ is true at all the possible worlds of structure M, thenφmust be true at all theworlds that an agent considers possible in any given world in M, so it must be the casethat Ki$\varphi$is true at all possible worlds of M.

More formally, we have the following Knowledge Generalization Rule For all structures M, if M $\vdash \varphi$ then M $\vdash K_i\varphi$.Note that from this we can deduce that if$\varphi$is valid, then so is $K_i\varphi$. This rule isvery different from the formula$\varphi \Rightarrow K_i\varphi$, which says that if $\varphi$is true, then agent I know it. An agent does not necessarily know all things that are true(Halpern et al., 2004).

However, from perspective of logics, agents know all valid formulas. From applied truth axiom we know that these are the formulas that are necessarily true. Despite the case that an agent may not know the facts that are true, it is clear that if an agent knows something, it is true (cases of belief or presumption are not considered at this point – only the actual knowledge). Another property$\vdash K_i\varphi \Rightarrow \varphi$is called the Knowledge Axiom or the Truth Axiom (for knowledge), has been taken by philosophers to be the major one distinguishing knowledge from belief. Although you may have false beliefs, you cannot know something that is false. This property follows because the actual world is always one of the worlds that an agent considers possible. If $K_i\varphi$holds at a particular world (M, s), then$\varphi$is true at all worlds that*i* considers possible, so in particular it is true at (M, s). The last two properties we consider say that agents can do introspection regarding their knowledge. They know what they know and what they do not know:

$$\vdash K_i\varphi \Rightarrow K_iK_i\varphi$$
$$\vdash \neg K_i\varphi \Rightarrow K_i\neg K_i\varphi$$

The first of these properties is typically called the Positive Introspection Axiom, while the second is called the Negative Introspection Axiom (Halpern et al., 2004).

Applying the Model on Social Marketing

This chapter has an aim to test the introduced model for social media marketing. One of the main assumptions behind social media is that the agents can participate in the construction of advertising messages. Indeed, we can identify consumers' attitudes towards brands through their interaction over the Web: blogs, forums, social networks (Facebook, Twitter), online media. With social media several a shift from an action strategy to an interaction strategy happened.

Let us have an example: Presumably we have a company, which runs two similar campaigns: a banner campaign on display network and a campaign on social network. Banner provides information φ and social media post provides information ψ. An easiest approach to compare the campaign effectiveness is to run the campaign simultaneously and measure the results – in most cases the goal is a conversion. The most straightforward and wrong approach would be to compare a simple ROI (return on investment). Let's say that the banner campaign costs 200 Euros and makes 400 Euros worth revenue and social media campaign delivers exactly the same results with same investment. Applying the simplest ROI approach these two campaigns have same results. But if we consider additional parameters, such as ability to measure what customers know, we could see that social media campaign even with the same sales results outperforms the banner campaign because it encourages the agents (customers) to interact with the brand in such ways that simple banners don't allow. From the perspective of common knowledge, difference between banners and social media posts is mainly because traditional display banners apply broadcasting technique, where the media campaign is streamed for the target group without anyone but the receiver knowing who else got the same message (unless the agents use third party solutions, such as a phone to discuss what kind of banners campaigns they see). Thus, with the banner campaigns we have the same model where

$$K_1\psi \wedge K_2\psi \wedge K_3\psi \ldots$$

But

$$K_1\psi \wedge K_2\psi \wedge K_3\psi \wedge \neg K_3K_2\psi \wedge \neg K_2K_3\psi \ldots$$

On the other hand, with social media campaigns we have a completely different outcome, where all agents know the received the information and they also are able to know who else received the information (if those people left a comment below the post) or they can indicate in the comments themselves that they have received the message. Thus, with social media there is a possible outcome where agent 1 knows the information, agents 2 and 3 know the information and in addition to this knowledge they also might know that other agents know the same information.

$$K_1\psi \wedge K_2\psi \wedge K_3\psi \wedge K_3K_2\psi \wedge K_2K_3\psi \ldots$$

From the perspectives of common knowledge, this property is much stronger than the simple broadcast-receive type of communication because all agents get the knowledge that the other agents also know ψ. In other words, as social media provides a "public announcement" type playground for the companies theoretically it is possible that $E_G^k\psi$ and therefore $C\psi$ which is impossible to achieve with traditional banner campaigns.

Conclusion

This paper presented a theoretical approach on social media from the perspectives of common knowledge. The idea behind common knowledge is that it is a state when all agents know certain information, know that the others know it, and know that the others know that they know… to the power of infinity. In this paper a theoretical model was built to explain the knowledge that agents of the group possess and later this model was applied in a practical scenario, where performance of two simultaneous campaigns was evaluated. Despite the fact that traditional ROI approach states that these two campaigns perform the same, application of common knowledge driven model indicates that these two campaigns had completely different results and theoretically it is possible that a banner campaign was greatly outperformed by social media campaign because it serves as a gateway for all agents to know that other agents know the information, which is impossible with traditional broadcasted banners.

$$K_1\psi \wedge K_2\psi \wedge K_3\psi \wedge K_3K_2\psi \wedge K_2K_3\psi \ldots \Rightarrow E^k\psi \Rightarrow C\psi$$

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