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Evaluation of Advertising Effectiveness Using Agent-Based Modeling and Simulation

Junwei Cao
Department of Computer Science
University of Warwick
Coventry, CV4 7AL, UK
junwei@dcs.warwick.ac.uk

Abstract

Advertising is a common commercial activity. The evaluation of advertising effectiveness is an active area of interest within the advertising research community, and, of course, is most concerned by the advertisers. The most important services in a computer-based advertising infrastructure are advertising effectiveness evaluation, analysis, prediction, and scheduling. This work presents an agent-based modeling and simulation approach to overcome the difficulties. A psychological process is added into the agent negotiation decision function between the information-exchanging process and decision-making process to model more accurate consumer behaviors. A demo version of Simulation Environment of Advertising (SEA) is developed to study the effectiveness of banner advertising on the Internet and provide sample simulation results.

1 Introduction

We are all surrounded by a vast amount of advertising. Nearly everybody, therefore, has some thoughts on the subject. The tendency is to judge advertising as good or bad, to single out advertisements that one likes or dislikes, to wonder if advertising is worth the large sums of money spent on it, to question the contribution advertising makes to social welfare, and so on. Advertising research also aims to answer these questions in academic ways mainly within the fields of social science.

The social simulation research community has developed rapidly in recent years. Computer simulation has proved useful for modeling phenomena of traditionally social scientific interest. This work is to use agent-based social modeling and simulation approach to evaluate the effectiveness of advertising. Some backgrounds are given below.

1.1 Advertising Research

Advertising is multidimensional. It can be viewed as a form of communication, as a component of an economic system, and as a means of financing the mass media [Sandage71]. Different kinds of businesses use advertising to motivate different kinds of markets toward different kinds of responses. These include national advertising, retail advertising, industrial advertising, trade advertising, professional advertising, idea advertising, and so on. The advertisements we see and hear are end products of a series of investigations, strategic plans, tactical decisions, and executions that all together comprise the total advertising process. The components of advertising are illustrated in Figure 1.

Information technology is playing more and more important role and offers the possibility of a computer-mediated environment, which can changes the traditional one-to-many communications model of advertising [Ranchhod98]. The capacity of computing power has given marketers a chance to

grapple with extraordinary detail, every consumer's preferences, the development of products and an integrated marketing strategy. The Internet is now becoming another possible source of advertising and of data collection. A computer-based integrated environment to support advertising is another new infrastructure in the next millennium.

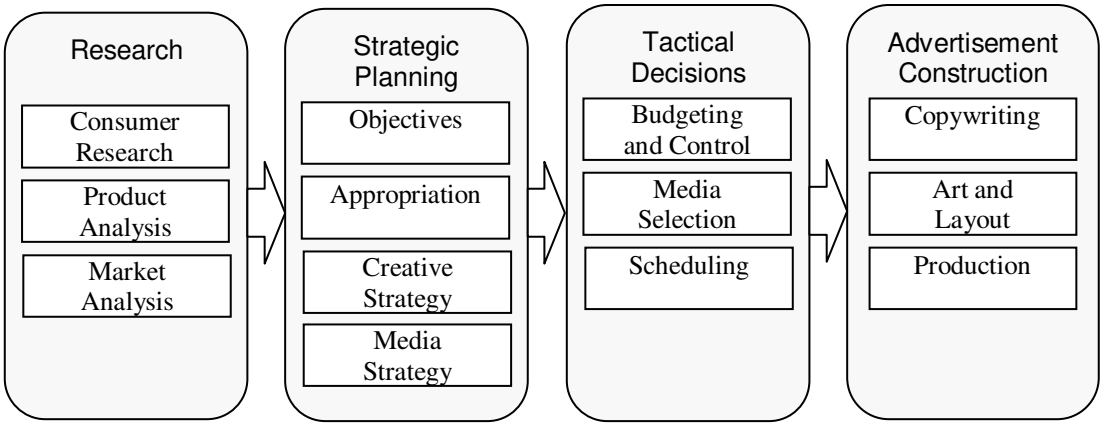

Figure 1. Components of Advertising

The environment of worldwide advertising is the integration of domestic, international, multinational and global or transnational business [Mooij97]. An advertising infrastructure is a computer hardware and software infrastructure that provides dependable, consistent, pervasive, and inexpensive supporting of advertising activities in this global advertising environment. The hardware infrastructure is comprised with personal computers and supercomputers connected by high-speed networks. The software can be divided into tools and services.

Advertising developers exploit the services provided by the infrastructure through the integrated tools to design, construct advertisements and evaluate the advertising effectiveness. These services include effectiveness analysis and scheduling, execution monitoring and steering, database management, visualization, security, accounting, and so on.

The advertising effectiveness evaluation, analysis, prediction, and scheduling are the most important services to be provided by the software infrastructure. The implementation depends on the other services as database management, security, and accounting. The results can be visualized and displayed to the users. Also they can be called to achieve execution monitoring and steering. The aim of this work is to use new software technologies to overcome these difficulties.

1.2 Agent-Based Social Simulation

Software agents are becoming a more and more important software development technology. The key sign of this trend is the emergence of diverse applications and approaches in many different areas [Jennings98]. With the development of faster hardware and advanced software technology, it becomes easier to express and simulate complex social phenomena as computer programs. Software agents provide a useful abstraction of complex systems. And the multi-agent system can be used to model the social phenomenon [Gilbert94]. Many works focus on using agent technologies to simulate social phenomena.

- RBSim [Gimblett97] is a computer program that simulates the behaviour of human recreators in high use natural environments, which use autonomous human agents to simulate human behaviour within geographic space.
- In the EOS [Doran95] project deliberative agents are used to explore possible trajectories to social complexity in the sense of centralized decision making.
- Swarm [Burkhart94] is a multi-agent software platform for the simulation of complex systems.

The software agents used in the social simulation systems have both rich personalities (e.g. believable and psychological) and complex relationships among them to simulation the characteristics of objects in the real world and their interactions. These will also be used in the simulation system in this work to evaluation the advertising effectiveness.

The rest of the paper is organised as follows: Section 2 introduces the concept of advertising effectiveness. Section 3 gives the details of the agent-based modeling approach. The Simulation Environment for Advertising (SEA) is introduced in Section 4. Section 5 illustrates the sample results for the studies of web advertising. Preliminary conclusions are discussed in Section 6.

2 Advertising Effectiveness

The main "actors" related to the effectiveness in the advertising activities are consumer, advertisement, product/service, medium, and environment. The advertising effectiveness can be studied from the different manifestations of these actors.

- *Consumers* are audience of the advertisement and potential purchasers of the product or service. Many models of consumer behaviour have been developed to measure the advertising effectiveness [Brierley97]. For example, in the attitude model in [Wheatley69], the effects of advertising on consumers can be described as a sequence of stages or steps that begins with an awareness of the existence of what is being advertised, through the knowledge on what the product or service has to offer, favourable attitudes, preference over all other possibilities, and the conviction that the purchase would be wise, and finally culminates in the actual purchase of the product or service.
- *Advertisement* in a traditional sense can influence the consumer behaviour. In new media advertising on the Internet, the advertisement can be influenced by the consumer behaviour as well to manifest the effectiveness. For example, clickthrough rates of a banner advertising on the web can be used to measure its effectiveness.
- *Product/service* represents the motivation of the advertising. Advertising is often used to try to increase sales of a product or the use of a service, to improve the firm's "corporate image": to persuade people that the company is benevolent and trustworthy, or to change people's behaviour such as anti-smoking. So the advertising effectiveness can be also measured through the achievements of the motivation, such as the profit and the brand value.
- *Medium* is the carrier of the advertising message. The principal media may be classified as newspapers, magazines, radio, TV, direct mail, Internet, outdoor and so on. The first criterion for effectiveness is that sufficient numbers of the target audience should get to see or hear the advertisement, which is mostly decided by the nature of the medium. For example, a TV advertising at peak-time like 6:00pm to 10:00pm, or a banner advertising on a famous web page like Yahoo with millions of visitors a day, can be considered to be more effective.
- *Environment* includes other factors around the medium that can effect the advertising. The environment can influence the audience attention and involvement level. For example, not all the people in front of a TV is watching TV let alone TV advertising.

Broadly speaking, the advertising effectiveness is achieved through the interactions of these actors, and factors in consumers, advertisement, product/service, medium, and environment are all related to the advertising effectiveness. In a narrow sense, the advertising effectiveness means only the effectiveness of the advertisement, which considers only the interaction between the consumer and advertisement excluding factors of product/service, medium and environment.

There are many techniques for advertising effectiveness measurement, such as test based on memory, opinion and attitude ratings, projective testing, laboratory tests and content analyses, and inquiries and sales measures [Lucas63]. The problems in the measurement of advertising effectiveness can be grouped into four major classifications. Not all of these problems are, however, explicitly identified in each of the approaches used in advertising evaluation.

- *Specification of goals*. Goals can be diverse especially in different advertising research, which decide all other research processes. The specification of a goal can include issues/hypothesis, examples and possible deliverables.
- *Acquisition of data*. The problems of data availability are common to all approaches to evaluating advertising. Traditional methods include questionnaire, sampling, inquires, interviews, group discussions, and so on.
- *Development of framework*. This is the kernel to explain how to exploit the data, through analytical procedures, to achieve research goals.

- *Procedures of analysis*. Many analytical techniques are developed. For example, correspondence analysis [Hair95] can examine the interdependence relationships among variables.

Though some of the computer techniques such as database have been used in the advertising research, further applications have not been found. This work introduces an agent-based modeling and simulation approach, which can be used to develop a unified computer modeling and simulation environment to assist the advertising effectiveness research to solve different kinds of problems. The main benefits to the media research industry include:

- *Low Cost.* Once the computer environment is established the research cost will be much lower than the traditional advertising research approaches.
- *Quick Response*. Once the models are founded, computers can implement complex simulation processes in several minutes at most. And the research results can easily retrieved from the simulation data according to different requirements.
- *Unification*. The software system can be implemented to be so flexible that it can meet almost all kinds of requirement of advertising effectiveness research.
- *Extensible*. The simulation environment for advertising effectiveness evaluation can be extended to meet high-level requirements such as strategic planning and tactical decisions.
- *Reusable*. The consumer models can be reused to meet different research requirements, which is difficult to achieve in other approaches.

In short, using computer simulation technology can make advertising effectiveness research much cheaper, faster and easier. The agent-based modeling approach and the simulation environment are described in Section 3 and 4 respectively.

3 Agent-Based Modeling Approach

Using computer simulation technology to do advertising research aims not to replace the other methods, but to make them more efficient. This section introduces how to use agents to model the actors and agent negotiations to model interactions among these actors.

Five actor mentioned in last section can be mapped into five kinds of agents. They are Consumer Agent (CA), Advertisement Agent (AA), Product/service Agent (PA), Medium Agent (MA), and Environment Agent (EA). They negotiate with each other in the multi-agent system to simulate the interactions of the actors in the real world. Each agent is composed with *attributes* and *operations*, which can be used to describe the agent's *states* and *processes* dynamically. The agents also need to retrieve model data from the databases.

Traditional agents are almost rational agents, which have only two layers of processes shown in Figure 2(a). AA, PA, MA, and EA can be modeled as rational agents that can make decisions on when and how to negotiate with others and exchange information. Some works focus on modeling and formalism of agent negotiation decision functions like [Faratin98].

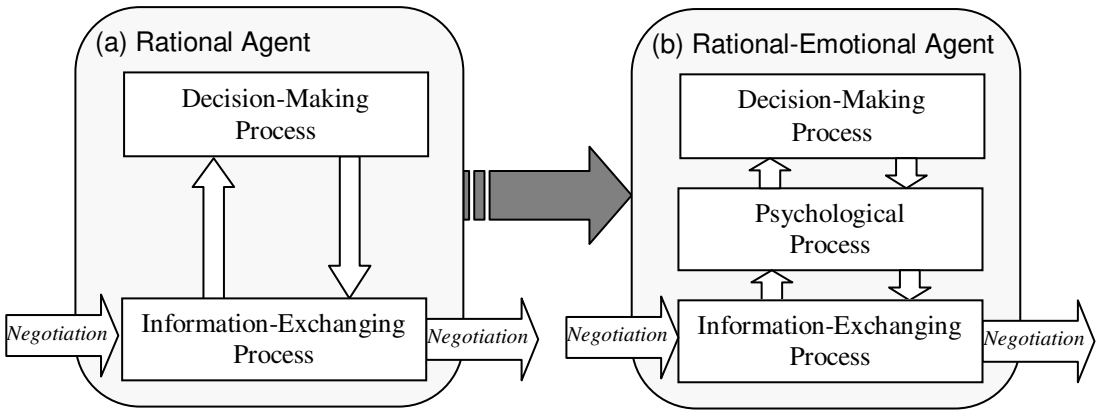

Figure 2. Agent Process Model

In social studies, people behaviours can be effected not only rationally but also emotionally. For example, successful advertising appeals both to the head and to the heart, to reason and emotions [Beatson86]. The concept of psychological agent is proposed in [Watt96]. In order to use CA to simulate the consumer behaviours, we add a psychological process between the information-exchanging process and decision-making process, which is shown in Figure 2(b). The details on these processes are described in the below.

3.1 Information-Exchanging Process

Many factors influence the advertising effectiveness, which are shown in Table 1. Some of the information must be exchanged between the actors. Information exchanging is the basic process, which can stimulate the psychological process and decision-making process. Also new information-exchanging process can be started by the result of decision-making process.

Actors	Factors	Values
Consumer	Resources	Time; Money; Information reception and processing capabilities
	Knowledge	Product knowledge; Usage knowledge; Purchase knowledge
	Attitudes	Cognitive Component (Beliefs); Affective Component (Feelings); Conative Component (Behavioral Intentions) [Engel95]
	Motivation	Need; Involvement; Self-concept
	Personality	Id; Ego; Superego (Psychoanalytic Theory) Compliant; Aggressive; Detached (Socio-Psychological Theory) Sociable; Relaxed; Internal control (Trait-Factor Theory)
	Personal Values	Comfortable; Exciting; Peace; Beauty; Equality; Security; Freedom; Happiness; Self-respect; Friendship; Wisdom
	Lifestyle	Activities; Interests; Opinions; Demographics
Advertisement	Type	Picture; Animation; Audio; Video; Multimedia
	Physical factors	Size; Position; Shape; Color; Contrast; Intensity; Isolation; Movement; Scene changes
	Content	Price or value; Quality; Performance; Components or contents; Availability; Special offer; Taste; Package or shape; Guarantee or warrantees; Safety; Nutrition; Independent research; Company-sponsored research; New ideas [Abernethy96]
Product/service	Category	Arts & Humanities; Business & Economy; Computers & Internet; Education; Entertainment; Government; Health; News & Media; Recreation & Sports; Reference; Regional; Science; Social Science; Society & Culture
	Brand	Worldwide; National wide; Local
	Information	Price or value; Quality; Performance; .....
Medium	Type	Newspapers; Magazines; Radio; TV; Direct mail; Internet; Outdoor; Yellow page
	Abilities	Using attention-getting device; Conveying details; Stimulating emotions; Changing attitude; Involving the audience; Precipitating action; Cost to reach target market; Creating awareness; Communicating product/brand image; Communicating corporate image [Leong98]
Environment	Culture	Values; Norms; Relationships; Work habits and practice; Language; Time consciousness; Beliefs and attitude
	Social class	Income; Wealth; Power; Occupation; Mobility; Class consciousness; Interaction
	Personal influence	Reference groups influence; Word-of-mouth influence
	Family	Individual roles; Spousal roles; Feminist roles; Gender; Singles; Divorce; Late marriages
	Situation	Communication; Purchase; Usage; Unexpected

Table 1. Factors of Advertising Effectiveness

3.2 Psychological Process

There are two main reasons for adding psychological process before decision-making process. One is that it is more accurate to model the consumer because advertising usually stimulates emotions first and then may have effects on human's decision. The other is that advertising effectiveness sometimes can only be evaluated at psychological layer and there can be no explicit effects on the decision and behaviour of the consumers. In order to represent psychology-layer effects, psychological states and processes must be included. There are five main activities in the psychological process illustrated in Figure 3.

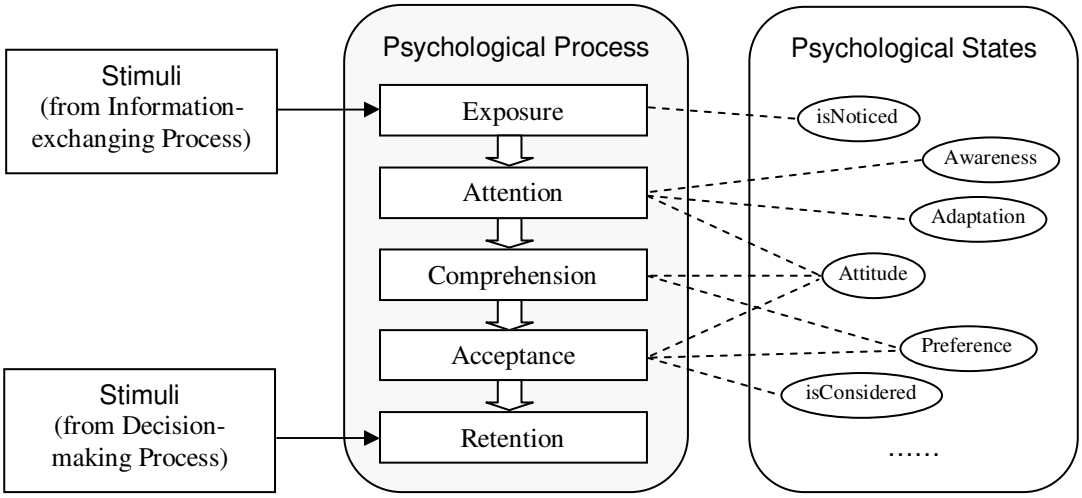

Figure 3. Psychological Process

- *Exposure*. Psychological process begins when patterns of energy in the form of stimulus inputs reach one or more of the five senses. Exposure occurs from physical proximity to a stimulus that allows the opportunity for one or more senses to be activated. In the consumer agent, the stimuli are the received information and several factors like the knowledge, need/motivation, and personality of the consumer can be used to determine the state of *isNoticed*.
- *Attention*. Not all the stimuli that activate our sensory receptors during the exposure stage will receive additional processing. It is impossible for us to process all the stimuli available at any given moment. Attention can be defined as the allocation of processing capacity to a stimulus. This will influence the *awareness* and *adaptation* of the consumer. The awareness turns the consumer's attention to the advertisement. The adaptation describes the level the consumer becomes habituated to a stimulus. The *attitude* to the stimulus, which is the most important psychological state, is also initialled.
- *Comprehension*. This is the third stage, which is concerned with the interpretation of a stimulus. The comprehension includes stimulus categorisation, elaboration and organization. It has further effects on the *attitude* begins to influence the *preference*.
- *Acceptance*. This focuses on the persuasive effect of a stimulus. The state of *isConsidered* is used to decide whether a decision-making process should be triggered.
- *Retention*. This final stage involves the transfer of stimulus interpretation and persuasion into long-term memory.

There are also stimuli from the decision-making process. This means that the process of making decision can also has effects on ones psychological states. But it influences the activity of retention directly.

3.3 Decision-Making Process

Not all of the psychological processes can result in a decision-making process. There are different kinds of decision-making process, but the results (e.g. consumer's behavior) are all taken as interactions of actors and simulated as negotiations among agents. The decision is made based on the model data, the information received and current psychological states. The main activity in this process

is *Need Recognition*, which decides whether there are necessities for further actions. The model of the process can be rule-based and many previous works can be referred to.

4 SEA: a Simulation Environment for Advertising

A modeling and simulation environment for advertising is designed to implement the approach described in Section 3. The main components are the user interface, modeling tools, the simulation engine and the information filter. The web-based system architecture is illustrated in Figure 4.

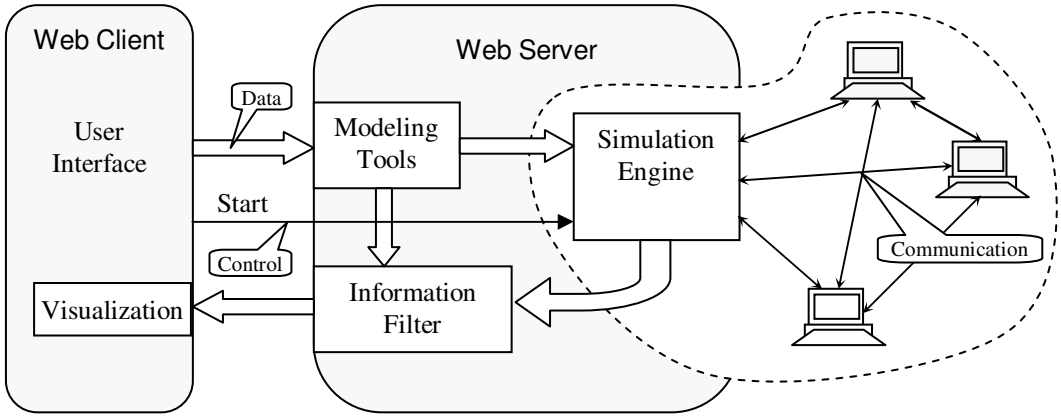

Figure 4. System Architecture

The system is designed to be web-based and implemented using Java applet to achieve cross-platform and easy use. The user interfaces are on the client, which are used to send modeling data or control information to the server and receive the simulation results to the users.

In order to meet different requirements, the system should allow users to construct their own models from the exist components. These include actor modeling, consumer model selection, negotiation modeling, definition of simulation data structure, and analysis modeling. The model tools process the data from the user and transfer them to simulation engine and information filter.

Simulation engine can be started with the command from the user. It can be composed with many machines, and each has a model database and an agent to manage it. The agents on these machines communicate with each other to achieve the simulation processes. And the simulation data are the input of information filter.

The simulation data produced from the complex simulation processes must be analyzed and filtered to meet the requirements of users. And at the client end, the output of the information filter should be visualized and displayed to the users dynamically or statically.

5 Web Advertising: A Case Study

Many companies are interested in the potential of advertising on the Internet, but there is little research to guide their decision. In this section, web advertising is studied to give a demonstration of how the agent-based approach is used and how the simulation environment works.

5.1 Introduction to Web Advertising

Jupiter projects that 10 billion dollars will be invested annually in web advertising by the year 2002 in American, up dramatically from the 37 million spent in 1995 [Jupiter97]. This is only a tiny fraction of the current worldwide market for traditional media advertisements but, clearly shown in Table 2, much has changed [CyberAtlas99]. And according to the latest report on CyberAtlas, Internet advertising revenues hit $693 million for the first quarter of 1999, nearly doubling the $351 million that was recorded in the same period a year ago.

Media	Spending(billions)	Annual growth
Newspapers	$44.3	6.2%
Direct mail	$39.7	7.5%
Broadcast TV	$39.5	7.0%
Miscellaneous	$25.5	7.2%
Radio	$14.6	8.2%
Yellow Pages	$12.0	5.0%
Magazines	$10.4	5.5%
Cable TV	$8.6	13.0%
Business papers	$4.4	7.0%
Internet	$1.9	111.8%
Outdoor	$1.6	7.9%
Farm pubs	$0.3	4.6%
Source: IAB/PwC		

Table 2. 1998 US Advertising Spending

Investigations show that about 50% advertising spending are wasted, so the effectiveness is most concerned by the media research industry. There are many kinds of advertising on the Internet, such as banner, applet, screensaver and push broadcasting [Barrett97]. Most web advertising currently involves banner advertisements, usually a rectangular graphic set at the top or bottom of a web page. These are commonly found at the gateways to the web and presently account for 80% of all advertising revenue.

The web advertising effectiveness is new for advertising research. However, it is the most suitable to be studied using computer simulation technology for the following reasons:

- When someone is exploring the Internet, he will usually pay all of the attention to the web contents. High involvement can be achieved and many factors can be ignored without sacrificing the accuracy.
- The advertisement (e.g. the banner) and media (e.g. web pages) modeling can be easier, because the factors that can influence the advertising effectiveness are easier to be parameterized and valued.
- One of the criteria of banner advertising effectiveness is the clickthroughs rate, which is easy to measure online. So the validation results can be used to test the simulation accuracy.

5.2 Banner Advertising Modeling and Simulation

We study the banner advertising as the interaction between the audience and advertisement ignoring all the other factors. The elements of the banner that can influence the effectiveness include type, size, color, contrast, position, and content. In consumer model, the attitudes of the consumer about these elements are included and the negotiation decisions are made by stochastic algorithms based on some empirical parameters. The models are simplified only to give an example of the methodology of advertising effectiveness evaluation using agent-based approach. The simulation results in Figure 5 show that the average clickthrough rate of this banner is 6.5%. In other works like [Voight96], the research results show that only 3%-13% of the visitors to a website click into a banner.

6 Conclusions

This work presents an agent-based social modeling and simulation approach to evaluate the effectiveness of advertising. In order to model the consumer behaviour, a psychological process is added between the information-exchanging process and decision-making process. A demo version of Simulation Environment of Advertising (SEA) is developed to study the effectiveness of banner advertising on the Internet and provide sample simulation results.

Many further works should be done. Research achievements in psychology can be used to get more accurate model of the consume agent. Consumer model database must be constructed to support different kinds of advertising research. The simulation environment can be extended to support high level requirements such as strategic planning and tactical decisions. This work is just a beginning to

give another methodology of advertising research. There is a long way to go to implement a practical software system that can really benefits the media research industry.

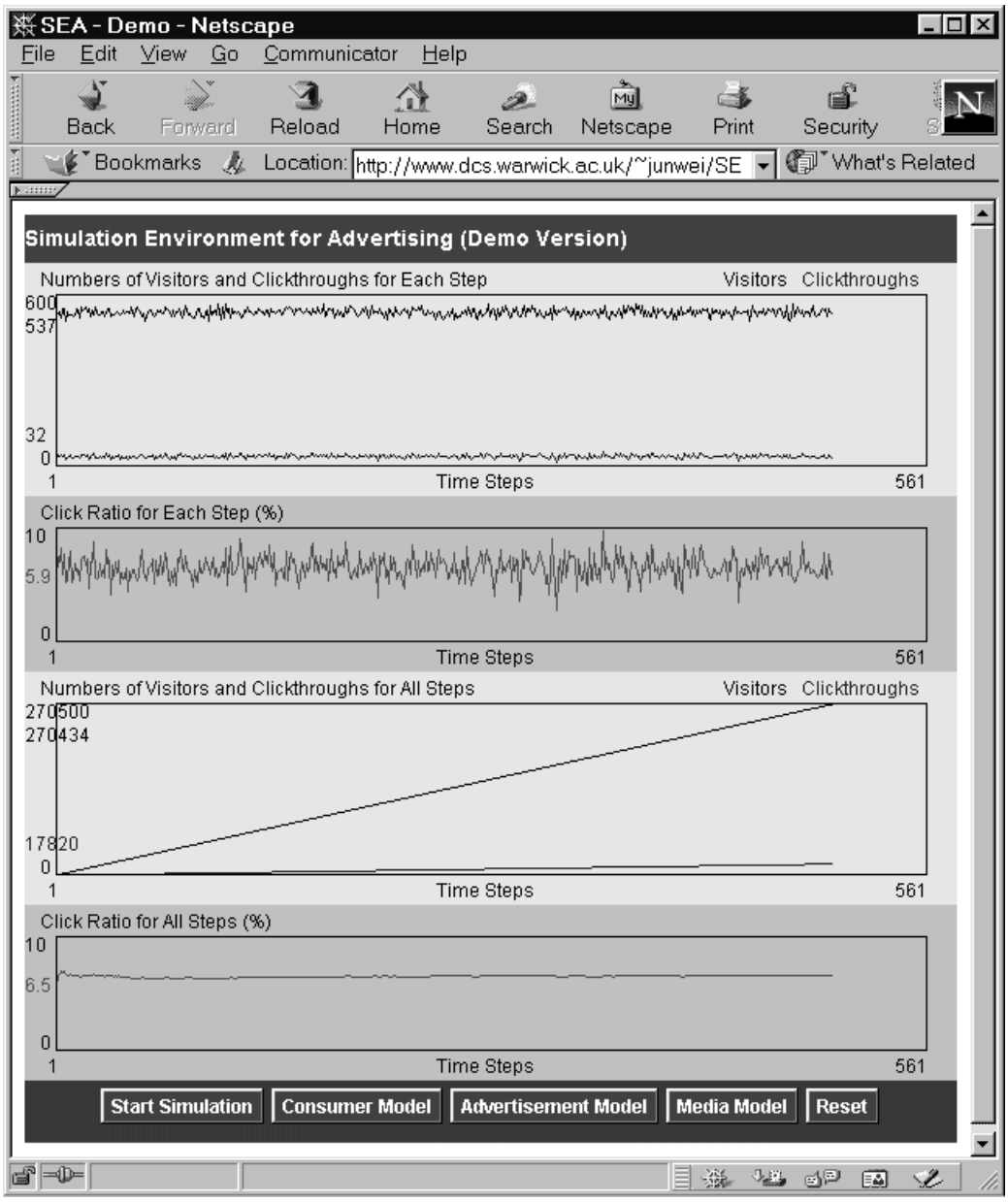

Figure 5. Simulation Results

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