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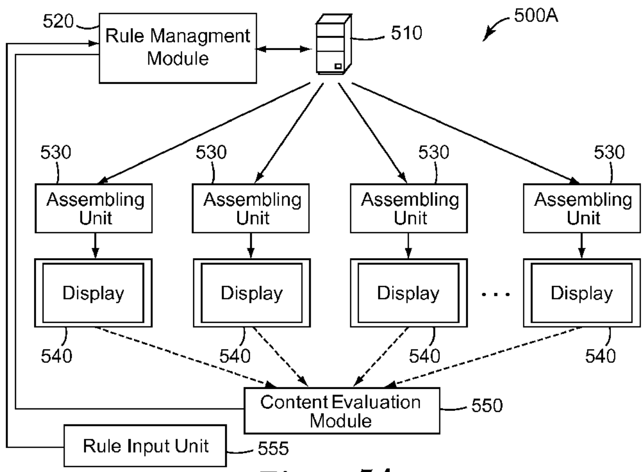

Figure 5A

(57) Abstract: At least one aspect of the present disclosure describes a computer-implemented system for optimization of animated content. The system includes a rule management module, a content generation module, and a content evaluation module. The content generation module is operative to generate an animated content configuration in accordance with a set of rules on content generation. The animated content configuration includes an initial configuration and a transition and is designed with a particular optimization objective. The content evaluation module is operative to evaluate content performance on reaching the particular optimization objective based on data acquired when a piece of animated content assembled from the animated content configuration is displayed. The rule management module is operative to amend the set of rules based on the evaluated content performance.

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SYSTEMS AND METHODS FOR RULE-BASED ANIMATED CONTENT OPTIMIZATION

Background

Display content, which includes text, images, video, sounds, and other content elements, is commonly seen in public and private places. Large amounts of content are created and presented at electronic displays, such as electronic menu boards, electronic billboards, cellular phones, tablet computers, laptops, etc. Many electronic displays use content created by people, where can be highly labor intensive.

Summary

At least one aspect of the present disclosure features a computer-implemented system for facilitating automatic optimization of animated content to be rendered on an electronically addressable display. The system includes a rule management module, a content generation module, and a content evaluation module. The content generation module is operative to generate an animated content configuration in accordance with a set of rules on content generation. The animated content configuration comprises an initial configuration and a transition and is designed with a particular optimization objective. The content evaluation module is operative to evaluate content performance on reaching the particular optimization objective based on data acquired when a piece of animated content assembled from the animated content configuration is displayed. The rule management module is operative to amend the set of rules based on the evaluated content performance. The initial configuration comprises a plurality of content elements and one or more relationships among the plurality of content elements, and the transition defines image transformations of one of the plurality of content elements.

At least one aspect of the present disclosure features a method for optimizing animated content, comprising the steps of: generating, by a processing unit, two animated content configurations in accordance with a set of rules on content generation; assembling, by a processing unit, the two animated content configurations to two pieces of animated content; conducting an experiment to obtain effectiveness data of the two pieces of animated content on reaching an optimization objective; determining relative effectiveness of the two animated content configurations based on the effectiveness data; and amending the set of rules on content generation based on the relative effectiveness of the two animated content configurations, wherein each animated content configuration comprises an initial configuration and a transition, the initial configuration comprises a plurality of content elements and one or more relationships among the plurality of content elements, the transition defines image transformations of one of the plurality of content elements.

Brief Description of the Drawings

The accompanying drawings are incorporated in and constitute a part of this specification and, together with the description, explain the advantages and principles of the invention. In the drawings,

Figure 1 illustrates an exemplary block diagram for a rule-based content generation system;

Figures 2A-2C are a set of simple images to illustrate positional relationship;

Figure 3 illustrates an exemplary block diagram of a rule-based content optimization system;

Figure 4A and 4B illustrate system diagrams for exemplary embodiments of a rule-based content generation system;

Figure 5A and 5B illustrate system diagrams for exemplary embodiments of a rule-based content optimization system;

Figure 6 illustrates an exemplary logical flowchart of a rule-based content optimization system;

Figure 7 illustrates a modular diagram of an exemplary embodiment of a rule-based content optimization system;

Figure 8 illustrates an exemplary data flow diagram of a rule-based content optimization system;

Figures 9A and 9B illustrate two pieces of content, to be presented on a display device, created by a rule-based content generation system;

Figure 9C and 9D illustrate two piece of content at the end of transitions with the content elements in solid line and the content element in changes in dash line;

Figure 10A provides an exemplary flowchart detailing the rules development process facilitated by user inputs via a user interface;

Figure 10B is an exemplary logical flowchart detailing automated rules development based on content performance;

Figure 10C illustrates an exemplary logical flowchart for content generation based on rules governing relationships among content elements; and

Figure 11 illustrates a logical flowchart for an exemplary embodiment directed to rule-based content optimization systems for digital signage networks; and

Figure 12 illustrates an exemplary flowchart for a content generation/optimization system using probability factors.

Detailed Description

Display content, such as digital advertising, that is presented on electronic displays is often created by people then rendered on the display. To optimize display content's effectiveness on influencing human behavior, a large number of pieces of content are usually needed. Since such optimization usually requires manual modification of the content, then testing, such optimization can be highly labor intensive. For example, to optimize a display content that has 10 content elements, where each content element can be selected from a pool of 100 content elements and variously positioned, the number of possible content permutation can be very large, easily in excess of 1 trillion. Human involvement is often required because machine-generated content may not be appropriate for display. For example, consider a piece of content including a content element of a person with outstretched hand and a content element of a sandwich. A machine may inappropriately position the sandwich below the person's hand instead of on the person's hand.

The present disclosure is directed to systems and methods for generating animated content based on rules of permissible relationships among content elements and rules on statistical probability of an occurrence of a particular value of a content attribute. The present disclosure is also directed to systems and methods for animated-content optimization to have an optimal effectiveness on realizing an objective utilizing the rule-based animated content generation approach. The present disclosure is also directed to systems and methods for animated-content optimization, that is, modifying the animated content so as to have a greater effectiveness on realizing an objective utilizing the rule-based animated content generation approach.

Display content, also referred to as content, refers to multi-dimensional presentation on an electronically addressable display (e.g., LCD, plasma, projection system, etc.) of media that can include text, images, video, sound, and other content elements. For example, a piece of content can include banner advertisements for websites. Content may take many forms, including visual or aural, or any form that can impact or be detected by the human sensory system (e.g., the five senses of the human sensory system, including tactile or touch, taste, and smell, in addition to vision and hearing). Content may be static, dynamic or a combination thereof. Animated content refers to a piece of content where a part of or the entire piece of content changes over a period of time. In other words, content that is subject to a transition event. Such change could be, for example, movement of a content element across the screen, the fade-in, or out, of a content element, the change of a content elements color, etc.

Creating content in measurement systems (i.e., a measurement system with specific units, such as a metric system, an x-y coordinate system) are poorly suited to developing and optimizing content for consumption because human recognizes and perceives an object by its relative size, position, orientation, and other visual characteristics, but not its actual size, position, or orientation rendered in a measurement system. For example, a person can perceive, by looking at a picture of the object and a house, whether the object is big by the relative sizes of the object and the house. A person cannot perceive, by looking at a picture of the object itself, whether the object is big. Additionally, measurement systems lack limitations or boundaries that are meaningful to human perception. For example, a template based content generation approach limits the dimension or dimension ratio of content elements but it does not have knowledge of the content elements and cannot address relationships between content elements. As a specific example, with a pool of content elements having a content element A – a visual representation of "car" and a content element B – a visual representation of "road", a template based content generation approach may not have the knowledge that the content element A represents a "car", the content element

B represents "road", and address the relationship between content elements A and B – for example, the content element A should be placed on the content element B but not be placed under the content element B. The present disclosure is directed to systems and methods that map closely to human perception to facilitate the generation and development of display content for human consumption using content elements and relationships. Specifically, embodiments of the present invention utilize an approach to generate content based on arranging content elements based on rules defining permissible categorical relationships among the content elements. Using the example above, a permissible categorical relationship can be the content element A being above the content element B.

Content elements, also referred to as primitives, are subcomponents of a piece of content. For example, content elements can be geons, which are small shapes that are the basis for larger objects and images. Content elements can be more complex than individual geons. In some embodiments, content elements may include, for examples, images (i.e., two dimensional, three dimensional, etc.), diagrams, photos, video, animated images, words, phrases, or the like. In some cases, content elements may include specific compositions of more than one component, such as a specific composition of a set of geons or a specific composition of a set of images. In some other cases, content elements may include visual representations of objects, for example, a two dimensional image representation an object. In such configurations, subprimitives are treated together as one content element for establishing categorical relationships with other content elements to create the overall configuration of a piece of content. Content elements may also include other set properties of the content, such as the background used for a two dimensional image. In yet other cases, a content element can refer to a group of content elements that is in a same category. A category can be, for example, a chicken sandwich of a particular type, a forest background, an image of a bird, an image of a blue jay, or the like.

Categorical relationships, also referred to as relationships or presentation relationships, describe how two or more content elements are arranged in relation to one another in a piece of content to be rendered on a display. A configuration of content elements that can be used to render content often includes a plurality of relationships because each relationship can govern an aspect of the associations among two or more content elements. This follows models of object recognition in the vision sciences, such as the models proposed by Hummel, J. & Stankiewicz, B. (1998) *Two Roles for Attention in Shape Perception: A Structural Description Model of Visual Scrutiny*, Visual Cognition, vol. 5, no. 1, pages 49-79. In two-dimensional visual space, for example, categorical relationships can include relative position, size, orientation, or other relationships of primitives.

Examples of categorical relationships include positional relationships, orientation relationships, color relationships, depth relationships, contrast relationships, opacity relationships, layer relationships, and size relationships. Positional relationships include, for example, one content element being above or below another content element, or to the left or right of another content element, or at other relative position with another content element. In some embodiments, positional relationships can be described by operators concerning position, such as “above()”. Orientation relationships include, for example, one content element being at acute or obtuse angles to another content element, perpendicular or parallel to another content element, and in other relative orientation of another content element. In some embodiments, orientation relationships can be described by operators concerning orientation, such as “parallel()” or “connected()”. Size relationships can be relative size of primitives compared to one another, for example, such as being larger or smaller. In some embodiments, size relationships can be described by operators concerning size, such as “larger()”. Layer relationships include, for example, one content element is at a layer on top of a layer where the other content element is at. In some embodiments, layer relationships can be described by operators concerning orientation, such as “front()” or “back()”. Categorical relationships vary sharply at their boundaries, like a step function or a logistic function. These functions may be used to describe categorical relationships. The logistic function may be used to describe both categorical descriptions and metric adjustments (i.e., size and position adjustments) since logistic functions include both linear and non-linear portions, for example, the non-linear portions describing the categorical relationships and the linear portions describing metric adjustments.

A transition acting on a content element can include an image transformation on the content element. An image transformation comprises a change over time on an attribute of the content element or on a relationship between the content element and another content element. In some cases, a transition defines changes over time on at least one aspect of relationships, velocity, size, opacity, degree of curvature, color, brightness, hue, and contrast. An attribute of a content element can be, for example, color, opacity, degree of curvature, color, brightness, hue, contrast, position, and the like. An attribute of a relationship among content elements can be, for example, type of relationship (i.e., a relative position, a relative layer, a relative color, a relative orientation, a relative depth, a contrast relationship, an opacity relationship, a relative size, etc.), value of relationship (i.e., "left", "darker", "more transparent", etc.), and the like. As an example, a transition can be a change of opacity of a content element from 100% to 0 in 10 seconds. As another example, a transition can be a change of size of a content element by shrinking it to half of its original size in 5 seconds. As yet another example, a transition can be a change of position relationship of two content elements from content element A being above(content element B) to content element A being below(content element B) by moving content element A down.

A configuration element refers to an element of a content configuration, which includes, for example, a content element, a relationship, a metric adjustment (i.e. size or position adjustment) within a relationship, a transition, and the like. A configuration element can have various attribute values. For example, the background as a configuration element can have different colors (e.g., blue, red, black, etc.). A content attribute refers to an attribute of a content element, an attribute of a relationship among content elements, an attribute of a metric adjustment of a content element, an attribute of a transition of one or more content elements in animated content, or other attributes related to a piece of content. An attribute of a content element can include, for example, category, selection, size, opacity, degree of curvature, color, brightness, hue, contrast, and the like. An attribute of a relationship can include, for example, a type of the relationship, a value of the relationship, and the like. An attribute of a transition can include, for example, type, selection, start time, end time, velocity, or the like. An attribute of a metric adjustment can include, for example, type, value, range, and the like. An attribute of a transition can be, for example, a type of transformation (i.e., color, position, hue, brightness, opacity, relationship, etc.), a speed of transformation, and the like. A content attribute can have discrete values (i.e., left or right for a position relationship, etc.) or continuous values (i.e., a range of possible positions in a measurement system, etc.). In some implementations, the continuous values of a content attribute can be transformed to discrete values by sampling at a selected interval. For example, values for a color of a content element can be a set of selected colors (i.e., 12 basic colors in a color wheel, a set of suitable accent colors, etc.).

Research in vision science suggests that most types of object recognitions are largely based on categorical relationships, such as those relating to position and orientation. Differences in categorical relationships typically have larger impact to human perception than differences in coordinate systems but within categorical boundaries. Figures 2A-2C are a set of simple images to illustrate position relationship. Figure 2A is a rectangle **220A** at the right of a line **210A** where the center of the rectangle **220A** is above the line **210A**. Figure 2B and 2C illustrate images with the same line and the same rectangle while the rectangle is moved for the same distance. More specifically, the rectangle **220B** in Figure 2B and the rectangle **220C** in Figure 2C move down the same number of pixels, where the line **210B** in Figure 2B does not move and the line **210C** in Figure 2C moves the same number of pixels. The center of the rectangle **220B** in Figure 2B is below the line **210B** but the center of the rectangle **220C** in Figure 2C is above the line **210C**. The categorical relationship between the line and the rectangle has changed in Figure 2B while the categorical relationship has not been changed in Figure 2C. While Figure 2B has fewer changes in an x-y coordinate system from Figure 2A than changes of Figure 2C from Figure 2B, Figure 2C is likely to be perceived as more similar to Figure 2A than Figure 2B.

One embodiment of the present invention is an automatic content generation system and process, which generate content in accordance with cognitive science and, in some embodiments, not need review or revision by a person before presentation. Additionally, embodiments of the present invention can help provide a flexible content generation approach, which is not limited to fixed or relatively fixed content element position as content generation using templates. Further, embodiments of the present invention may reduce the number of permutations of content elements by generating content in conforming to rules defined and revised by the content generation system. In some embodiments, to generate a piece of content with a specific objective, possible permutations of content can be filtered by, for example, rules, permissible relationships, visual perception, and permissible content elements, or other constraints.

Some embodiments of the present disclosure are directed to systems and methods for content generation and optimization utilizing probability factors to control the permutations that are tested. As used herein, a probability factor refers to a statistical probability that a piece of content expresses a particular value of a content attribute. In such embodiments, a content generation/optimization system may set and/or update rules on probability factors, (i.e., set/update probability factors for a particular value of a content attribute) such that permutations of content are evaluated systematically. In some cases, a content generation and/or optimization system may record content attribute values of pieces of content and content performance data of the pieces of content. Content performance data is also referred to as content effectiveness data or effectiveness data. Based on the historical content performance data, the system can predict what content variations (i.e., changes to one or more content attributes) will produce more significant changes to content performance, then the system can assign probability factors related to this prediction. For example, if the system determines that relative positions (i.e., left or right) of two content elements (i.e., content element A and content element B) produce significant changes to content performance, the system can assign high probability factors to these relative positions (i.e., 80% content can be designed to test the relative positions of the two content elements A and B, the other 20% content may not have content elements A and B).

In some other cases, a content generation/optimization system may use probability factor to reduce the number of combinations and/or permutations to be tested. Where the rules governing content generations include multiple ways in which content may be varied, the number of combinations can quickly grow. However, if situations where combinatorial effects can be treated as unimportant, governing by rules on probability factors, the system may apply changes to only one variable and hold the others constant to determine the effects of one variable, then test the next variable, and so on. In some cases, the combinatorial effects may be determined by historical data, user input, or visual attention modeling. For example, there may be three variations of content element A (A1, A2, A3) and five variations of content element B (B1, B2, B3, B4, B5) permissible under the rules for a set of content configurations. This would ordinarily produce 15 variations to test. If, however, the two content elements could be considered distinct and effects of combining specific variations can be ignored (i.e., the effects of the combination being small or nonexistent), the system may generate rules on probability factors such that initially, the rule on probability factor of content element B having a specific value (i.e, B2) being 100% and the rule on probability factor of content element A for each of the three variations being 33.3%, for example. Once the best variation of content element A is identified (i.e., A2), the system may update the rules on probability factors, such that initially, the rule on probability factor of content element A having the specific value (i.e, A2) being 100% and the rule on probability factor of content element B for each of the five variations being 20%, for example. This reduces the number of permutations for testing from 15 to 8 (3 variations followed by 5 variations), so the speed for finding a piece of optimized content or a piece of content with satisfying performance requirement or visual goal is increased.

Search space refers to a pool of permissible pieces of content constrained by rules on content generation. In some embodiments, the search space has a number of quality factors, including but not limited to, the number of permutations of content pieces, the diversity of the permissible content pieces, and the predicted content values. The predicted content values can be based on, for example, historical content performance data, similarity between a generated piece of content and a past piece of content, an output from a visual attention model, other content value measures, and a combination thereof.

Figure 1 illustrates an exemplary block diagram for a rule-based content generation system **100**. The rule-based content generation system **100** can include a content element repository **110**, a rule management module **120**, and a content generation module **130**. The content element repository **110** can provide content elements to be used in content generation. In some implementations, the content element repository **110** can provide metadata of content elements. The metadata of content elements can include, for example, content element identification, content element description, content element category, content element title, content element size information, and other information.

The rule management module **120** receives, defines, and revises rules for content generation. The rules for content generation can include, for example, rules defining relationships among content elements (i.e., rules on permissible relationships, rules on impermissible relationships, etc.), rules on content elements (i.e., rules on permissible content elements, rules excluding some content elements, rules on required content elements, etc.), and rules on metric adjustments (i.e., rules on permissible size and/or position adjustments to a content element, rules on impermissible size and/or position adjustments to a content element, etc.). In some implementations, the rules for content generation can also include rules on probability factors. A rule on probability factor refers to a statistical probability that a piece of content will express a particular value of a content attribute (i.e., the content attribute of the piece of content will have the particular value). A probability factor rule specifies the probability of content configurations including a configuration element that has a particular attribute value. Again, a content attribute can include an attribute of a content element, a relationship, a metric adjustment, a transition, or other attributes related to a piece of content. For example, a rule on probability factor can be "a piece of content has a 50% probability of having red background." As another example, a rule on probability factor can be "a piece of content has a 30% chance of having content element A to the left of content element B." As yet another example, a rule on probability factor can be "a piece of content has a 15% probability to have content element A increasing in opacity."

Rules can be defined or revised based on a number of factors, for example, such as, locality, day-part, inventory data, point-of-sale data, trigger data (data requiring a change in what content is permissible to display, i.e., a pre-determined trigger such as low inventory on a certain item, or interactive activity such as a click at a kiosk or a signal from a sensor), or the like. For example, a rule can be defined or revised such that a particular content element or a particular category of content element is required or impermissible for a certain location. As another example, a rule can be defined or revised such that a particular content element is impermissible when the inventory on an item represented by the particular content element is low. In some embodiments, at least some of rules are based on vision science. For example, visual attention models may be used to limit the number of content elements appearing in an image to restrict the system from creating content that would be cluttered or distracting to viewers. In another example, information from visual attention models, such as the tendency of viewers to focus on the center of an object, may be combined with metadata about a content element such as metadata identifying a content element as a product to be featured, to create rules that arrange content elements according to their role and the ways in which viewers perceive the content. The content generation module **130** can generate content in accordance with rules provided by the rule management module **120** using content elements in the content element repository **110**. The rule management module **120** and the content generation module **130** are implemented by software, computing device, firmware, circuitry, or a combination thereof.

In some implementations, the content generation module **130** can generate content configurations that can be assembled to pieces of content. A content configuration can include content elements and categorical relationships among the content elements. As used herein, a content element is also referred to content element metadata relating to a content element, which can be used to retrieve the content element from a repository, instead of the actual content element. In a particular embodiment, for a content configuration including a plurality of content elements and one or more relationships among the plurality of content elements, at least one of content elements has more than one allowable position in accordance with the one or more categorical relationships. In some implementations, a content configuration can also include metric adjustments of the content elements, where each metric adjustment can be within a categorical relationship among two or more elements. A content configuration can be assembled to a piece of content (i.e., in the format of image file, clip, etc.), either static or animated, by arranging the content elements in accordance with the categorical relationships, and then the piece of content is ready to be rendered on a display. A display can be any of the various types of electronically addressable displays that are controllable by a computer or processor, for example, such as, a flat panel display, a television, the display on a laptop, a computer screen, a projection display, a tablet computer, the display on a cellular phone, or the like.

In some embodiments, the content generation module **130** can generate animated content configurations that can be assembled as animated content. Animated content refers to a piece of content that either part of the piece of content or the entire piece of content changes over time. An animated content configuration can include an initial configuration and a transition of a content element that is selected in the initial content configuration. The animated content configuration is operable to be assembled to a piece of animated content. The initial configuration can include a plurality of content elements and one or more relationships among the plurality of content elements. In some cases, the initial configuration can include a duration of the piece of animated content. In some other cases, the initial configuration can include a start time of the content element to be animated and/or an end time of the content element. In yet other cases, the initial configuration can include a duration, a start time, and/or an end time of at least one of the plurality of content elements.

An animated content configuration can be assembled to a piece of animated content by arranging the content elements in accordance with categorical relationships and compiling an animation of the content element according to the transition. For example, the transition can be defined as the opacity of a content element changing from 100% to 0 in 10 seconds, so the assembled piece of animated content will have the content element fading away. As another example, the transition can be defined as a movement of a content element A to the left in 5 cm per second until the content element A has a same horizontal position of a content element B, then the assembled piece of animated content can have the content element A moving to the left.

In some embodiments, the rule management module **120** is configured to receive a plurality of rules on content generation, where the plurality of rules includes a rule on probability factor. The content generation module **130** is coupled to the rule management module **120** and configured to generate one or more content configurations in accordance with the rule on probability factor, where each content configuration includes an initial configuration and a transition. The rule on probability factor may define a probability of an occurrence of a particular value of a content attribute.

In some implementations, the rules for content generation can include rules on visual perception, for example, rules on relative salience of objects in a piece of content, rules on a desired saliency map of a piece of content, rules on desired saliency numbers for one or more objects in a piece of content, rules on particular orders that a viewer will likely attend to objects or regions in a piece of content, or other rules on visual perception. In some embodiments, the visual perception of a piece of content can be evaluated by a visual attention model (VAM). A visual attention model simulates neurological processes and psychological effects in a biological visual system. By applying a VAM to a piece of content, a VAM output on visual perception can be generated. The rule-based content generation system **100** can use the VAM output to determine whether an assembled piece of content satisfies the rules for content generation, which can include rules on visual perception. In some embodiments, if the rules on visual perception are not satisfied, the assembled piece of content may not be used.

The rule manager **120** can maintain a set of rules for content generation, which include rules on categorical relationships among content elements, rules on content elements, rules on metric adjustments, rules on visual perception, and/or rules on probability factors. For example, a rule can be content element A is larger than content element B. As another example, a rule can be that content element C is not permissible. In some implementations, the permissible content elements can be defined as a particular type of content element or other characteristics of a group of content elements. In some cases, the rule defining permissible content elements can be conditioned on some aspects related to the target display. For example, a rule can be that content type T is permissible at location L1 but content type T is not permissible at location L2. In some other cases, a rule on content element can specify a particular permissible value and range of values for an attribute of a content element (i.e., size). The content generation module **130** can generate a content configuration including selected content elements and relationships among the selected content elements, where the relationships are in accordance with the set of rules and the selected content elements are also in accordance with the set of rules. In some implementations, the content generation module **130** can algorithmically identify permissible content elements and permissible relationships among content elements in accordance with the set of rules. For a set of selected content elements, content element A and content element B, and a rule defining content element A left of content element B, an exemplary content configuration generated by the content generation module **130** is illustrated in Table 1.

Table 1 An Example of Content Configuration

Content Configuration 1	
Content Elements:	Content Element A; Content Element B.
Relationships:	Content Element A is to the left of Content Element B; The bottom of Content Element A is above the top of Content Element B; Content Element A is larger than Content Element B.

Figures 9A and 9B illustrate two pieces of content, to be presented on a display device, created by a rule-based content generation system. As an example of illustrating content generation, the set of rules for generating content with the objectives of selling hamburgers are listed in Table 2.

Table 2

Rules
Content element type A (visual representation of a hamburger) must be included; Content element type B (visual representation of a beverage) can be included; Content element type C (visual representation of French fries) can be included; Content element type D (promotional phrase) must be included; Content element of type A is on the left of Content element of type B or type C.

Based on the rules in Table 2, a rule-based content generation system can create five exemplary content configurations in Table 3. A content configuration can be expressed as a vector. The vector can include identifiers of a set of content elements and categorical relationships among the content elements expressed in a series of operators. In an exemplary embodiment, each operator can describe the relationships in sequential order. For example, BELOW(element x, element y) would place element y below element x, and RIGHT(element x, element y, element z) would place element y to the right of element x, and element z to the right of element y. Relative size operators can function similarly. For example, LARGER(element x, element y) may mean element y is larger than element x. Operators may also describe relative orientations of content elements. For example, PARALLEL(element x, element y) may mean that element x is parallel to element y. Metric adjustment can be also included in the vector. For example, (x, y) can describe adjustment with pixels as unit in (x, y) metric space. As illustrated in the vector for Content 3 in Table 3, the visual representation of the beverage will be shifted to the right by 100 pixels and upwards 50 pixels relative to the position of the visual representation of the hamburger. Content 1 in Table 3 is assembled into a content illustrated in Figure 9A and Content 3 in Table 3 is assembled into a content illustrated in Figure 9B.

Table 3

Content	Vector
Content 1	BELOW(phrase, hamburger) BELOW(phrase, beverage) RIGHT(hamburger, beverage) LARGER(phrase, hamburger) PARALLEL(phrase, hamburger, beverage)
Content 2	BELOW(phrase, hamburger) BELOW(phrase, beverage) RIGHT(hamburger, beverage (+100, + 50)) LARGER(phrase, hamburger) PARALLEL(phrase, hamburger, beverage)
Content 3	BELOW(hamburger, phrase) BELOW(French fries, phrase) RIGHT(hamburger, French fries) LARGER(phrase, hamburger) PARALLEL(phrase, hamburger, French fries)

Content 4	Initial Configuration: BELOW(phrase, hamburger) BELOW(phrase, beverage) RIGHT(hamburger, beverage) LARGER(phrase, hamburger) PARALLEL(phrase, hamburger, beverage) Transition: ChangeOpacity(beverage, 10, 15, LinearReduce, 0%) Move(hamburger, 15, 20, Right, 80)
Content 5	Initial Configuration: BELOW(phrase, hamburger) BELOW(phrase, beverage) RIGHT(hamburger, beverage) LARGER(phrase, hamburger) PARALLEL(phrase, hamburger, beverage) Transition: ChangeOpacity(beverage, 10, 15, LinearReduce, 0%) Move(hamburger, 15, 18, Right, 80) Move(hamburger, 15, 21, Left, 80)

In some embodiments, the rule management module **120** can maintain a set of rules for animated content generation, which include rules on relationships, rules on content elements, rules on transitions, rules on probability factor, or a combination thereof. For example, a rule can be a position transition of content element A is from left to right. The content generation module **130** can generate an animated content configuration including an initial configuration specifying selected content elements and relationships among the selected content elements and one or more transitions, each transition applied to one or more of selected content elements. In some cases, the other content elements than the ones having transitions can be held static in their original configurations. In some embodiments, the content generation module **130** generates the transitions applying to one or more content elements while such transitions do not break any rule on relationships among content elements. For example, the set of rules for content generation includes a rule specifying content element x being above content element y, the content generation module **130** can generate an animated content configuration specifying transition of content element x to move horizontally but preserving its vertical relationship with content element y.

A transition can also be expressed in operator specifying the start time and end time of the transition, the type of transition, and other relevant parameters of the transition. For example, ChangeOpacity(content element x, start time, end time, type of change, end value) can be used to specify a content element x's change in opacity in the time period specified by start time and the end time, the type of change (i.e., increase opacity, decrease opacity, etc.), and the final opacity level. As another example, Move(content element x, start time, end time, orientation, speed) can be used to specify a content element x's change in position with a specific orientation (i.e., right, left, up, down, up-left, down-right, etc.), speed (i.e., 10 pixels per second, etc.), the start time, and the end time. In some cases of position transition, the speed parameter can be a function of time (i.e., speed as (time-start time) so speed becomes higher over time) instead of a constant speed. As yet another example, ChangeLayer(content element x, start time, end time, type of change, end value) can be used to specify a content element x's change in layer in the time period specified by the start time and the time, the type of change (i.e., increase layer, decrease layer, etc.), and the end value of the layer. In some embodiments, the content generation module **130** can use simple or complex computation algorithms, such as ("ADD"), to generate permissible transitions based on the set of rules on relationships, content elements, transitions and probability factors.

Based on the rules in Table 2, a rule-based content generation system can create an animated content configuration as listed in Content 4 in Table 3. The initial configuration of Content 4 is the same as Content 1 in Table 3, as illustrated in Figure 9A. The two transitions specified in the content configuration includes: 1) to reduce the opacity of the content element "beverage" to 0% starting from 10 seconds after the piece of content being displayed and ending at 15 seconds; and 2) to move the content element "hamburger" to the right at a steady velocity of 80 pixels per second starting from 15 seconds when the piece of content being displayed and ending at 20 seconds. Figure 9C illustrates a piece of content at the end of transition specified in Content 4 in Table 3 with the content elements in solid line and the content element in changes in dash line.

Based on the rules in Table 2, a rule-based content generation system can create an animated content configuration as listed in Content 5 in Table 3. The initial configuration of Content 5 is the same as Content 1, as illustrated in Figure 9A. The three transitions specified in the content configuration includes: 1) to reduce the opacity of the content element "beverage" to 0% starting from 10 seconds after the piece of content being displayed and ending at 15 seconds; 2) to move the content element "hamburger" to the right at a steady velocity of 80 pixels per second starting from 15 seconds when the piece of content being displayed and ending at 18 seconds; and 2) to move the content element "hamburger" to the left at a steady velocity of 80 pixels per second starting from 18 seconds when the piece of content being displayed and ending at 21 seconds. Figure 9D illustrates a piece of content at the end of transition specified in Content 5 with the content elements in solid line and the content element in changes in dash line.

In some embodiments, the content generation system **100** uses rules on probability factors to reduce the number of permutation for content generation. In such embodiments, the rule management module **110** can add or modify rules on probability factor to expedite the process of generating a piece of content satisfying the performance requirement. Rules on probability factors may be generated stochastically, or may be derived by other methods to further reduce the search space and accelerate system learning. How a content generation system adds and modifies a rule on probability factor will be described in details hereinafter.

To produce the content configurations shown in 9A and 9B, the system first receives the rules. In this case, the rules for content generation may include: 1) a rule requiring that the text “Buy Now” (content element "text") and the content element "hamburger" cannot be on the same horizontal alignment, restricting the relationship between content element A and content element B to either ABOVE or BELOW relationships; 2) a rule requiring that a third content element (content element C) is positioned to the right of content element "text" and content element "hamburger"; and 3) a rule requiring that content element C is selected from a group of permissible content elements (i.e., content element "fries" and content element "beverage").

The system analyzes the rules and identifies the areas that are free to vary the content. In the example above, the system selects either an above() or a below() relationship between the content element "text" and the content element "hamburger", and also selects the content element that will be presented to the right of the content element "text" and the content element "hamburger". Other important content attributes exist, such as background color or the scale factors of the content elements used. But if each of these content attributes allows one permissible value, the system does not need to assign rule on probability factors on these content attributes because these attribute cannot vary.

The system proceeds to generate initial rules on probability factors, also referred to as initial probability values. If, for example, the content performance data of prior content pieces indicates that the above() relationship and the below() relationship between the content element "text" and the content element "hamburger" has similar performance, the system can generate a rule that content has a 50% likelihood to have the above() relationship and 50% likelihood to have the below() relationship. In addition, if the content performance data of prior content pieces indicates that the content element "fries" has similar performance as the content element "beverage", the system may generate a rule that content has a 50% likelihood to have the content element "beverage" on the right portion of the content and a 50% likelihood to have the content element "fries" on the right portion of the content.

The system then generates a plurality of pieces of content according to the rules on probability factors and displays the plurality of pieces of content, including the configurations of content shown in Figures 9A and 9B. Performance data of the plurality of pieces of content are collected and evaluated. As an example, assume that the performance data suggests that the performance of content having content element "fries" is better than the performance of content having content element "beverage" the drink as the content element with some certainty (i.e., 60%, 70%, etc.), while the performance of content having the above() relationship between the content element "text" and the content element "hamburger" and the performance of content having the below() relationship are similar. Assuming that no combinatoric effects were observed based on interactions between the above two content aspects, the system can modify the rule on probability factors on content elements where the rule on probably factor on the content element "fries" is changed to 80% and the rule on probably factor on the content element "beverage" is changed to 20%; the system may not modify the rules on probability factors on the above() relationship and the below() relationship. This approach can reduce the opportunity cost by allowing content with better performance to display more often, at the same time continuing the test on which content element likely has better performance.

In some cases, after other pieces of content generated from the updated set of rules is presented and performance data is collected, the certainty of the performance of content having content element "fries" being better than the performance of content having content element "beverage" the drink as the content element is greater than a predetermined threshold (i.e., 95%, 90%, 80%, etc.), the rule on probably factor on the content element "fries" can be changed to 100% and the rule on probably factor on the content element "beverage" can be changed to 0%. In some implementations, the system may add a rule that the content element "beverage" is impermissible to the set of rules for content generation.

The present disclosure is also directed to creating and optimizing content by arranging content elements according to a set of rules defining permissible categorical relationships. A content configuration including a plurality of content elements and relationships among the plurality of content elements can be generated. A content configuration can be assembled as a piece of content by arranging the content elements in accordance with the categorical relationships. Such assembling is typically implemented by a processing unit, including but not limited to, a processor, a computer, a server, a smart phone, a tablet computer, or other computing devices. In some embodiments, a content configuration can include metric adjustments of content elements. In some implementations, a metric adjustment can describe a first content element's adjustment relating to a second content element in units of a measurement system. For example, a metric adjustment can be the first content element to be 50 pixels to the right of the second content element. As another example, a metric adjustment can be the first content element to be 5 pixels larger in the x-dimension than the second content element. As yet another example, a metric adjustment can be the first content element to be at 45° angle from the second content element. In such implementation, a metric adjustment of a first content element relating to a second content element is typically aligned with the relationship between the first content element and the second content element.

In some embodiments, a content configuration can be designed to be assembled into a piece of animated content. In some cases, the animated content configuration includes an initial configuration and one or more transitions. This animated content may be assembled into an initial content by receiving an initial content configuration, comprising the initial selection of content elements and their relationships and arranging the initial content according to the initial content configuration. The transitions are then made to act on content elements and/or relationships over a predetermined time period. The action of the transitions upon the initial content produces changes in the content over time. These changes over time can be captured and used in order to render a content file that will play the content according to the content elements, relationships and transitions. Alternatively, individual moments of this change over time may be captured and used as frames in a rendered animated file. The rendered files may be in a standard format such as .mpeg or .swf.

In some embodiments of a rule-based content optimization system, two content configurations of a same set of content elements that differ in a categorical relationship are designed to influence a particular behavior, if one piece of content is tested be more effective than the content assembled from the other configuration, a rule on the categorical relationship can be generated by a processing unit. For example, a rule can be generated that only the categorical relationship presented in the more effective content configuration is permitted. Embodiments of a rule-based content optimization system can generate and utilize content according to a search space defined by rules governing permissible categorical relationships and/or content elements and/or transitions, as the number of content configurations can be significantly reduced. Further, embodiments of a rule-based content optimization system can optimize aspects according to factors that are significant to human perception, for example, categorical relationships among content elements. Such embodiments can help provide rapid and meaningful testing and analysis of the effects of various content configurations on human viewers, which can lead to a quicker optimization process. Additionally, representing a piece of content with a content configuration, which may be recorded as metadata of the set of content elements and the rules defining relationships, can be used for a variety of purposes. For example, a content configuration can be used for analyzing the impact of content elements, reviewing the permissibility of relationships, assembly of content for consumption. Further, a content configuration typically requires a much less storage space than a piece of content, such that it is particular suitable for content distribution.

In some embodiments, content elements are arranged according to a set of relationships to create a piece of content. In some other embodiments, content elements can be arranged according to a set of rules on categorical relationship and metric settings to create a content configuration. In yet other embodiments, after a piece of content is optimized based on the selected content elements and a first set of rules on categorical relationships, the piece of content can be optimized according a second set of rules on metric adjustment to improve effectiveness of the piece of content. In some implementations, optimizing content elements on metric adjustment can be limited within an established category. For example, if a rule on a content element 'pear' and a content element 'apple' is defined as 'apple' to the left of the 'pear', a second rule can be created on how much distance (i.e., 50 pixels, 4 cm, etc.) between the 'apple' and the 'pear' while the 'apple' is to the left of the 'pear'. Embodiments in accordance with such implementations allow initial screening and constraints on search space based on categorical relationships, such that fine tuning in measurement systems is more amenable to the optimization of content for impact on human viewers.

In some embodiments, content effectiveness of a piece of content can be collected by a rule-based content optimization system, where the data collected is also referred to as content performance data. The rule-based content optimization system typically optimizes display content in reaching optimization objectives, for example, reaching certain goals or influencing particular behaviors. The system can use the effectiveness data to optimize the piece of content to improve content effectiveness. In some cases, experiments on the piece of content can be conducted to determine effectiveness of content. In some cases, the rule-based content optimization system can define the content by content elements and categorical relationships among the content elements. In such cases, it becomes possible to analyze the effectiveness of individual aspects of a piece of content, such as content elements and categorical relationships. Additionally, the content optimization system can also associate the effectiveness of a piece of content to an individual aspect of the content, such as a content element or a categorical relationship. The association can lead to revising an existing rule or generating a new rule that can be used in the rule-based content optimization system.

In some embodiments, the rules can be defined or revised by a number of factors, for example, such as locality, inventory data, point-of-sale data, visual perception, or the like. For example, a rule can be defined that content A should be more salient than content B. As another example, a rule can be that content A is not permissible at location A while content B is permissible at location A. In some embodiments, rules can be dynamically changed by some factors, such as inventory data, trigger data, day-part, or the like. For example, a rule can be added that content A is not permissible when the inventory of the item represented in content A becomes low. As another example, a rule that content A is permissible can be changed to a rule that content A is not permissible when the day-part has changed from morning to afternoon.

In some embodiments, a content configuration can include a metric adjustment of a content element relating to another content element that is aligned with categorical relationships of the content element and the other content element in the content configuration. In such embodiments, the rule-based content optimization system can associate the effectiveness of the piece of content with metric adjustment and generate a new rule or modify an existing rule on the metric adjustment based on the effectiveness data.

Figure 3 illustrates an exemplary block diagram of a rule-based content optimization system **300**. The rule-based content optimization system **300** can include a content element repository **310**, a rule management module **320**, a content generation module **330**, and a content evaluation module **340**. The content generation module **330** can create a content configuration including content elements and categorical relationships among the content elements, where content elements can be disposed in the content element repository **310** and the categorical relationships can be governed by a set of rules provided by the rule management module **320**. In some cases, the initial set of rules on content generation are developed according to historical data on the effects of particular categorical relationships and metric adjustments. The content generation module **330** can also assemble a piece of content according to a content configuration. In some embodiments, the content generation module **330** can be implemented by one processing unit. In some other embodiments, the content generation module **330** can be implemented by more than one processing units. For example, the content generation module **330** can include one or more processors to generate content configurations and some other processor(s) to assemble the content configurations to pieces of content. The content evaluation module **340** can evaluate content effectiveness of the piece of content assembled by the content generation module **330**.

Based on the content effectiveness data gathered by the content evaluation module **340**, the rule management module **320** can revise the set of rules to create content with improved effectiveness. More specifically, if two content configurations differing in an aspect of configuration, for example, a content element or a relationship, and the two content configurations are different in content effectiveness based on data collected by the content evaluation module **340**, the rule management module **320** can revise the set of rules governing the content generation to incorporate the aspect of configuration that is part of the content configuration having higher effectiveness. The rule management module **320** can revise the set of rule governing a content optimization in a number of ways, for example, creating a new rule, revising an existing rule, adjusting a weight factor of a parameter, or other approaches. In some embodiments, the rule management module **320** can revise the set of rule by adding a rule on a relationship; modifying a rule on a relationship; adding a rule on a content element; modifying a rule on a content element; adding a rule on a metric adjustment; modifying a rule on a metric adjustment; adding or modifying a rule on a relationship and at the same time adding or modifying a rule on a metric adjustment within the relationship.

In some embodiments of systems optimizing animated content, the content generation module **330** is adapted to generate an animated content configuration, which specifies an initial configuration and a transition, in accordance with a set of rules on content generation and to reach a particular optimization objective. The initial configuration includes a plurality of content elements and one or more relationships among the plurality of content elements. The transition defines image transformations of one of the plurality of content elements. The content evaluation module **340** is adapted to evaluate content performance on reaching the particular optimization objective based on data acquired when a piece of animated content assembled from the animated content configuration is displayed. The rule management module **320** is adapted to amend the set of rules based on the evaluated content performance.

Systems and methods in the present disclosure can utilize experimental design principles to determine effectiveness of a piece of content. In some embodiments, the content evaluation module **340** can conduct experiments to gather data to determine the effectiveness of a piece of content. The experiments conducted by the content evaluation module **340** can be, for example, correlational designs, quasi-experiments, true experiments, or the like.

Embodiments of the present invention can be used to generate content and/or optimize content on internet. Embodiments of the present invention can also be used to generate content and/or optimize content on digital signage networks. Digital signage networks, typically including many displays, can be controlled electronically by one or more computers or processors. Various aspects of experimental design are disclosed in details in commonly assigned U.S. Patent Application Publication No. 2010/0017288, entitled "Systems and Methods for Designing Experiments," U.S. Patent Application Publication No. 2009/0012848, entitled "System and Method for Generating Time-slot Samples to Which Content May be Assigned for Measuring Effects of the Assigned Content," U.S. Patent No. 8,392,350, entitled "System and Method for Assigning Pieces of Content to Time-slots Samples for Measuring Effects of the Assigned Content," and U.S. Patent Application Publication No. 2009/0012847, entitled "System and Method for Assessing Effectiveness of Communication Content," which are incorporated herein by reference in entirety.

Figure 4A illustrates a system diagram for an exemplary embodiment of a rule-based content generation system **400**. The rule-based content generation system **400** includes a content generation module **410**, a rule management module **420**, one or more assembling units **430**, and optionally one or more displays 440. Various components of the rule-based content generation system **400** can be implemented by one or more computing devices, including but not limited to, circuits, a computer, a processor, a processing unit, a microprocessor, and/or a tablet computer. In some cases, various components of the rule-based content generation system **400** can be implemented on a shared computing device. Alternatively, a component of the system **400** can be implemented on multiple computing devices. In some implementations, various modules and components of the rule-based content generation system **400** can be implemented as software, hardware, firmware, or a combination thereof. In some cases, various components of the rule-based content generation system **400** can be implemented in software or firmware executed by a computing device. The rule management module **420** manages rules that govern content creation. The rules for content creation can include, for example, rules on relationships among content elements (i.e., rules defining permissible relationships, rules defining impermissible relationships, etc.), rules on content elements (i.e., rules defining permissible content elements, rules defining required content elements, rules excluding some content elements, etc.), and rules on metric adjustment. The content generation module **410** can be implemented on one or more processing units. The rule management module **420** and the content generation module **410** can reside on a same computer or a different computer. In some embodiments, the content generation module **410** can generate content configurations specifying composing content elements and relationships among the composing content elements in accordance with rules provided by the rule management module **420**.

In some embodiments, content configurations are transmitted from the content generation module **410** to the one or more assembling units **430**. The assembling units **430** can create pieces of content by arranging content elements in accordance with relationships among the content elements, where both the content elements and the relationships are specified by content configurations. In some implementations, the assembling units **430** can create pieces of content suitable to target displays. For example, the assembling units **430** can create pieces of content based on characteristics of target displays, for example, such as aspect ratio, resolutions, or the like. In some implementations, the assembling units **430** can retrieve content elements from a central content element repository or a local content element repository (both not shown in Figure 4). The assembling units **430** can further provide the created content to the displays **440**. In some implementations, an assembling unit **430** can provide content to more than one display **440**.

In some implementations, the content generation module **410** can be implemented on computing devices that are co-located with the assembling units **430**. In some cases, the content generation module **410** can be on a same computing device as the assembling unit **430** at a location. In some other cases, the rule management module **420** can be implemented on computing devices that are co-located with the assembling units **430**. In some cases, the rule management module **420** can be on a same computing device as the assembling unit **430** at a location.

Figure 4B illustrates a system diagram for another exemplary embodiment of a rule-based content generation system **400B**. The content generation system **400B** can include one or more assembling units **430** at central servers or local servers that are remote from the displays 440. This implementation can be suitable for an internet based application, where pieces of content can be assembled by the assembling unit **430** at an internet server.

Figure 5A illustrates a system diagram for an exemplary embodiment of a rule-based content optimization system **500**. The rule-based content optimization system **500** includes a content generation module **510**, a rule management module **520**, optionally one or more assembling units **530**, optionally one or more displays 540, a content evaluation module **550**, and optionally a rule input unit **555**. The rule management module **520** manages rules that govern content creation. The rules for content creation include, for example, rules on relationships among content elements, rules on content elements, and rules on metric adjustment. The content generation module **510** can be implemented on one or more processing units. The rule management module **520** and the content generation module **510** can reside on a same computer or a different computer. In some embodiments, the content generation module **510** can generate content configurations specifying composing content elements and relationships among the composing content elements in accordance with rules provided by the rule management module **520**.

Various components of the rule-based content optimization system **500** can be implemented by one or more computing devices, including but not limited to, circuits, a computer, a processor, a processing unit, a microprocessor, and/or a tablet computer. In some cases, various components of the rule-based content optimization system **500** can be implemented on a shared computing device. Alternatively, a component of the system **500** can be implemented on multiple computing devices. In some implementations, various modules and components of the rule-based content optimization system **500** can be implemented as software, hardware, firmware, or a combination thereof. In some cases, various components of the rule-based content optimization system **500** can be implemented in software or firmware executed by a computing device.

In some embodiments, content configurations are transmitted from the content generation module **510** to the one or more assembling units **530**. The assembling units **530** can create a piece of content by arranging content elements in accordance with relationships among the content elements, where both the content elements and the relationships are specified by a content configuration. The assembling units **530** can further provide the created content to the displays 540. In some implementations, the assembling unit **530** can provide content to more than one displays 540. In some embodiments, the assembling unit **530** can be implemented on computing devices co-located with the display **540**. In such implementations, network traffic can be significantly reduced as only content configurations not the actual assembled pieces of content are transferred through the network.

In some implementations, the content generation module **510** can be implemented on computing devices that are co-located with the displays 540. In some cases, the content generation module **510** and the assembling unit **530** can be implemented on a same computing device. In some other implementations, the rule management module **520** can also be implemented on computing devices that are co-located with the displays 540. In some cases, the rule management module **520** and the assembling unit **530** can be implemented on a same computing device.

The content evaluation module **550** can evaluate the effectiveness of pieces of content. A content configuration, corresponding to a piece of content, can be designed to influence a particular behavior. For example, an advertisement can be designed to promote sales of a product. The content evaluation module **550** can collect data indicative of activities when the content is displayed to evaluate the effectiveness of the piece of content. Using the example above, the content evaluation module **550** can collect point of sales data for the product to evaluate the effectiveness of the advertisement on promoting sales.

In some embodiments, the rule management module **520** can maintain a set of rules governing generation of content that is designed to influence a particular behavior. A first content configuration and a second content configuration are generated in accordance with this set of rules. The content evaluation module **550** can compare the two content configurations and effectiveness of the two pieces of content assembled from the two content configurations. The content evaluation module **550** can generate an effectiveness evaluation corresponding to one or more aspects of content configurations and provide the evaluation to the rule management module **520**. The rule management module **520** can modify the set of rules governing generation of content that is designed to influence the particular behavior. The optional rule input unit **555** can provide rule related factors (i.e., inventory data, locality, saliency, etc.) to the rule management module **520** to modify the set of rules.

Figure 5B illustrates a system diagram for another exemplary embodiment of a rule-based content optimization system **500B**. In some implementations, the assembling unit **530** can be implemented on one or more central servers or local servers that are remote from the displays. This implementation can be suitable for an internet based application, where pieces of content can be assembled by the assembling unit **530** at an internet server.

Figure 6 illustrates an exemplary logical flowchart of a rule-based content optimization system. The rule-based content optimization system typically optimizes display content in reaching optimization objectives, for example, reaching certain goals or influencing particular behaviors. First, content elements are received (step **610**). The content elements may include specific geons, individual images, a group of images, or other specific pieces that are susceptible to assembly into a piece of content. In some embodiments, the content elements can be retrieved from a data repository or received from, for example, user input, network input, or other sources. These content elements can be a set of selected content elements suitable for generating content suitable in reaching the optimization objectives. A set of rules governing content generation are received (step **615**). These rules include rules defining permissible categorical relationships among content elements, rules on content elements, and, optionally, further include rules on metric adjustments within those categorical relationships. In some embodiments, these rules may include rules on what consist of permissible content elements. These rules can be retrieved from a data repository or received from, for example, user input, computing device, or other sources. The set of rules can be defined toward reaching the optimization objectives. When the content elements and the rules have been received, content configurations can be generated (step **620**), by arranging some or all of the content elements in a manner that is consistent with the rules. The generated content configurations can be assembled to pieces of content for display (step **625**) by assembling the content elements in accordance with the relationships and any other adjustments within the relationships as specified in the content configurations. In some implementations, the content configurations can be assembled to different pieces of content that are suitable for the target displays. In some embodiments, optionally, the assembled pieces of content can be evaluated by a visual attention model (VAM) (step **627**) and the result of the evaluation can be used to determined whether the assembled pieces of content satisfy the set of rules governing content generation, which include rules related to visual perception (step **628**). For example, whether the relative saliency of items represented in the content satisfied the rules. As a specific example, a rule can be that item A should have higher saliency (i.e., more likely to be attended) than item B. In some cases, verifying if the assembled piece of content satisfies the set of rules is performed by referencing historical data regarding saliency and object importance. If the assembled pieces of content satisfy rules related to visual perception, the pieces of content can be rendered for display. Otherwise, the system will route back to generate content configurations (step **620**).

The content effectiveness in reaching the optimization objectives can be evaluated when the pieces of content are rendered for display (step **630**). The content evaluation may include the step of, for example, designing a playlist for the content to be displayed, defining percentages of play for different pieces of content, or other means of regulating the content to which viewers will be exposed over time. The results of the experiments can be used to evaluate the effectiveness of the content. In some embodiments, the content effectiveness can be evaluated when playing these pieces of content in an experiment designed in accordance with experiment design principles. The experiment may be, for example, a correlational design, a quasi-experiment or a true experiment. In some embodiments, the experiment can be performed in a manner that reduces carryover effects.

The effectiveness data can be used to associate effectiveness with one or more content elements (step **635**) and/or to relationships among elements (step **640**). These associations can be made by comparing content performance and determining what differences can be attributed to variations in selection of content elements or the relationships among those elements. With that effectiveness information, the rule-based content optimization system may optionally include a further step of revising the rules (step **650**). The revision of the rules can create or update a rule of, for example, removing low-performing content elements, creating or revising permissible relationships. The revision of the rules can help optimize content generated in later iterations toward reaching the optimization objectives.

Figure 7 illustrates a modular diagram of an exemplary embodiment of a rule-based content optimization system **700**. In the embodiments illustrated in Figure 7, the rule-based content optimization system **700** can include a content generation module **702**, a experiment design module **704**, a rule management module **706**, an assembling module **708**, a display module **710**, a data repository **712**, a data acquisition module **714**, an analysis module **716**, and a communication interface **718**. The content generation module **702** is configured to create configurations of content elements and relationships among content elements. The content generation module **702** can generate the content configurations in accordance with rules provided by the rule management module **706**. An experiment design module **704** is configured to design an experiment to evaluate content performance. The experiment design module **704** can create schedules and playlists that control content display so that content performance may be measured through a correlational design, quasi-experiment or true experiment.

The assembling module **708** can receive content configurations of content elements and relationships and process those configurations to create a piece of content in a format suitable for play on a display. This may include assembly of content from content elements and relationships into an image file in a known format, such as .jpeg or other image formats, or creation of video in appropriate known formats such as .swf or .mpeg formats by assembling reference points and applying transitions governing permissible changes of content elements and relationships over time between the reference points to fill in the frames between reference points.

The display module **710** allows rendered content to be presented to viewers. In some embodiments, the display module **710** includes a plurality of digital displays. In some cases, the display module **710** can include displays dispersed at multiple locations.

In some embodiments, the data acquisition module **714** is configured to measure or collect data indicative of activities during the experiment. The data acquisition module **714** may perform or facilitate acquisition of data via any method. For example, the data acquisition module **714** may be coupled to various sensor or data acquisition devices that gather information including product movement, product sales, customer actions or reactions, and/or other information. Sensors may be used to detect, for example, if a customer picks up the product, or if a customer is in the vicinity of the display when the content is displayed. Sales may be determined based on information acquired by a point of sales (POS) system. One or more devices that validate the display of content may also be used. Changes in inventory levels of a product may be available via an inventory control system. Customer reactions may be acquired via questionnaires. One or more types of data collected by the data acquisition module **714** can be used to evaluate content performance.

Content performance data can be evaluated by the analysis module **716** to allow for the attribution of content effectiveness to particular relationships or content elements. Content performance data can be, for example, data indicative of activities at a site, data indicative of view behavior, results from visual attention models (i.e., salience maps, progressions of attention through the content over time, etc.). Content performance data may show that among two types of content where the only difference is the selection of one content element, the optimization system may attribute the difference in performance among those two elements to the different content elements selected. In some embodiments, the optimization system can use data from multiple pieces of content, attribute differences in performance to specific elements of the pieces of content by analyzing matrixes of the differences among the multiple pieces of content.

The rule management module **706** can receive, create, and modify rules for content creation. For example, the rule management module **706** may modify the rules to eliminate less-effective variants of specific content by restricting the content elements that can be used, or by restricting the set of permissible relationships among specific elements or types of elements. The rule management module **706** may also receive or create rules, for example, rules defined through a user interface. The rule management module **706** is discussed further below.

One or more modules of the rule-based content optimization system **700** can be implemented on a same computing device or several computing devices having non-transitory computer readable medium.

Each module of the rule-based content optimization system **700** can be implemented on an array of computing device. For example, the assembling module **708** may include a plurality of computers dispersed at multiple locations where displays are located. As another example, the assembling module **708** may include a computing device controlling a plurality of displays at one location or at multiple locations. One or more modules of the rule-based content optimization system **700** can be co-located or remotely located. For example, the assembling module **708**, the display module **710**, and the data acquisition module **714** may be co-located. In some embodiments, the content generation module, the analysis unit, and the experimental design module may be co-located. The assembling module **708** may, in some embodiments, be located with the content generation module **702**, but preferably is located with one or more displays of the display module **710**.

The communication interface **718** can provide electronic communication among the components of the rule-based content optimization system **700**. The communication interface **718** can include both short-range and long-range communication interfaces. The short-range communication interfaces may be, for example, local area network (LAN), interfaces conforming to a known communications standard, such as Bluetooth standard, IEEE 802 standards (e.g., IEEE 802.11), a ZigBee or similar specification, such as those based on the IEEE 802.15.4 standard, or other public or proprietary wireless protocol. The long-range communication interfaces may be, for example, wide area network (WAN), cellular network interfaces, satellite communication interfaces, etc. The communication interface **718** may be either within a private computer network, such as intranet, or on a public computer network, such as the internet.

Data repository **712** provides data storage for the rule-based content optimization system **700**. The data repository **712** can provide data storage for one or more modules in the rule-based content optimization system **700**. In some cases, the data repository **712** may run on a single computer or storage device. In some other cases, the data repository **712** may run on a series of networked computers, servers, or devices. In some implementations, the data repository **712** includes tiers of data storage devices including local, regional, and central. In some embodiments, the data repository **712** can provide data storage for the content generation module **702** and/or the rule management module **706** to store data, for example, such as content elements, metadata of content elements, rules governing content generation, relationships among content elements, and the like. In some embodiments, the data repository **712** provides data storage for the data acquisition module **714** and/or analysis module **716** to store data, for example, for example, such as data collected by the data acquisition module **714**, the content performance data, and the like.

The data repository **712** may be any non-transitory computer readable medium. For example, it may be random access memory, a flat file, a XML file, or one or more database management systems (DBMS) executing on one or more database servers or a data center. A database management system may be a relational (RDBMS), hierarchical (HDBMS), multidimensional (MDBMS), object oriented

(ODBMS or OODBMS) or object relational (ORDBMS) database management system, and the like. The data repository **712**, for example, may be a single relational database such as SQL Server from Microsoft Corporation. In some cases, the data repository **712** may include a plurality of databases that can exchange and aggregate data by data integration process or software application. In an exemplary embodiment, part of the data repository **712** may be hosted in a cloud data center.

Figure 8 illustrates an exemplary data flow diagram of a rule-based content optimization system **800**. In this embodiment, the rule-based content optimization system includes a content element repository **840**, a content generation module **850**, an assembling module **852**, a display module **854**, a data acquisition unit **858**, an analysis unit **860**, an evaluation module **862**, and a rule management module **864**. The content generation module (**850**), based on a set of rules **801** provided by the rule management module **864**, generates a content configuration **802**, which includes a selection of content elements, the categorical relationships among those selected content elements, and optionally, metric adjustments within the categorical relationships. This content configuration **802** is received by the assembling module **852**, which arranges the selected content elements according to the content configuration, and creates an assembled piece of content **804** in a format appropriate for display. The evaluation module **862** generates a set of play instructions **806** of the piece of content to allow the performance of the piece of content to be measured. In some embodiments, this set of play instructions **806** is transferred to the display module **854** to govern the display content **808** to viewers **856** in a manner that carries out a correlational design, a quasi-experiment, a true experiment, or other performance measurement scheme. Assembled content **804** is presented on one or more displays in the display module **854** and presented to viewers in accordance with the play instructions **806**. Viewer behavior and/or content effects **810**, such as purchase decisions, movement among areas, visual effects, or other data potentially driven by content are captured or collected by the data acquisition unit **858**. This acquired data **812** is transmitted to the analysis unit **860**, in order to assess the effectiveness of content. The analysis unit **860** can transform the acquired data **812** into effectiveness data **814** by examining the differences in content configurations (e.g. the use of different content elements or differences in the relationships among those content elements). The effectiveness data **814** is received by the rule management module **864** to revise the set of rules **801** in further iterations of creating and testing content. Optionally, other rule factors **816** (i.e., inventory data, locality, visual perception, etc.) can be input to the rule management module **864** to revise the set of rules **801**.

Referring back to Figures 9A and 9B, the two pieces of content can be generated by a rule-based content optimization system with the optimization objectives of selling hamburgers. The rule-based content optimization system can evaluate the performance of these two pieces of content and potentially update the set of rules for content generation based on the content performance data. Between Figures 9A and 9B, the visually important differences are the location of content element **902** relative to the other content elements **904** and 906/908, and the replacement of content element **906**, illustrating a visual representation of a beverage, with content element **908**, illustrating a visual representation of French fries. In this example, once an experiment is conducted to identify the content performance associated with each piece of content, the optimization system can identify several possible sources of the differences in performance. In the example of Figures 9A and 9B, there are several potential visually important differences between the two pieces of content. The differences in content performance could be due to the substitution of content element **906** for 908, or the change in position of content element **902**. Experiments with other permutations involving the position of 902 and the relative effectiveness of 906 and 908 may further identify the source of differences in content performance, by supplying more extensive data on the impacts of different content configurations and allowing for statistical isolation of a content element or relationship's impact among a diverse set of content configurations. Additional content performance data can also be used to identify higher-order effects, such as synergistic effects of sets of relationships (i.e., the impact of the position of content element **902** below the other content elements), selection of content element (i.e., selecting content element **906** other than content element **908**), or combinations of relationships and/or content elements, or other effects. For example, based on the content performance data, the content optimization system can add a rule that Content element type C (visual representation of French fries) should be excluded, or add a rule that Content element type D (promotional phrase) should be on the left of Content element type A (visual representation of a hamburger).

According to some aspects of the present disclosure, the content in Figures 9A and 9B can be generated through the use of probability factors to select content attributes. For example, the probability factors could dictate the selection of content elements such that a hamburger **904** is always displayed; that a content element "Buy Now" 902 is always displayed (i.e., a probability of 100%); that there is a 50% chance of selecting a content element "beverages" 906 and a 50% chance of selecting fries **908** to be included in the content. Probability factors can also be used to control the relationships among the content elements; for example, the probability factors that could generate the content of Figures 9A and 9B could dictate that either the drink **906** or fries **908** will be to the right of the hamburger **100**% of the time, and that there is a 50% chance of the call to action **902** being above the hamburger and a 50% chance of it being below the hamburger. In the case of Figures 9A and 9B, the probability factors dictated the selection of the content elements, with Figure 9A expressing the drink **906** possibility, and Figure 9B expressing the fries **908** possibility. The probability factors also influenced the relationships, resulting in the drink **906** and fries **908** appearing only to the right of the hamburger **904**, while the call to action **902** expressed relationships where it was above the hamburger **904** in Figure 9A and below it in Figure 9B. With the probability factors in this example, it would be impossible for a piece of content to exist without expressing the hamburger **904**, or for it to express the drink **906** or fries **908** to the left of the hamburger **904**.

In some embodiments, a set of rules on content generation can be updated by the system to reflect the data collected during content testing. Table 4 provides pseudo code for an exemplary embodiment of rule modification and improvement. The search space is initially narrowed both by user input and the nature of the content element and categorical relationship structure, allowing all initially permissible configurations of content to be tested. Next, the successful several configurations can be selected and the set of rules governing content generation can be modified based on the selection. Further, the successful configurations can have additional testing. Optionally, the additional testing can include different metric adjustments within the categorical relationships of those successful configurations. The metric adjustments are made by starting with an approved set of content elements and relationships, and determining adjustments to test. The adjustments may also be audited to ensure that they remain within the established categorical relationships, or the metric adjustments may be selected from a range known to maintain those categorical relationships, and not to move any element outside the boundaries of the display. The metric adjustments are then tested for each of the selected content configurations and from that pool. Experimental data can be obtained for the adjusted pieces of contents. Again, the successful configurations including metric adjustments are selected, and the rules governing content generation are adjusted to eliminate less successful configurations and metric adjustments. Metric adjustments may optionally be further improved through use of one or more of the known prediction and improvement algorithms, which may draw data from experiments on different metric adjustments and use that data to identify different metric adjustments to test.

Table 4

Rule Modification Pseudo Code
Modify Rule () • Receive content performance data for content generated based on a set of rules on content elements and permissible relationships among the elements • Select the pieces of content producing successful results according to the experimental data. • Modify the set of rules based on the selected pieces of content • Apply metric adjustments to the selected pieces of content • Receive content performance data for the pieces of content with metric adjustment • Select the adjusted pieces of content successful results according to the experimental data. • Further modify the set of rules based on the adjusted pieces of content
Metric Adjustment() • Select one of the successful pieces of content • Select metric adjustments to be made to the piece of content   o Ensure that metric adjustments will not cause content elements to cross categorical boundaries or content boundaries • Apply metric adjustments to that piece of content by moving content elements according to the adjustments. • Repeat until each piece of content has been selected and adjusted

Creating initial rules and/or manual modification to rules may be undertaken by way of a user interface on an electronic display device, where the user can be presented with content and then makes a decision regarding whether the content is acceptable and rules can be created based on the user's decision. Rules can also be automatically updated based on data from tests of various configurations of content. In some embodiments, a content generation/optimization system can include a user interface allowing users to provide or select rules governing permissible relationships among content elements and a processor to generate content, where the processor arranges content elements according to the rules. Figure 10A provides an exemplary flowchart detailing the rules development process facilitated by user inputs via a user interface. First, a piece of potential content is generated according to the initial set of rules (step **1002**). The initial set of rules can be generated with or without user inputs, such as the type of content, the content objective, or the like. The piece of potential content is then presented to the user via the user interface (step **1004**). Next, user input can be provided via an input device (step **1006**). The user input can be in the form of either an approval or rejection of the presented piece of content. After user input is taken, the system compares the attributes of the potential content to the current set of rules (step **1008**). Based on these comparisons, the system can analyze which attributes of the piece of potential content contributed to the decision (step **1010**). The rules are updated based on the analysis (step **1012**). For example, the system can generate or modify rules to exclude attributes that are sufficiently certain to lead to rejection. Optionally, the system may identify content attributes that require additional review, and ensure inclusion of permutations of those attributes in subsequent potential content configurations.

Figure 10B is an exemplary flowchart detailing automated rules development based on content performance. A content optimization system can optimize content for a particular objective. The content optimization system receives content performance of test content (step **1022**). The test content can be denoted as content configurations that include content elements and relationships among the content elements. The system determines content performance attributable to content elements and relationships, which are also referred to as content attributes (step **1024**). Optionally, the system can compare content performance across comparable content elements and relationships (step **1026**). Comparable content elements may be defined through metadata concerning the nature or purpose of the content element, derived from the similarity of the relationships among the content elements, or otherwise determined, such as by user input. The comparisons are then fed into a rules generation algorithm that, depending on the comparisons, determines whether the information is sufficient to justify a rule set amendment (step **1028**). If it is justified, the system can implement the rule set amendment (step **1030**). Amendments to the rules can include the exclusion of content elements and relationships that are found to be inferior to other comparable elements and relationships, but may also be adjustments to the frequency with which certain content elements or relationships are used, or other alterations that influence the typical form of the content generated. The determination of whether an amendment is justified is based on the certainty regarding the compared effectiveness metrics, as well as the system used to identify and implement the rules updates, for example, identification of Pareto improvements, use of prediction engines, known optimization algorithms, or individual incremental improvements.

Figure 10C illustrates an exemplary flowchart for content generation based on rules governing relationships among content elements. Steps of this flowchart may be implemented on a single computer at one site or may be distributed across a series of networked computers. For example, the first three steps can be implemented on a central server, while the assembly of content elements and rendering are implemented on computer(s) at a separate location. First, the rule set is received (step **1042**). The rule set provided may optionally be selected or generated based on a specific goal the content is directed to. Then, the set of content elements to be used in the content are selected according to the rules (step **1044**). The rules may include both mandatory content elements that must be present in a piece of content, as well as content elements that are optional, and content elements that are excluded from the piece of content. In some case, the rules may also govern which optional content elements may appear together, or specific optional content elements that must be included or excluded based on specific selections from the required content elements. In some embodiments, a content element may be categorized through metadata descriptive of the content element or its purpose, and the rules or content configurations may refer to this metadata. After the content elements are selected, the system generates a content configuration including a set of categorical relationships among the content elements based on the set of rules (step **1046**). Optionally, the content configuration can further include metric adjustments. A content generation system can generate a piece of content by placing the content elements according to the content configuration (step **1048**). This can be done in several ways. In some implementations, the centroids of each content element are calculated and used as the reference points, by which each content element is placed in the center of its various categorical relationships (i.e. diagonal arrangements can be at a 45 degree angle from horizontal arrangements). In some other implementations, a logistic function may be used to place content elements according to the categorical relationships. In some cases, the generation of content also includes steps of placing content elements according to metric adjustments specified in the content configuration. Optionally, once the content elements have been arranged according to the categorical relationships, the content generation system can audit the arranged content to ensure that the content will fit specific display dimensions or categories. Once the content generation and optional display testing are complete, the content is rendered for display (step **1050**).

Figure 11 illustrates a logical flowchart for an exemplary embodiment directed to rule-based content optimization systems for digital signage networks. Initially, a set of rules governing content generation for certain optimization objectives are retrieved (step **1110**). The rules can be retrieved from a data repository or received from user input or network commands and a combination thereof. A processing unit creates two content configurations (step **1120**), by selecting a set of content elements and defining categorical relationships among the set of selected content elements, and optionally defining metric adjustments among the set of selected content elements within the categorical relationships, in accordance with the set of rules. The two content configurations are designed to reach certain optimization objectives, for example, to influence particular behavior(s). The system further assembled two pieces of content based on the two content configurations (step **1125**). For digital signage networks, the rendering step may be completed either at a remote location from a display, where the assembled content is transferred to displays on the network, or at a local location of a display, where a piece of content is assembled by a computing device with a local content element repository in accordance with the content configuration. Optionally, the rendering step may include an additional step of making metric adjustments to the positions of the content elements, where the metric adjustments are typically within the boundaries of categorical relationship(s) specified by the content configuration.

Next, the performance of the two pieces of content in reaching the optimization objectives can be evaluated (step **1130**). In some embodiments, experiments are typically done by allocating content to specific time periods in a manner that carryover effects and related confounds are reduced in the measurements of content performance. In some implementations, experiments are typically done in a way that ensures an appropriate amount of display duration to generate a statistically valid sample. Content performance can be evaluated based upon data collected during a time period when the content is likely viewed. In some cases, the collected data can be pre-processed to reduce confounds before it is used in content evaluation.

Further, the differences in content performance can be associated with relationships (step **1135**) and/or content element selections (step **1140**). In some cases, additional data regarding content performance in reaching the optimization objectives can optionally be used to supplement the analysis of the two content configurations, for example, assisting in associating the effectiveness of content with particular content elements or relationships among content elements. The set of rules for content generations for reaching the optimization objectives can be revised based upon the association step(s) (step **1145**). For example, the system can revise the set of rules by adding a rule of excluding some content elements, a rule of excluding some content elements and relationships combinations, or a rule of relationships among two or more content elements. In another example, the system can revise the set of rules by revising an existing rule of permissible categorical relationships among content elements, an existing rule of permissible metric positions for content elements, or the like. Such embodiments can improve and optimize content by amending the rules to eliminate less effective options from the potential search space and focus on the more effective potential configurations.

In an exemplary embodiment, if the analysis shows that one content element has better performance than another content element (such as content element **906** always producing superior responses to 408, from the examples of content in Figures 9A and 9B), the optimization system can amend the rules to include the content element with better performance but not the content element with inferior performance. In some cases, the amending of the rules may also include adding and/or modifying rules on metric adjustments such that metric adjustments to the positions of content elements are within specific categorical boundaries identified. In some embodiments, rules governing permissible categorical relationships among content elements are optimized before rules governing permissible metric positions of content elements are adjusted. In some other cases, rules may also be developed by a prediction engine that identifies areas of content elements and relationships most likely to be successful based on the collected data, then creates or adjusts rules that focus on those areas. The prediction engine can use algorithms based on a variety of known statistical means of prediction or known optimization methods, for example, reinforcement learning routines, logistic regression routines, neural networks, supervised or unsupervised learning routines, transduction, genetic algorithms, support vector routines, learning-to-learn routines, or the like. By focusing on successful area in the search space, the system can explore content configurations effectively in optimizing content.

In an exemplary embodiment directed to generating and optimizing content in internet applications, the content generation and rendering steps can be similar to the optimization systems for digital signage networks. Content performance can be evaluated based upon data collected when the content is displayed. The collected data can be, for example, data indicative of behavior of viewers of content, data related to click behavior, or the like. In some implementations, data can be collected when content is displayed in according with an experiment design. In some cases, the experiment can be conducted by distributing the assembled pieces of content to similar advertising opportunities appearing on websites, which may be similar in a variety of dimensions such as overall page layout, the profile of website visitors, and other variables. In some implementations, the relative content effectiveness can be adjusted to account for differences in the population of advertising opportunities. When the content performance is evaluated, the association steps and the revising step can be similar to these steps for embodiments of the rule-based content optimization systems for digital signage networks as described above.

Figure 12 illustrates an exemplary flowchart for a content generation/optimization system using probability factors. Initially, the system receives a rule on probability factor, where the rule on probability factor specifies a statistical probability that a piece of content expresses a particular value of a content attribute (step **1210**). Next, the system generating a plurality of pieces of content in accordance with the rule on probability factor (step **1220**). The system further receives content performance data of the plurality of pieces of content when the plurality of pieces of content are in use (step **1230**). The system determines an aggregated performance data for the content attribute having the particular value based on the content performance data of the plurality of pieces of content (step **1240**). The system modifies the rule on probability factor based on the aggregated performance data (step **1250**).

A content generation/optimization system using probability factors can use the same systems illustrated in Figure 1 and Figure 3. The system includes a rule management module, a content generation module, and a content evaluation module. In some embodiments specific to system using probability factors, the rule management module in the content generation/ optimization system maintains a set of rules for content generation, where the set of rule includes one or more rules on probability factors. A rule on probability factor specifies a statistical probability that a piece of content expresses a particular value of a content attribute. The content generation module is operative to generate a plurality of pieces of content in accordance with the set of rules, where the plurality of pieces of content is designed with a particular optimization objective. In some cases, the content generation module is operative to generate a plurality of pieces of content by reference to the one or more rules on probability factors. The content evaluation module is operative to evaluate content performance on reaching the particular optimization objective based on data acquired when the plurality of pieces of content are displayed. The content evaluation module is further operative to determine an aggregated performance data for the content attribute having the particular value based on the evaluated content performance. Further, the rule management module is operative to amend the rule on probability factor based on the aggregated content performance data, where the rule on probability factor controls the selection of content elements and/or relationships.

In some embodiments, the content evaluation module is operative to determine a deviation value for the aggregated performance data for the content attribute based on the content performance data of the plurality of pieces of content. After the deviation value is determined, the rule management module is operative to modify the rule on probability factor based on both the aggregated performance data and the deviation value for the content attribute. In some cases, the rule management module is operative to identify a changeable content attribute based on the set of rules for content generation and compose a rule on probability factor for the changeable content attribute.

In some embodiments, a content generation/optimization system analyzes a set of rules for content generation to see what content attributes are free to vary, also referred to as modifiable content attributes or changeable content attributes. In some implementations of content generation/optimization system using experimental design principles, the system consults past content performance data relating to the modifiable content attributes, and from that as well as experimental design goals and constraints, and derives probability factors governing how frequently a particular value of one of the content attributes is presented. For example, an experimental design may require a certain number of experiments of some specific configurations, and given the number of displays on the network and the time to complete the experiment, the probability factors will be set so that the required number of experiments for each of the specific configurations can be met. In some implementations, the one or more composed rules on probability factor assign an equal probability to each value of a set of selected values for the changeable content attribute. In some cases, adjusting the probability factors can be done based on changes to the experimental constraints (for example, if the content is performing better or worse than anticipated and fewer experiments are required to establish its usefulness for optimization) or based on experimental progress (such as number of experiments actually completed). The adjustments may also take into account opportunity costs and optimization. For example, if a specific value of a content attribute is outperforming other values of the content attributes, while the number of experiments needed to establish sufficient value to use in optimization may be reduced, the probability factor for the specific value of the content attribute may remain the same or increase so that this superior content variation is used more frequently.

In some implementations, probability factors are set to implement an experimental design, for example, a specific fractional factorial and/or response surface experimental design. These may be implemented by setting/updating probably factors for a content attribute equally, relying on historical data relating to attribute performance and the volume of prior collected data, and heuristics (such as references to the cognitive and vision sciences to estimate what changes matter, and/or visual attention models). In addition to that, setting/updating probability factors can also be influenced to control the number of combinations and/or permutations and further constrain search space or direct the order of experiments within the search space; this may also rely on heuristics (such as cognitive and vision sciences information and visual attention models) for identifying where combinations are unlikely to have effects, or rely on historical data relating to the effects of changes in different content aspects on the performance of those content aspects (for example, if one content element can be A or B and another can be C or D, does the selection of C vs. D tend to affect the performance of content with respect to content element A vs. content element B), when determining what variations must be tested.

In some embodiments, a content configuration may be rendered in a number of different variations, each suitable for a particular display based on display characteristics such as resolution, aspect ratio, particular models of display and their inherent characteristics, and for differing types of displays (digital signage displays, mobile phone displays, etc.). In some embodiments, different rendering processes for various display types that may receive content on a digital signage network may be used. In other embodiments, multiple separate files may be rendered, each adapted to a particular display. In other embodiments, players on the digital signage network each have their own rendering tools, which are used to render content in a display-suitable format for that player based on received content attributes.

In some embodiments, the content is generated for a network of displays. In these embodiments, required elements are identified, and displays are networked to one another to communicate data regarding display status and what content is being played. In the event of a display failure, the content on the displays is altered to ensure that all essential content elements are still being presented somewhere on the network of displays. In some embodiments, this is done by having essential content elements play in place of other content elements. In some embodiments, the content itself will be altered to ensure that essential individual content elements or essential categories of content elements such as a particular product line will be included in the content that is being displayed on the network.

Exemplary Embodiments

Embodiment One is a computer-implemented system for facilitating automatic optimization of animated content to be rendered on an electronically addressable display, the system comprising:

a content generation module operative to generate an animated content configuration in accordance with a set of rules on content generation, the animated content configuration comprising an initial configuration and a transition, the animated content configuration designed with a particular optimization objective;

a content evaluation module operative to evaluate content performance on reaching the particular optimization objective based on data acquired when a piece of animated content assembled from the animated content configuration is displayed; and

a rule management module operative to amend the set of rules based on the evaluated content performance,

wherein the initial configuration comprises a plurality of content elements and one or more relationships among the plurality of content elements, and

the transition defines image transformations of one of the plurality of content elements.

Embodiment Two is the computer-implemented system of Embodiment One, wherein the set of rules on content generation are developed according to historical data on effects of particular categorical relationships and metric adjustments.

Embodiment Three is the computer-implemented system of Embodiment One or Embodiment Two, wherein the rule management module is further operative to amend the set of rules by at least one of the steps of adding a rule on probability factor and modifying a rule on probability factor, the rule on probability factor specifying probability of content configurations including a configuration elements that has a particular attribute value.

Embodiment Four is the computer-implemented system of any one of the Embodiment One through Embodiment Three, wherein the transition defines changes over time on at least one aspect of relationships, velocity, size, opacity, degree of curvature, color, brightness, hue, and contrast.

Embodiment Five is the computer-implemented system of any one of the Embodiment One through Embodiment Four, wherein the configuration element comprises at least one of a content element, a relationship, a transition, a size adjustment, and a position adjustment.

Embodiment Six is the computer-implemented system of any one of the Embodiment One through Embodiment Five, wherein the rule management module is further operative to amend the set of rules by at least one of the steps of adding a rule on a content element and modifying a rule on a content element.

Embodiment Seven is the computer-implemented system of any one of the Embodiment One through Embodiment Six, wherein the rule management module is further operative to amend the set of rules by at least one of the steps of adding a rule on a relationship and modifying a rule on a relationship.

Embodiment Eight is the computer-implemented system of Embodiment Seven, wherein the rule management module is further operative to amend the set of rules by at least one of the steps of adding a rule on probability factor and modifying a rule on probability factor, the rule on probability factor specifying a statistical probability that a piece of content expresses a particular value of a metric adjustment within the relationship.

Embodiment Nine is the computer-implemented system of any one of the Embodiment One through Embodiment Eight, wherein the rule management module is further operative to amend the set of rules by at least one of the steps of adding a rule on a transition and modifying a rule on a transition.

Embodiment Ten is the computer-implemented system of any one of the Embodiment One through Embodiment Nine, wherein the set of rules comprises at least one of rules on relationships, rules on content elements, rules on metric adjustments, rules on transitions, and rules on visual perception.

Embodiment Eleven is the computer-implemented system of any one of the Embodiment One through Embodiment Ten, wherein the content configuration further comprises a size or position adjustment of a content element.

Embodiment Twelve is the computer-implemented system of Embodiment Eleven, wherein the rule management module is further operative to amend the set of rules by at least one of the steps of adding a rule regarding a metric adjustment of the content element and modifying a rule regarding a metric adjustment of the content element.

Embodiment Thirteen is the computer-implemented system of any one of the Embodiment One through Embodiment Twelve, wherein the evaluated content performance comprises at least one of data indicative of activities at a location where the piece of content is displayed, data indicative of view behavior, and result from a visual attention model.

Embodiment Fourteen is the computer-implemented system of any one of the Embodiment One through Embodiment Thirteen, wherein the rule management module is further operative to amend the set of rules by at least one of the steps of adding a rule on visual perception based on the particular optimization objective and modifying a rule on visual perception based on the particular optimization objective.

Embodiment Fifteen is the computer-implemented system of any one of the Embodiment One through Embodiment Fourteen, further comprising:

an assembling module adapted to assemble the animated content configuration to a piece of animated content by arranging the plurality of content elements according to the one or more relationships and compiling an animation of the one of the plurality of content elements according to the transition, wherein the assembling module is further adapted to store the piece of animated content as a multimedia digital file.

Embodiment Sixteen is the computer-implemented system of Embodiment Fifteen, further comprising:

a computer coupled to an electronically addressable display, and wherein the computer is programmed to cause the multimedia digital file to be rendered on the electronically addressable display.

Embodiment Seventeen is the computer-implemented system of any one of the Embodiment One through Embodiment Sixteen, further comprising:

a visual attention model (VAM) evaluator operative to apply a VAM on the assembled piece of content to generate a VAM output and verify if the assembled piece of content satisfies the set of rules based on the VAM output.

Embodiment Eighteen is the computer-implemented system of Embodiment Seventeen, wherein verifying if the assembled piece of content satisfies the set of rules is performed by referencing historical data regarding saliency and object importance.

Embodiment Nineteen is the computer-implemented system of any one of the Embodiment One through Embodiment Eighteen, the rule management module is further operative to amend the set of rules by adding a rule or modifying a rule based upon at least one of factors comprising inventory data, point-of-sale data, locality, day-part, and trigger data.

Embodiment Twenty is a method for optimizing animated content, comprising:

generating, by a processing unit, two animated content configurations in accordance with a set of rules on content generation;

assembling, by a processing unit, the two animated content configurations to two pieces of animated content;

conducting an experiment to obtain effectiveness data of the two pieces of animated content on reaching an optimization objective;

determining relative effectiveness of the two animated content configurations based on the effectiveness data; and

amending the set of rules on content generation based on the relative effectiveness of the two animated content configurations,

wherein each animated content configuration comprises an initial configuration and a transition,

the initial configuration comprises a plurality of content elements and one or more relationships among the plurality of content elements,

the transition defines image transformations of one of the plurality of content elements.

Embodiment Twenty-one is the method of the Embodiment Twenty, wherein the amending step comprises amending the set of rules by at least one of the steps of adding a rule on probability factor and modifying a rule on probability factor, the rule on probability factor specifying probability of content configurations including a configuration element that has a particular attribute value.

Embodiment Twenty-two is the method of the Embodiment Twenty or the Embodiment Twenty-one, wherein the transition defines changes over time on at least one aspect of relationships, velocity, size, opacity, degree of curvature, color, brightness, hue, and contrast.

Embodiment Twenty-three is the method of any one of the Embodiment Twenty-one through Embodiment Twenty-two, wherein the configuration element comprises at least one of a content element, a relationship, a transition, a size adjustment, and a position adjustment.

Embodiment Twenty-four is the method of any one of the Embodiment Twenty through Embodiment Twenty-three, wherein the amending step comprises amending the set of rules by at least one of the steps of adding a rule on a content element and modifying a rule on a content element.

Embodiment Twenty-five is the method of any one of the Embodiment Twenty through Embodiment Twenty-four, wherein the amending step comprises amending the set of rules by at least one of the steps of adding a rule on a relationship and modifying a rule on a relationship.

Embodiment Twenty-six is the method of Embodiment Twenty-five, wherein the rule management module is further operative to amend the set of rules by at least one of the steps of adding a rule on a transition and modifying a rule on a transition.

Embodiment Twenty-seven is the method of any one of the Embodiment Twenty through Embodiment Twenty-six, wherein the set of rules comprises at least one of rules on relationships, rules on content elements, rules on metric adjustments, rules on probability factors, and rules on visual perception.

Embodiment Twenty-eight is the method of any one of the Embodiment Twenty through Embodiment Twenty-seven, wherein the content configuration further comprises a metric adjustment of a content element.

Embodiment Twenty-nine is the method of any one of the Embodiment Twenty through Embodiment Twenty-eight, wherein the amending step comprises amending the set of rules by at least one of the steps of adding a rule regarding a metric adjustment of the content element and modifying a rule regarding a metric adjustment of the content element.

Embodiment Thirty-one is the method of any one of the Embodiment Twenty through Embodiment Thirty, wherein the effectiveness data comprises at least one of data indicative of activities at a location where the piece of content is displayed, data indicative of view behavior, and result from a visual attention model.

Embodiment Thirty-three is the method of any one of the Embodiment Twenty through Embodiment Thirty-two, wherein the amending step comprises amending the set of rules by at least one of the steps of adding a rule on visual perception based on the particular optimization objective and modifying a rule on visual perception based on the particular optimization objective.

Embodiment Thirty-four is the method of any one of the Embodiment Twenty through Embodiment Thirty-three, further comprising:

applying a visual attention model (VAM) on one of the two assembled piece of content to generate a VAM output and verify if the one of the two assembled piece of content satisfies the set of rules based on the VAM output.

Embodiment Thirty-five is the method of any one of the Embodiment Twenty through Embodiment Thirty-four, wherein the amending step comprises amending the set of rules by adding a rule or modifying a rule based upon at least one of factors comprising inventory data, point-of-sale data, locality, day-part, and trigger data.

The present invention should not be considered limited to the particular examples and embodiments described above, as such embodiments are described in detail to facilitate explanation of various aspects of the invention. Rather the present invention should be understood to cover all aspects of the invention, including various modifications, equivalent processes, and alternative devices falling within the spirit and scope of the invention as defined by the appended claims and their equivalents.

What is claimed is:

1. A computer-implemented system for facilitating automatic optimization of animated content to be rendered on an electronically addressable display, the system comprising:

a content generation module operative to generate an animated content configuration in accordance with a set of rules on content generation, the animated content configuration comprising an initial configuration and a transition, the animated content configuration designed with a particular optimization objective;

a content evaluation module operative to evaluate content performance on reaching the particular optimization objective based on data acquired when a piece of animated content assembled from the animated content configuration is displayed; and

a rule management module operative to amend the set of rules based on the evaluated content performance,

wherein the initial configuration comprises a plurality of content elements and one or more relationships among the plurality of content elements, and

the transition defines image transformations of one of the plurality of content elements.

2. The computer-implemented system of claim 1, wherein the set of rules on content generation are initially developed according to historical data on effects of particular categorical relationships and metric adjustments.

3. The computer-implemented system of claim 1, wherein the rule management module is further operative to amend the set of rules by at least one of the steps of adding a rule on probability factor and modifying a rule on probability factor, the rule on probability factor specifying probability of content configurations including a configuration element that has a particular attribute value.

4. The computer-implemented system of claim 1, wherein the transition defines changes over time on at least one aspect of relationships, velocity, size, opacity, degree of curvature, color, brightness, hue, and contrast.

5. The computer-implemented system of claim 3, wherein the configuration element comprises at least one of a content element, a size adjustment, a position adjustment, a relationship, and a transition.

6. The computer-implemented system of claim 1, wherein the rule management module is further operative to amend the set of rules by at least one of the steps of adding a rule on a content element and modifying a rule on a content element.

7. The computer-implemented system of claim 1, wherein the rule management module is further operative to amend the set of rules by at least one of the steps of adding a rule on a relationship and modifying a rule on a relationship.

8. The computer-implemented system of claim 7, wherein the rule management module is further operative to amend the set of rules by at least one of the steps of adding a rule on probability factor and modifying a rule on probability factor, the rule on probability factor specifying a statistical probability that a piece of content expresses a particular value of a metric adjustment within the relationship.

9. The computer-implemented system of claim 1, wherein the rule management module is further operative to amend the set of rules by at least one of the steps of adding a rule on a transition and modifying a rule on a transition.

10. A method for optimizing animated content, comprising:

generating, by a processing unit, two animated content configurations in accordance with a set of rules on content generation;

assembling, by a processing unit, the two animated content configurations to two pieces of animated content;

conducting an experiment to obtain effectiveness data of the two pieces of animated content on reaching an optimization objective;

determining relative effectiveness of the two animated content configurations based on the effectiveness data; and

amending the set of rules on content generation based on the relative effectiveness of the two animated content configurations,

wherein each animated content configuration comprises an initial configuration and a transition,

the initial configuration comprises a plurality of content elements and one or more relationships among the plurality of content elements,

the transition defines image transformations of one of the plurality of content elements.

11. The method of claim 10, wherein the transition defines changes over time on at least one aspect of relationships, velocity, size, opacity, degree of curvature, color, brightness, hue, and contrast.

12. The method of claim 10, wherein the effectiveness data comprises at least one of data indicative of activities at a location where the piece of content is displayed, data indicative of view behavior, and result from a visual attention model.

13. The method of claim 10, wherein the amending step comprises amending the set of rules by at least one of the steps of adding a rule on visual perception based on the particular optimization objective and modifying a rule on visual perception based on the particular optimization objective.

14. The method of claim 10, further comprising:

applying a visual attention model (VAM) on one of the two assembled piece of content to generate a VAM output and verify if the one of the two assembled piece of content satisfies the set of rules based on the VAM output.

15. The method of claim 10, wherein the amending step comprises amending the set of rules by at least one of the steps of adding a rule on a relationship, modifying a rule on a relationship, adding a rule on a transition, modifying a rule on a transition, adding a rule on a content element, and modifying a rule on a content element.

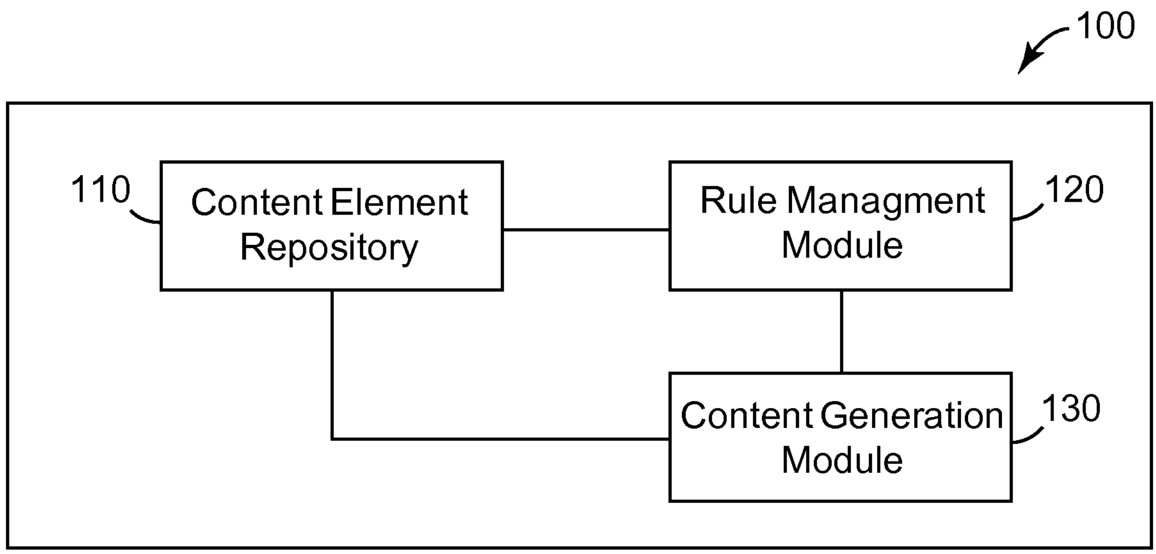

Figure 1

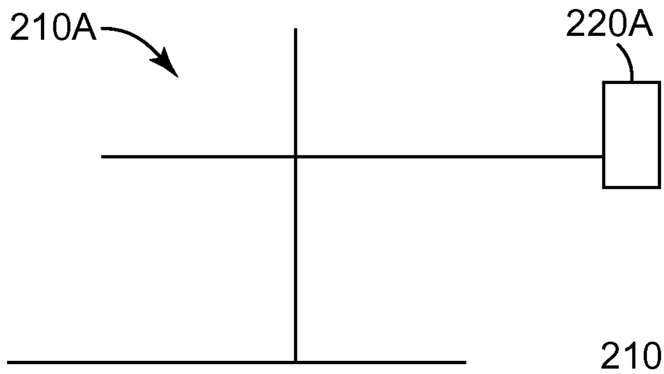

Figure 2A

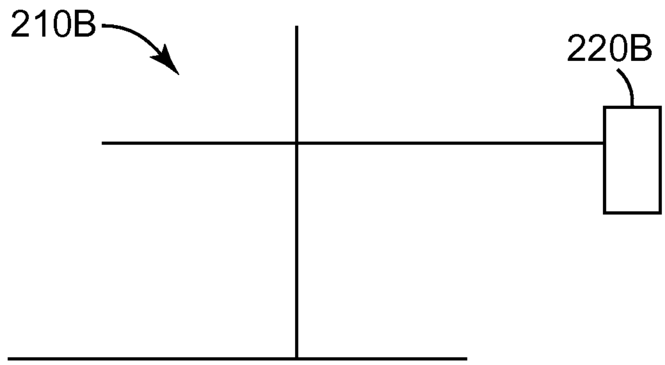

Figure 2B

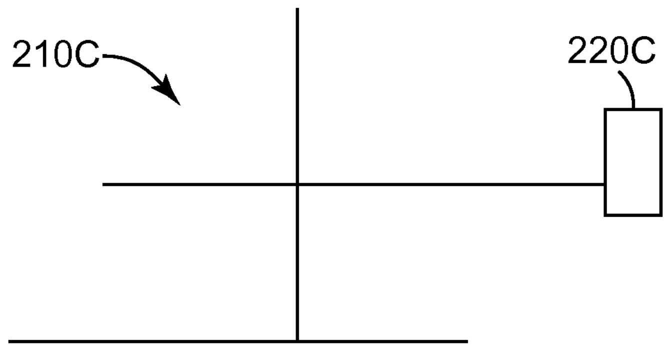

Figure 2C

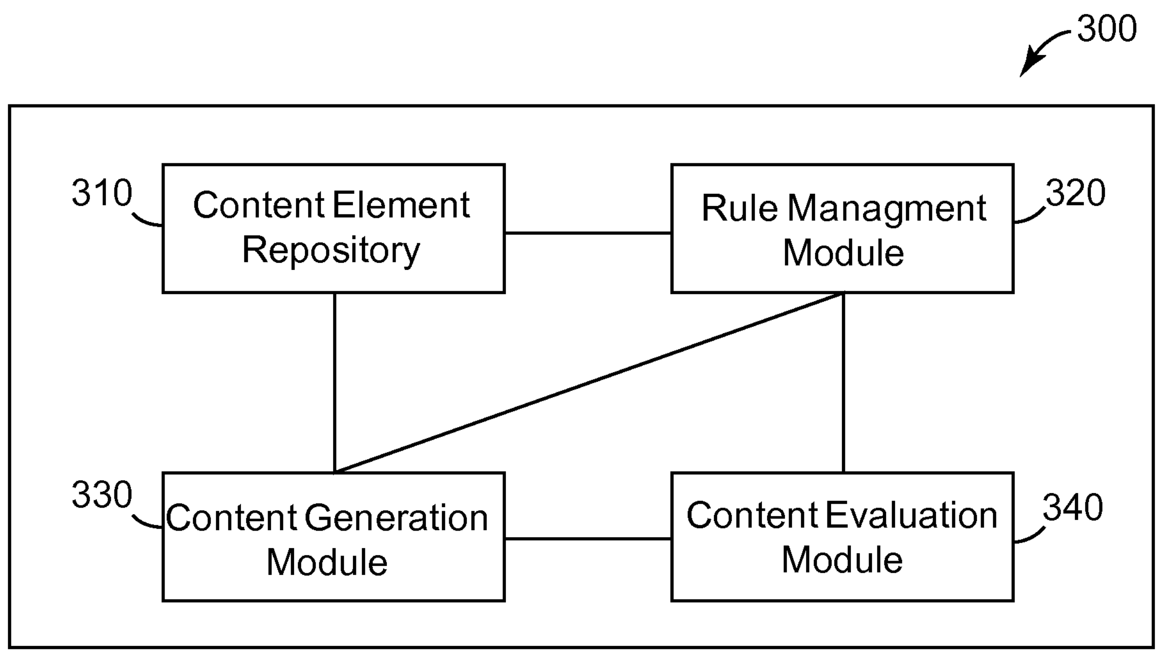

Figure 3

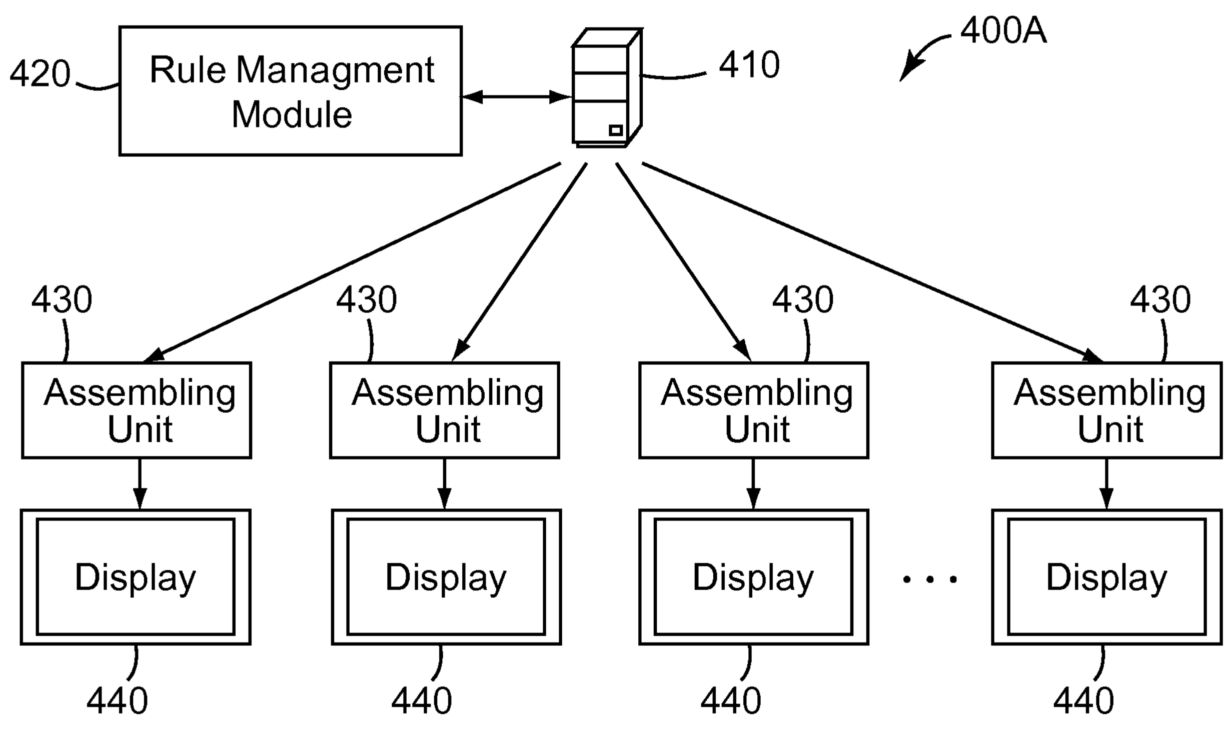

Figure 4A

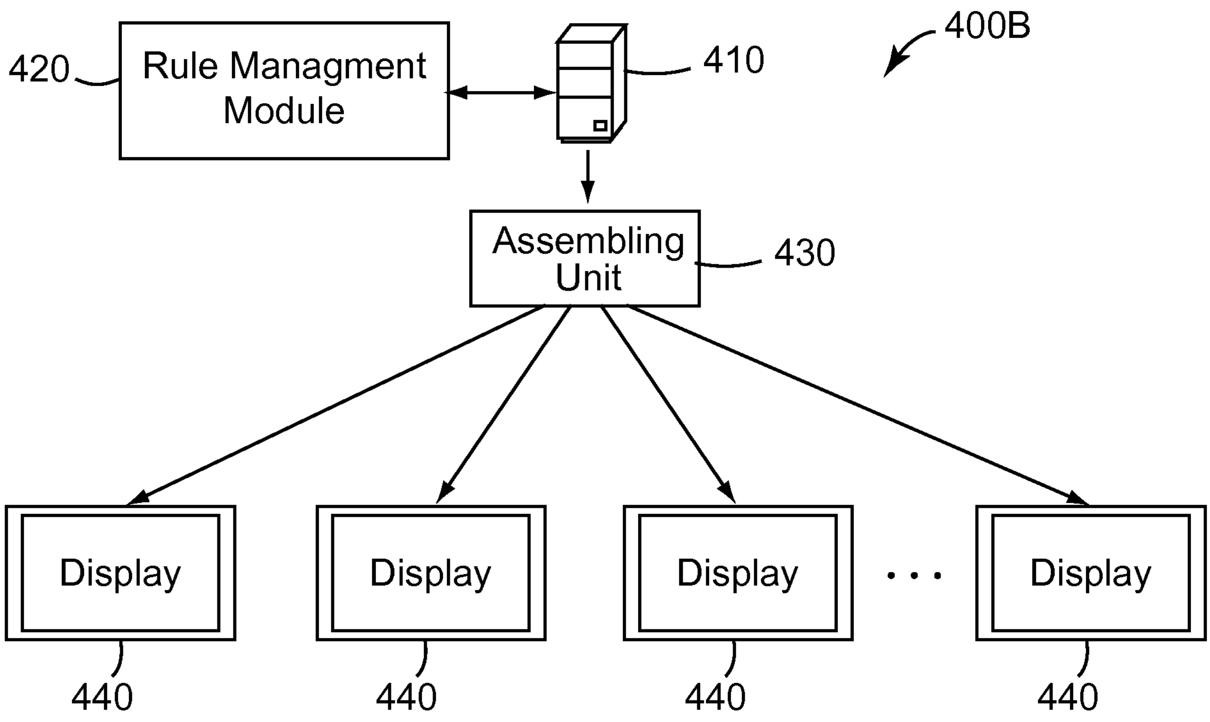

Figure 4B

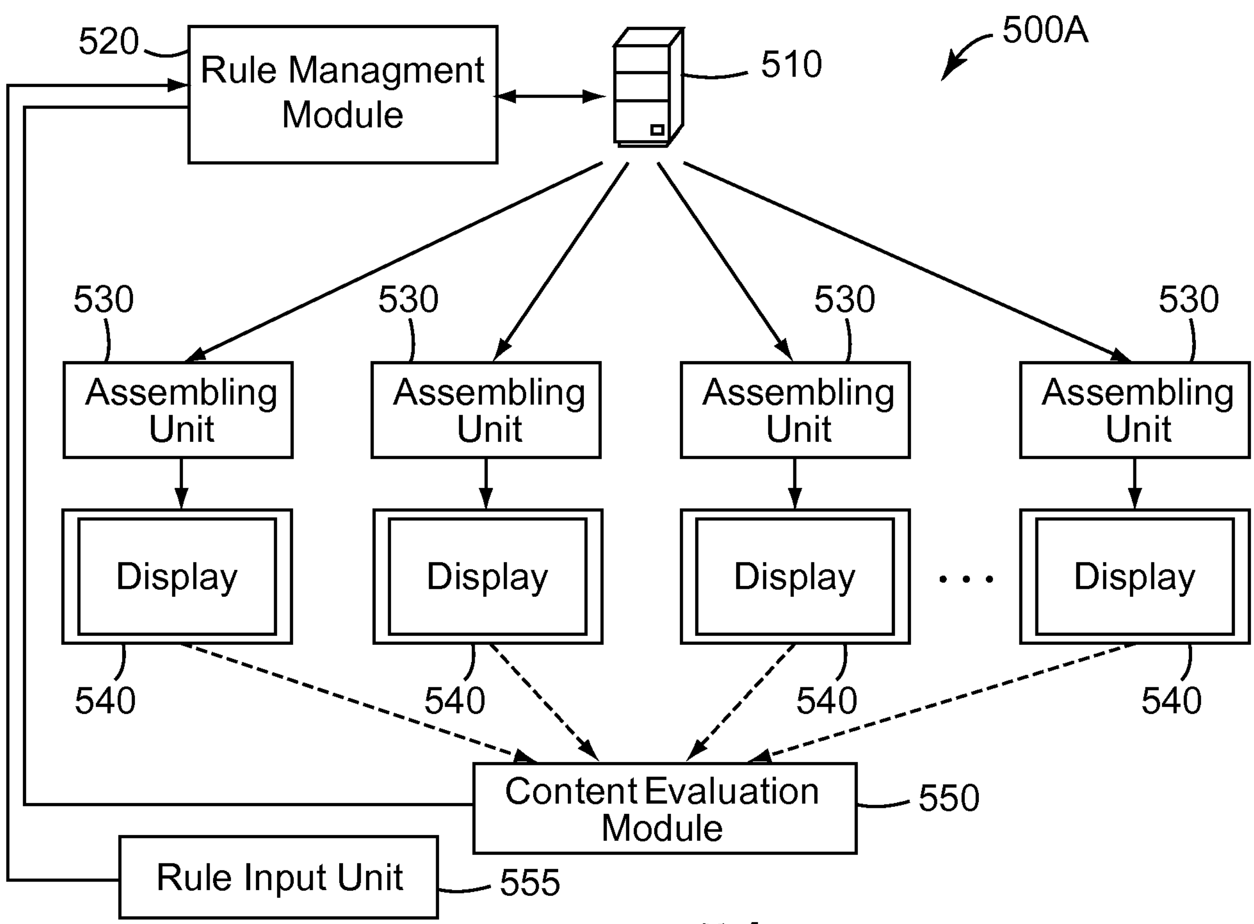

Figure 5A

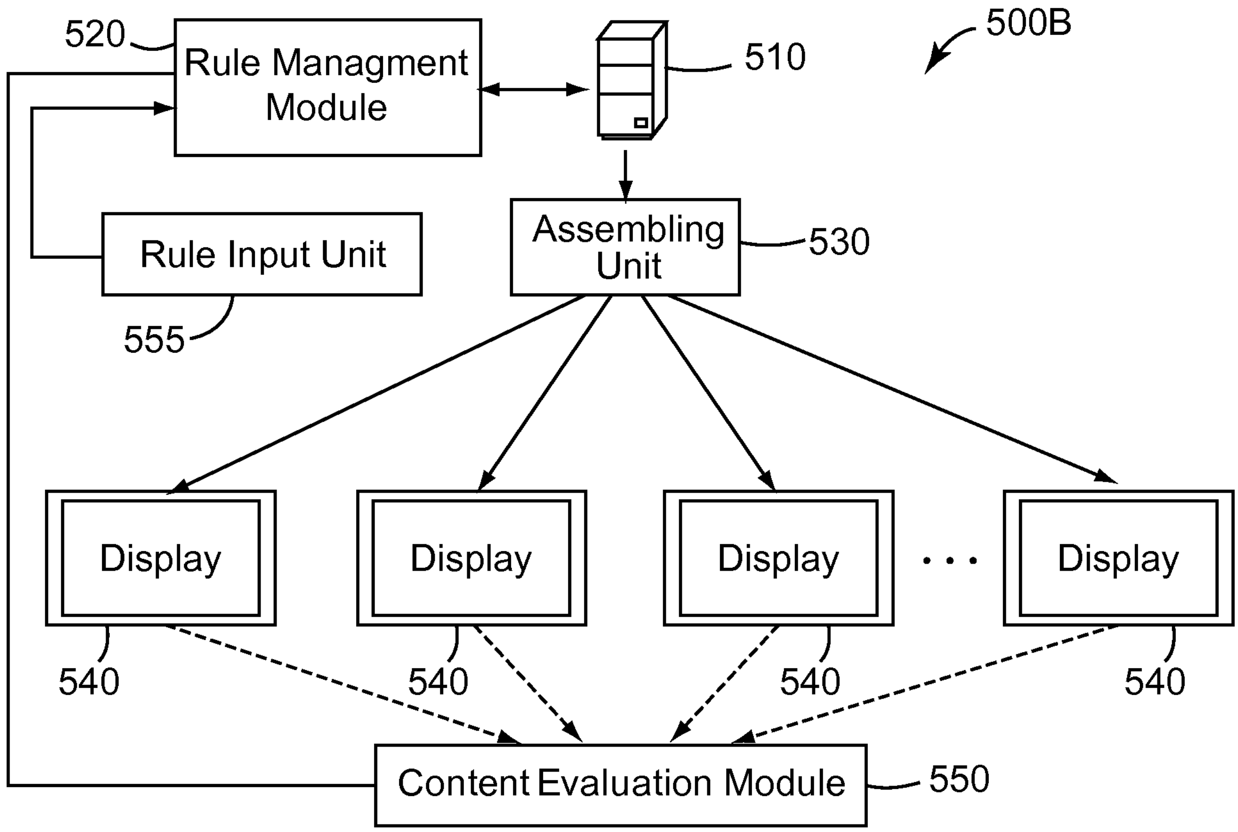

Figure 5B

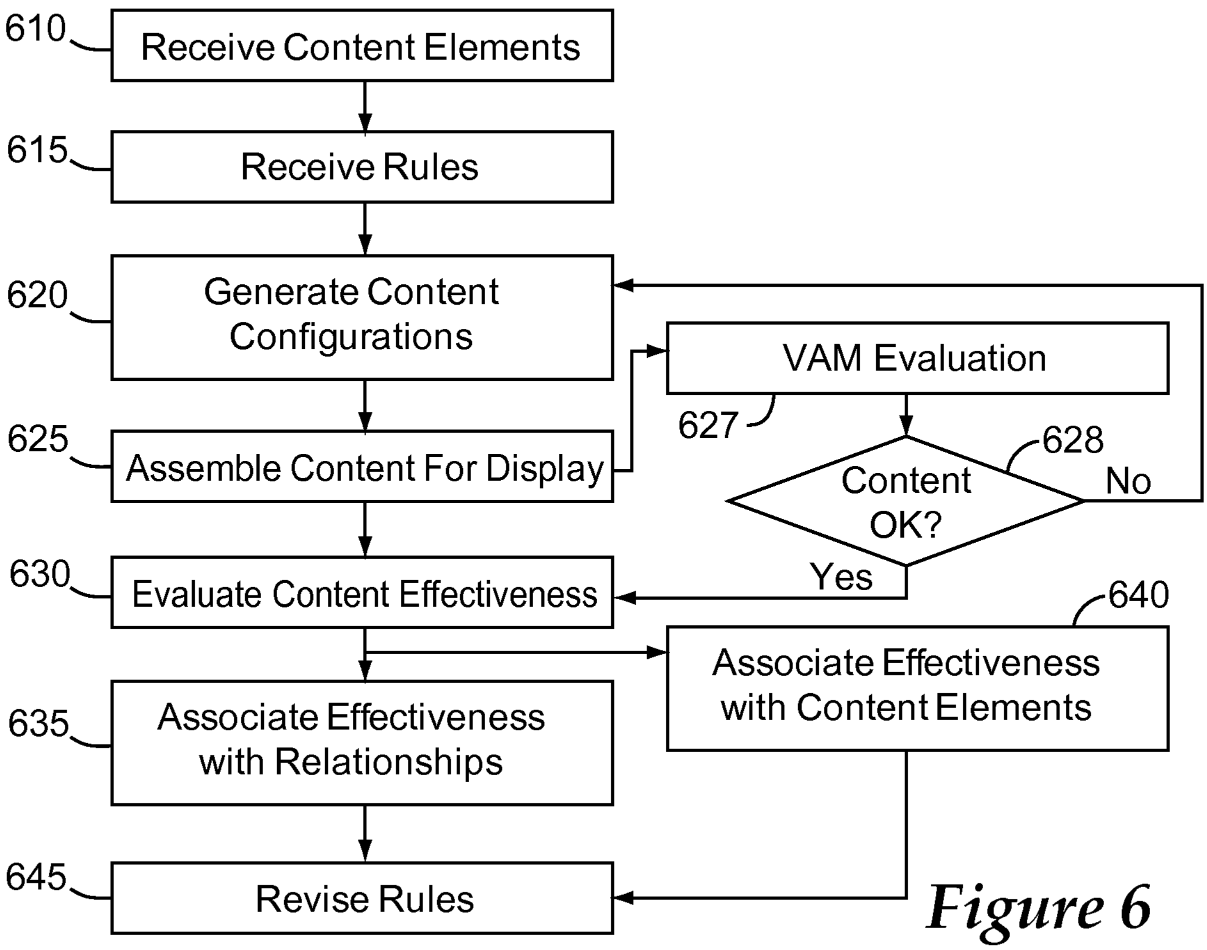

Figure 6

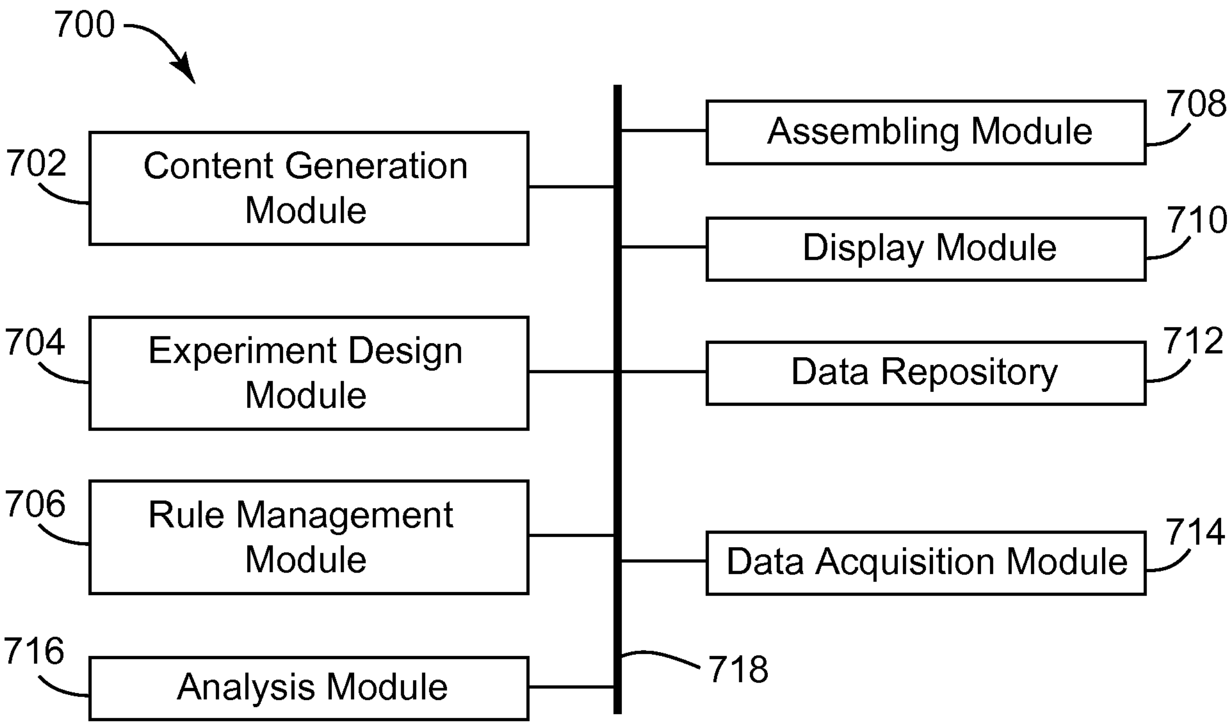

Figure 7

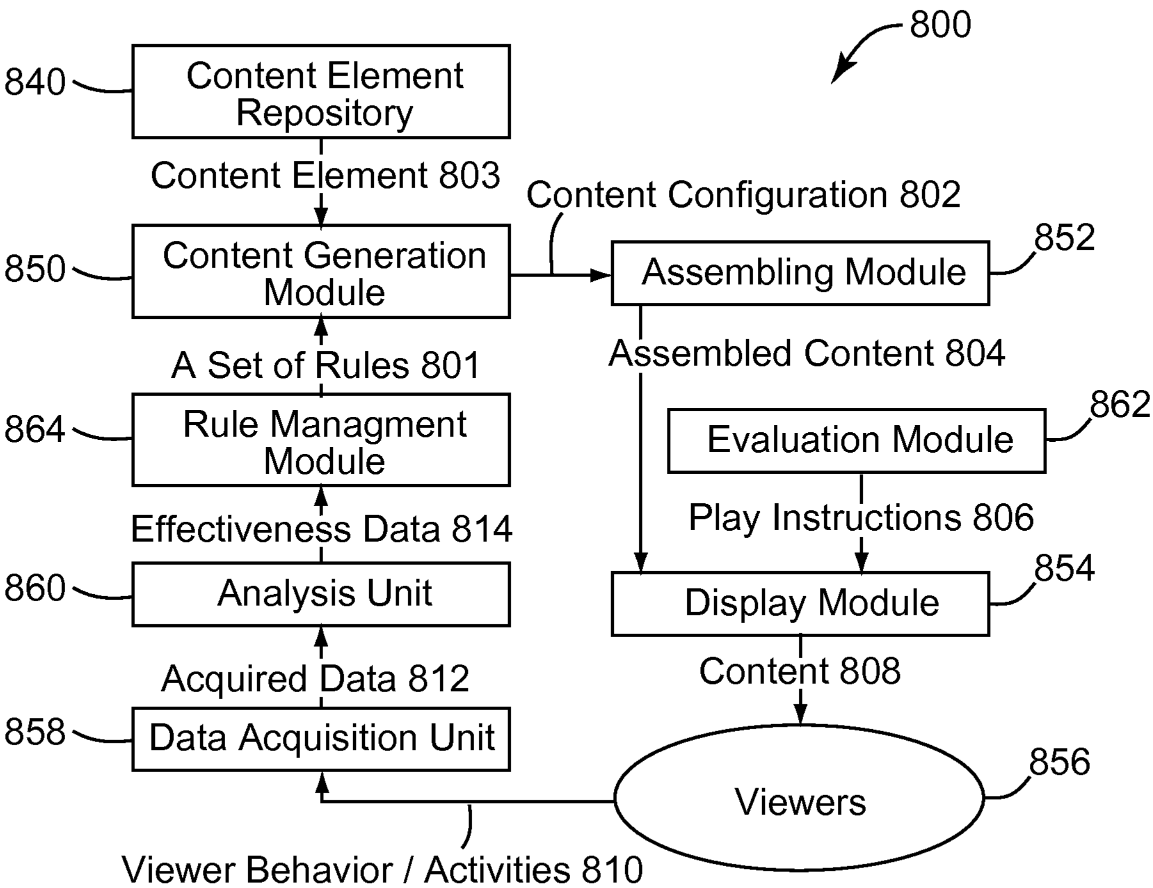

Figure 8

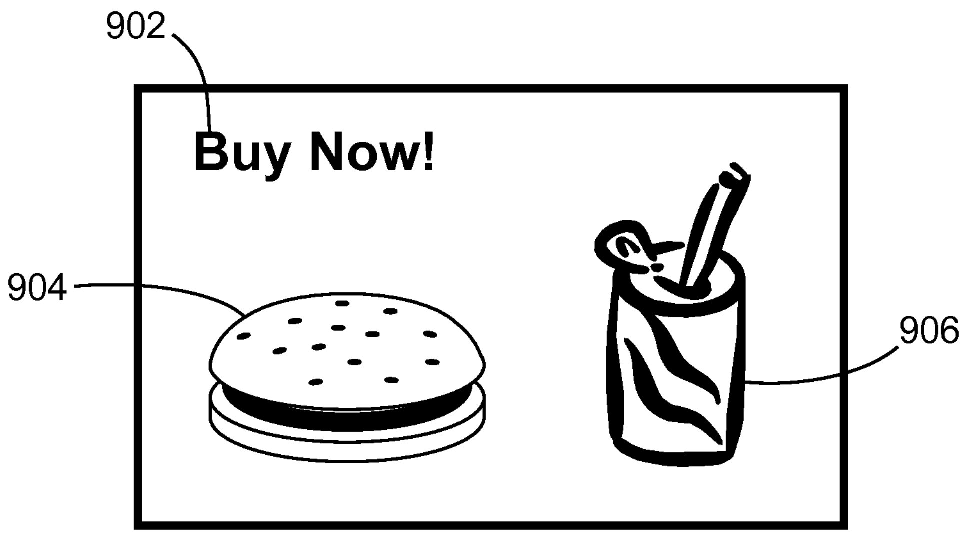

Figure 9A

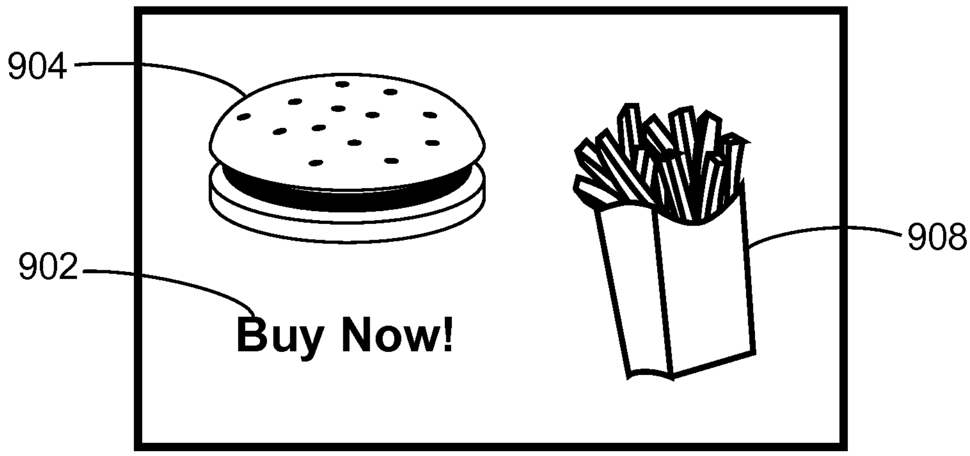

Figure 9B

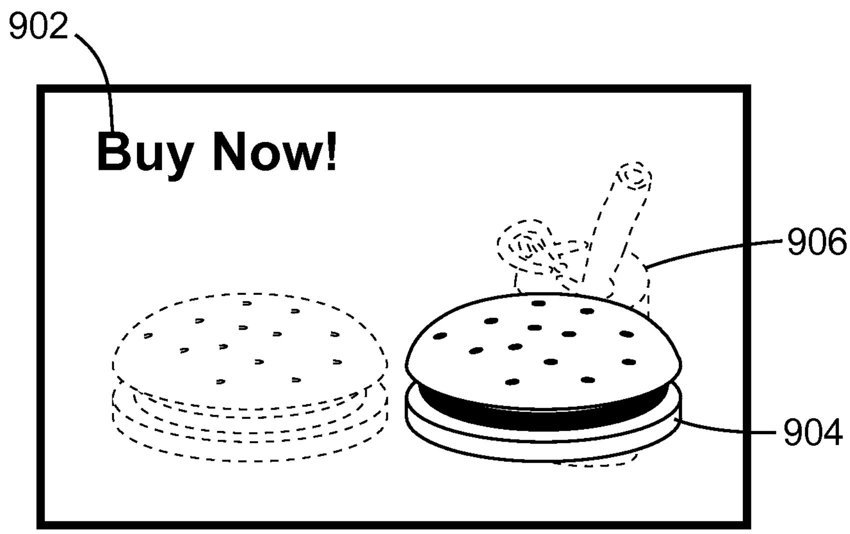

Figure 9C

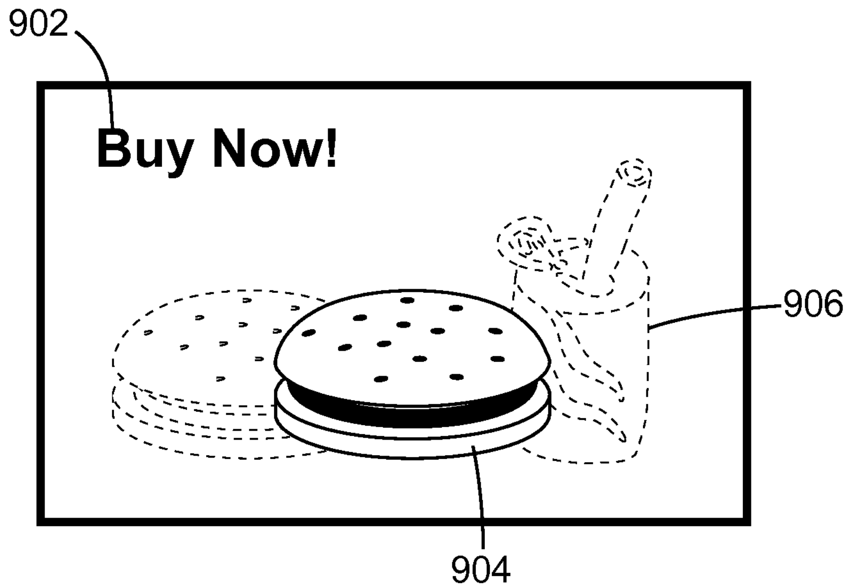

Figure 9D

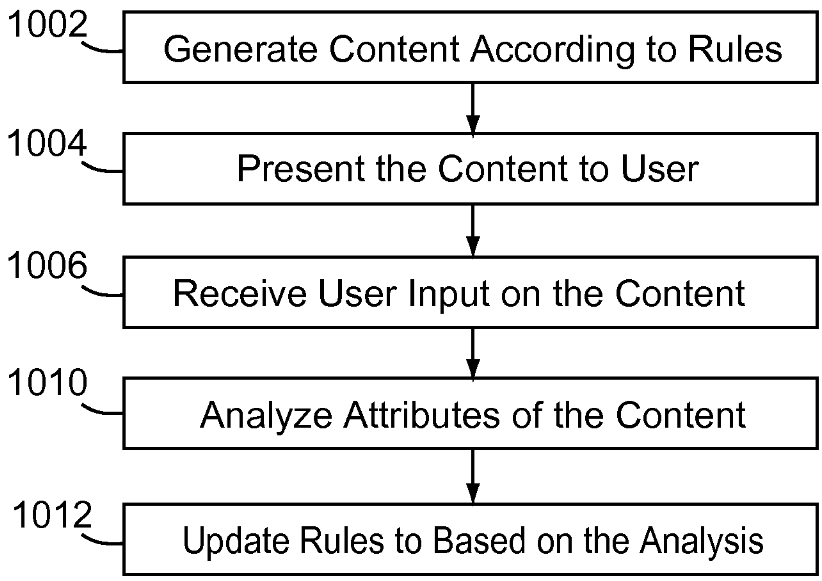

Figure 10A

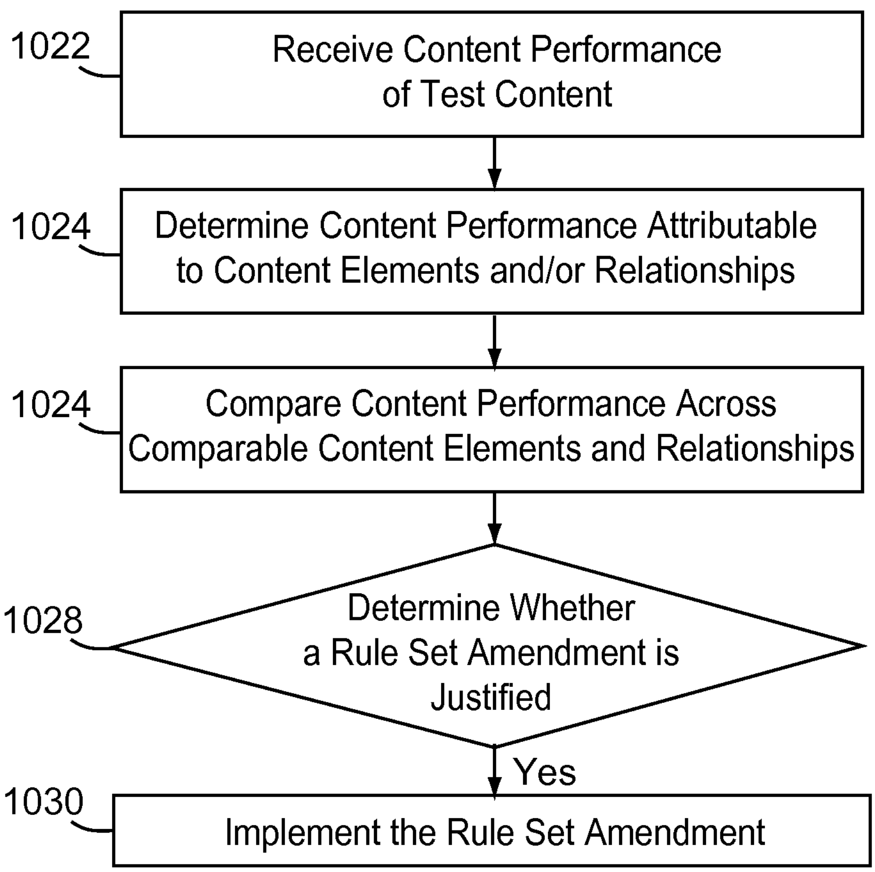

Figure 10B

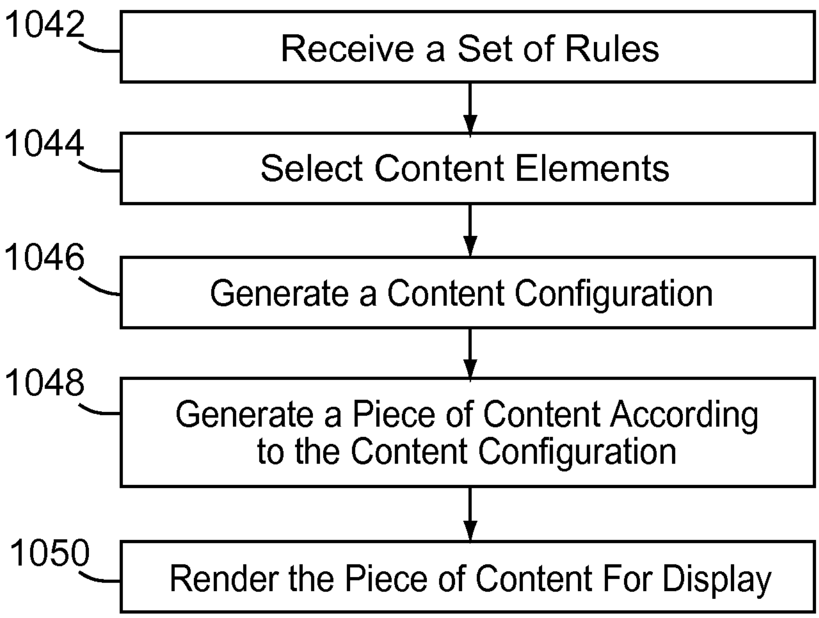

Figure 10C

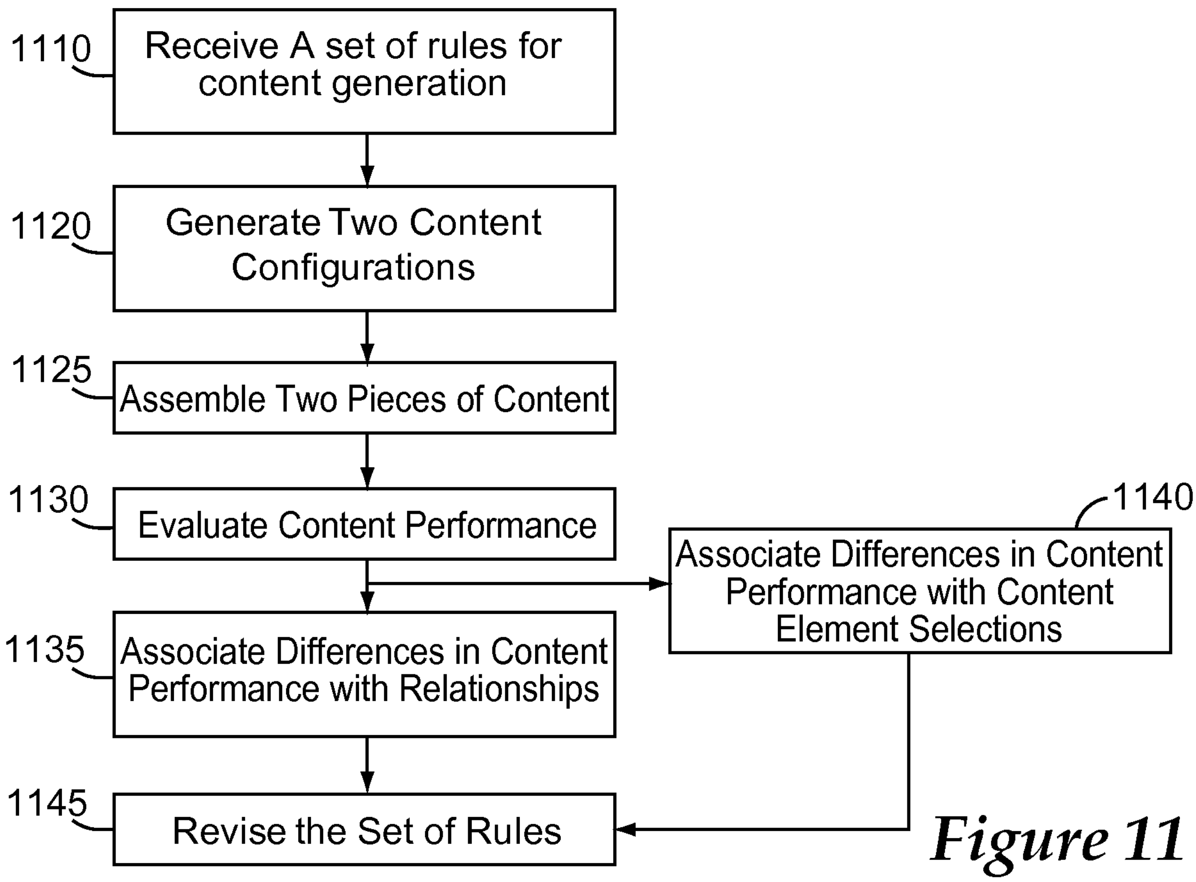

Figure 11

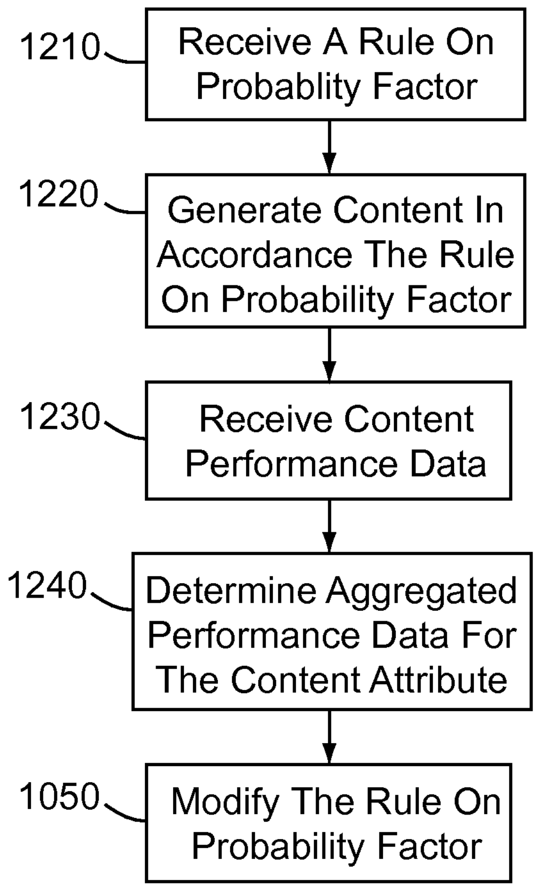
1210
Receive A Rule On Probablity Factor
1220
Generate Content In Accordance The Rule On Probability Factor
1230
Receive Content Performance Data
1240
Determine Aggregated Performance Data For The Content Attribute
1050
Modify The Rule On Probability Factor

Figure 12

INTERNATIONAL SEARCH REPORT

International application No.
PCT/US2013/074547

A. CLASSIFICATION OF SUBJECT MATTER
IPC(8) - G06F 19/26 (2014.01)
USPC - 345/418
According to International Patent Classification (IPC) or to both national classification and IPC

B. FIELDS SEARCHED

Minimum documentation searched (classification system followed by classification symbols)
IPC(8) - G06F 19/26, 9/40 G09F 5/00 (2014.01)
USPC - 345/418, 345/619, 345/440, 345/473, 345/474, 700/245

Documentation searched other than minimum documentation to the extent that such documents are included in the fields searched
CPC - G06F 19/26, 17/30781, G09F 5/00 (2014.02)

Electronic data base consulted during the international search (name of data base and, where practicable, search terms used)
Orbit, Google Patents, Google Scholar

C. DOCUMENTS CONSIDERED TO BE RELEVANT

Category*	Citation of document, with indication, where appropriate, of the relevant passages	Relevant to claim No.
X --- Y	US 7,088,374 B2 (DAVID et al.) 08 August 2006 (08.08.2006) entire document	1, 4, 6 ------ 2, 3, 5, 7-15
Y	US 2010/053154 A1 (HORVITZ et al.) 4 March 2010 (04.03.2010) entire document	2, 3, 5, 7, 8
Y	US 2008/0291216 A1 (CHENG et al.) 27 November 2008 (27.11.2008) entire document	9-15
A	US 5,808,617 A (KENWORTHY et al.) 15 September 1998 (15.09.1998) entire document	1-15
A	US 5,907,704 A (GUDMUNDSON et al.) 25 May 1999 (25.05.1999) entire document	1-15
A	US 7,511,718 B2 (SUBRAMANIAN et al.) 31 March 2009 (31.03.2009) entire document	1-15
A	US 7,953,682 B2 (SMITH et al.) 31 May 2011 (31.05.2011) entire document	1-15

☐ Further documents are listed in the continuation of Box C. ☐

* Special categories of cited documents:
"A" document defining the general state of the art which is not considered to be of particular relevance
"E" earlier application or patent but published on or after the international filing date
"L" document which may throw doubts on priority claim(s) or which is cited to establish the publication date of another citation or other special reason (as specified)
"O" document referring to an oral disclosure, use, exhibition or other means
"P" document published prior to the international filing date but later than the priority date claimed

"T" later document published after the international filing date or priority date and not in conflict with the application but cited to understand the principle or theory underlying the invention
"X" document of particular relevance; the claimed invention cannot be considered novel or cannot be considered to involve an inventive step when the document is taken alone
"Y" document of particular relevance; the claimed invention cannot be considered to involve an inventive step when the document is combined with one or more other such documents, such combination being obvious to a person skilled in the art
"&" document member of the same patent family

Date of the actual completion of the international search	Date of mailing of the international search report
30 April 2014	16 MAY 2014

Name and mailing address of the ISA/US	Authorized officer:
Mail Stop PCT, Attn: ISA/US, Commissioner for Patents P.O. Box 1450, Alexandria, Virginia 22313-1450 Facsimile No. 571-273-3201	Blaine R. Copenheaver PCT Helpdesk: 571-272-4300 PCT OSP: 571-272-7774