Content Scheduling and Adaptation for Networked and Context-Aware Digital Signage: A Literature Survey

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Abstract Digital signage (DS) is becoming well accepted as a ubiquitous medium that can deliver and display various types of information by specifying the location and time. In this paper, we put our focus on the following two directions of DS development: (1) Networked DS: networking displays to form a large-scale open DS network that allows content providers to submit contents, and schedule, deliver, and display the contents at the right place and time, (2) Context-aware DS: displaying contents appropriate to the current status of people, places, and objects around the display, that is, changes in context. This paper gives an overview of the research being done on these issues, specifically, content scheduling, real-time content adaptation, and context sensing. Finally, some of the future challenges will be discussed.

Key words: Digital signage, Public display, Content scheduling

1. Introduction

Digital signage (DS) is known as a public medium that can deliver and display various types of information by specifying the location and time. It has been rapidly spreading throughout public spaces since the late 2000s. DS is also called public display, pervasive display, digital out-of-home (DOOH), and is defined as “a system that transmits information using electronic display devices connected to the network at all places, such as outdoor, shop front, public space, transportation facilities.” (definition by Digital Signage Consortium19).

DS is widely used, not only for advertising and sales promotions but also in information sharing, media facade, entertainment and so on.

(1) Advertising and Sales Promotion

The advertising objectives are classified into the following three categories53): (a) cognitive objective: to acquaint the user with a product or brand, (b) emotional objective: to link a product or service with specific emotions, (c) conative objective: to stimulate potential buyers to buy, order, use, or undertake some action.

DS displays that show advertisements aimed at cognitive objectives and emotional objectives are widely deployed in stations24 and trains23.

DS is primarily aimed at advancing conative objectives and so is widely deployed in retail stores and commercial facilities. As a famous example, the SMART Network20 of Walmart in USA, has 27000 displays installed in most stores with 140 million impressions per day. Display placement and contents are carefully designed so as to encourage sales; campaign messages are shown on a large welcome screen at the entrance of the store, each department has a category screen, while each aisle has endcap screens. According to data gathered from an 18 month operation period, sales were increased for many products advertised on the DS network.

There are many research projects aiming at advertising or sales promotions: e.g. an interactive wall and a targeted advertisement display in retail stores86, and an interactive shopping system called WallSHOP61.

(2) Information Sharing

DS used for information sharing or notifications can be found in public and semi-public spaces everywhere, e.g., city centers, offices, university and educational institutions.

Research projects for the purpose of information sharing between employees in the office include Notification Collage33, BlueBoard74, and Plasma Poster Network9,10.

There are many research projects that target information sharing within universities: e-Campus84, which is installed at conference venues, exhibition halls, bus stops, and iDisplay28, which provides two types of signs, Reminder display and News display.
Examples for information sharing in urban spaces include: CityWall\textsuperscript{40}, which provides photo browsing by multi-touch displays, UBI-hotspots\textsuperscript{36,37,41,45}, which provides interactive contents such as maps, MobiDiC Shopfinder\textsuperscript{26}, which navigates users to the store via their mobile terminals, and DigiFieds\textsuperscript{51}, which digitizes paper-based posters on bulletin boards. DS can also be used in rural areas. WrayDisplay\textsuperscript{49} is an attempt to share news and information about rural communities in rural areas.

There are other use cases, e.g., navigating users in a museum where RFID and WiFi are used for indoor positioning\textsuperscript{23}, and providing emergency information in disaster situations\textsuperscript{38,40}.

(3) Environmental Display and Entertainment

There are examples of DS being used for the purpose of environmental displays on the outer and inner walls of buildings, and for entertainment such as games. Examples of research projects include Media Facade\textsuperscript{11}, which is a large display embedded in a building, a multiplayer game called Flashlight Jigsaw\textsuperscript{7}, multi user interactive entertainment MobiLenin\textsuperscript{28} integrated with multi-track music videos, and Magical Mirrors\textsuperscript{19} which gives displays visual effects on the screen in response to passerby's gestures.

In this manner, DS applications are extremely diverse, ranging from small scale of just one display to large scale with the interworking of tens of thousands of displays via a network.

Large-scale DS systems in many cases have multiple stakeholders: typically (a) content providers, (b) display owners, (c) platform providers, and (d) the audience. Bauer et al.\textsuperscript{23} added context information providers, who provide information such as weather forecasts or local events. Small-scale DS like those that display restaurant menus is likely owned by the shop owner. In such cases, the stakeholders from (a) to (c) are the same organization or individual.

The contents providers (a) correspond to “advertisers” in advertising, while the content providers in information sharing use can be people in any department, such as general affair department or top-level executives. The display owners (b) are often the owners of the locations of where the displays are installed; the display owners of train DS can be the railway companies, while those of university DS can be the facility management department. The platform providers (c) are the companies or people who manage the DS system and distribute contents. They may sometimes be the same entities as the display providers.

1.1 Directions in Digital Signage Development

This section introduces three directions of DS development: (1) networked, (2) context-aware, and (3) interactive DS.

(1) Networked Digital Signage

One direction is to connect simple and distributed displays by a network, to form an large-scale open DS network, that allows users to submit contents, and schedule and distribute the contents direct to displays to show the contents at the right place and right time.

In order to realize the networked DS, we need standards that can ensure the interoperability of DS systems and content, and content-scheduling mechanisms to meet the requirements of the stakeholders.

Standardization. Most current commercial DS systems are closed and proprietary. If you want to simultaneously distribute content to displays managed by signage systems of Company A and Company B, you need to create contents in their proprietary formats and submit them using different procedures. This is time-consuming and inefficient. To address these problems, ITU-T\textsuperscript{42} is working on standards for ensuring DS system and content interoperability, W3C\textsuperscript{62,93} is working on a standard for Web-based digital signage using Web standard technologies such as HTML5. In terms of file formats of image, video and metadata for programmatic ad buying, standardized specifications are being studied in Digital Place-based Advertising Association (DPAA)\textsuperscript{21,22}.

Content scheduling. In an open DS network, a content scheduling mechanism is important to immediately and flexibly determine the optimal destination and timing for content display. Merely connecting DS systems by a high-speed network does realize quick information display. As the number of stakeholders will increase with deeper DS networking, the coordination between stakeholders will become more complicated, necessitating an automatic content-scheduling mechanism.

The triggers of content schedule revision are not only at events of content addition, update, and deletion but also content removal due the moderation enforced by display owners. In DS networks providing advertisement services, advertisement contents are submitted well in advance, e.g., a few days before their publication, the platform operators therefore have enough time to make sophisticated content schedules and playlist for
delivery to DS terminals in the day before publication. A problem is that it is difficult to implement immediate schedule changes in response to emergencies.

(2) Context-Aware Digital Signage

Given the rapid increase in the spatial coverage of DS displays, the status of people, places, objects, and devices around the display, that is context, will vary greatly. In most current DS systems, the content is simply replayed in rotation according to a predetermined schedule without considering the situation. Context-aware DS that flexibly responds to context changes have been studied.

(3) Interactive Digital Signage

Interactive DS applications or contents that allow access through touch panels and mobile devices are commonly used to improve the effectiveness of individual displays.

Veenstra et al. performed a field study to compare the impact of interactive and non-interactive displays in city centers. It was shown that interactive DS attracted more attention and they observed the phenomenon of the “honey-pot effect” in which more people are attracted by other people watching and interacting with the DS. There are also many products and services that use mobile devices to interact with DS.

1.2 Scope of This Survey

In this paper, we present a literature survey on research papers and commercial cases with the scope of (1) networked DS and (2) context-aware DS. As for (3) interactive DS, She et al. has already provided a comprehensive review. We classify and outline previous works on content scheduling required for networking DS, content adaptation, context sensing and aggregation techniques and frameworks required for context-aware DS in Sections 2, 3, and 4, respectively. Based on the survey, we discuss some future technical challenges in Section 5.

2. Content Scheduling

This section divides automatic content scheduling into five types: constraint-based, recommendation-based, advertisement optimization, display-owner oriented, and hybrid approach. The classification reflects the importance of requirements or constraints of stakeholders as shown in Fig. 1. The content scheduling methods are summarized in Table 1.

2.1 Day-Parting and Scheduling

First, we describe the general scheduling of the current commercial DS systems, such as Scala content manager and BroadSign Core. The current DS system is basically designed for broadcast-type services. Contents are manually scheduled in advance of publication, typically a few days before their publication, and delivered to the players (display terminals). A day is divided into time zones called dayparts; a playlist, which is a list of contents in order of playback, is allocated to each daypart. In the case of the advertisement model, the time zone in which advertisements can be displayed is called an ad slot.

Content scheduling consists of the following two procedures: (1) content assignment: to determine the assignment of displays (or places) and time slots for each content provided by content providers, (2) playlist creation: to determine the replay order of the allocated contents. Although content scheduling is almost always manual, some DS systems have functions (called e.g. smart playlist) that automate the process of choosing content items for display by specifying the display condition.

2.2 Constraint-Based Approach

The constraint-based approach schedules content items by considering requirements provided by the stakeholders, content providers, display owners, and platform providers, as shown Fig. 1(a), (b), (c). To illustrate the complexity of the requirements, the following examples are listed.

The requirements of content providers, Fig.1(a), as follows:

- Time constraints: a) show an advertisement of breakfast menu from 6:00 to 9:00 in the morning, b) do not show any content item after 20:00, c) show a content item precisely at 12 o’clock every day like a time signal.
- Publish date: show an item for two weeks from
May 1 to May 14.

- Destination constraints: a) show an item on all displays, b) show an item on specific displays, e.g., displays within an organization.

The requirements from display owners include the following:

- Format constraints: a) show only portrait content since the display is portrait, b) mute sound output in particular locations.
- Genre constraints: a) do not show content items that are not suitable for the place, e.g., advertisements for alcoholic beverages are prohibited in hospitals. In many cases, manual moderation of content is necessary to check if content is suitable for the place where the display is deployed.

The following constraints are imposed by platform providers based on the contract with content providers (or advertisers):

- Frequency constraints: show the content according to the agreed-upon conditions, such as display frequency or audience number, according to the advertisement budget.
- Sequence constraints: a) advertisements of competing products should not be displayed consecutively, b) content B must be displayed right after content A; e.g., an ad for a refreshing drink must be displayed immediately after weather forecast content (contextual advertisement).

Harrison and Andrusiewicz proposed a scheduling method that considers display requirements generated by content providers and assigns contents to the slots so as to satisfy the display requirements (constraints). The requirements or constraints are specified as time-based, standard, and recurring display orders. Constraint-based scheduling schemes are similar to the TV commercial allocation problem and the Internet banner allocation problem. Bollapragada et al. proposed a method to equalize the broadcasting intervals so that commercials are not continuously broadcast under the given constraints, which can also be applied to DS.

2.3 Recommendation-Based Approach

The recommendation-based approach puts more importance on viewer preference and interest, see Fig. 1 (c), when selecting content items for display.

Two recommendation criteria have been proposed: (1) the relevance to the viewer interest profile and (2) the timeliness of the contents.

Viewer Interest Profile. McCarthy et al. tested the GroupCast system that identifies individuals using infrared tags, acquires the interest profile of multiple people in front of the display, and selects and displays content items that best match the viewers’ interest. Ferdinando et al. proposed the MyAds system, it acquires interest profile by using RFID instead of infrared tags; When there is more than one content that matches the interests of the audience at that location, the MyAds system takes “economic efficiency” into account, that is the ad budget and cost effectiveness of each content as well.

Timeliness. Ribeiro and José introduced two “timeliness” measures for dynamic information sources (news, magazines, blogs, announcements and events) to provide timely information. In the case of information with publication date, such as news and magazines, timeliness is defined by a function that gradually decreases with the time elapsed since the time of publication. In case of event-related information, the timeliness is defined as a function that steadily increases as the event approaches and drops abruptly when the event finishes. Their method was extended to use both timeliness and audience profiles.

2.4 Advertisement Optimization Approach

The advertisement optimization approach selects content items so as to maximize some utility function for the content provider (in many cases, the advertiser) under the constraints set by the platform providers and the display owners. This approach puts more importance on the information in Fig. 1 (a), (b), and (c).

Examples of effectiveness metrics for advertising are (1) reach, (2) the number of possible viewers, (3) viewing time, (4) the number of activated customers, and (5) the amount of sales lift. An effectiveness metric similar to TV ratings has not been established for DS. Digital Place Based Advertising Association (DPAA) introduced the average unit audience metric for DS in “Audience Metrics Guidelines”.

Reach. Payne et al. proposed a system that maximizes the number of viewers exposed to content, i.e., “reach”, by reducing the number of people who watch the same content multiple times; it uses Bluetooth device ID to identify viewers near a display and selects the content item suitable for the largest number of viewers who see the item first time under a budget constraint using a second price seal auction. Rogers et al. also maximized reach. The difference is that (a) the number of viewers is predicted by a probabilistic model using a Poisson distribution and (b) the proba-
The number of people who will see the advertisement for the first time is estimated as the utility of allocating an advertisement to an ad slot.
The content with the highest value is selected in a first-price sealed bid auction.

**Number of Possible Viewers.** Taniguchi et al. proposed a model for automatically optimizing content schedules by maximizing the number of possible viewers.

**Viewing Time.** Müller et al. developed ReflectiveSigns, which automatically learns viewer preference for certain content in different contexts for better scheduling. The Naive Bayes method is used to train and predict viewing time as an indicator of viewer preference based on content type and display location. The training data contains viewing time, content type and location; the viewing time is obtained by detecting faces from camera images on the display. ReflectiveSigns selects content items by weighting with the expected viewing time.

**Number of Activated Customers.** The self-optimizing digital signage of Müller et al. uses coupons to measure the sales promotion effect of advertisements. Customers can receive a discount by taking a photo of a coupon displayed on DS and taking it to the store. The Naive Bayes classifier is used to estimate the number of activated customers, i.e. those that will visit the real store, and bids are determined based on that value.

**Sales Lift.** Salimi and Wang introduced the concept of promotional value as a measure of the benefits that a vendor receives from the sales uplift created by an advertisement. The promotion value can be defined for each vendor based on demand forecast, taking into account response to advertisement exposure of products, inventory cost, and product expiration date. An iterative auction is performed while incrementally raising the price until the total of vendor’s purchase falls within the number of empty slots.

### 2.5 Display-Owner Oriented Approach

This approach selects content items appropriate for DS site primarily from the perspective of the display owners (Fig. 1 (b)).

Clinch et al. separated the roles of the content provider and the display owner: the content provider publishes their contents through a “channel”. The display owner subscribes channels suitable for that location. Unlike current DS systems, the content included in the channel is displayed in order by round-robin scheduling. This mechanism dispenses with centralized control.

### 2.6 Hybrid Approach

In practice, sophisticated scheduling mechanisms are required as content providers have various communication goals. In order to raise brand awareness, for example, it might be desirable to have evenly spaced and long-term advertisement campaigns. On the other hand, in the case of sales promotion and event announcement, you might want to display ads intensively immediately before the expiration date or the date of the event. The introduction of interactive contents causes difficulties in that it is impossible to interrupt other contents until the user finishes viewing the interactive contents. When planning a campaign that occupies the entire DS network in a city for a product, it is necessary to schedule to display the same contents simultaneously on the displays.

**Application Program Interface (API)** Storz et al. provided a scheduling API rather than a single scheduler, so domain dependent schedulers can be created according to the communication purpose of the display. The API makes it easy to create applications that display contents synchronized across multiple displays. Multiple schedulers are prepared and switched in practice. Clinch et al. developed Yarelay player to automatically schedule display content items posted by multiple content providers. Content Descriptor Sets are defined to describe display conditions of the content items. Elhart et al. proposed a scheduling framework that takes into consideration interactive applications as well as concurrently running applications. One feature of the framework is that it is equipped with a sensor management component that makes it possible to change application schedules in response to context and user interaction. The display scheduler operates on a browser. They described the capability and behavior of the application using the notation of scheduling theory.

**Lottery Scheduling.** Mikusz et al. applied the Lottery Scheduling algorithm used in OS resource scheduling to DS. The algorithm makes it possible to efficiently generate a proportional-share fair schedule by allocating lottery tickets to applications and randomly drawing tickets. It is relatively easy to combine multiple scheduling policies.

### 3. Content Adaptation

The term content adaptation refers to the processing of content to adapt to context change in real time. Unlike the scheduling approaches described above, it is
intended to adapt to changes in the context by processing and editing the contents instead of replacing the contents.

**Proxemics.** Greenberg et al.\textsuperscript{32} presented interactive DS with content adaptation according to proxemics, which is deemed to have five dimensions: distance, orientation, movement, identity, and location. Vogel and Balakrishnan\textsuperscript{31} developed “Interactive Public Ambient Displays” with adaptive presentation of content according to the distance between the display and the viewer; specifically, as the viewer approaches the display, personal information incrementally overlays the public information. This idea is also incorporated in commercial DS systems such as the next-generation vending machine\textsuperscript{46},\textsuperscript{95}, shown in Fig. 2. It was first deployed at Shinagawa station in August 2010 and is now installed in more than 200 stations in Japan. Upon automatically detecting a possible user by an infrared sensor, it switches the advertisement message from “remote mode” to “proximity mode”. When a person approaches the front of the vending machine, it recommends some drinks from 34 types of products based on the gender and age group estimated by face recognition technology.

**People Detection and Tracking.** Schönböck\textsuperscript{79} developed MirrorBoard which extracts a region of moving people from the camera image and the region is superimposed on other background images for display as an advertisement at a travel agency. Müller et al.\textsuperscript{54} presented Communiplay, a public display media space that shows the silhouettes of people watching DS; the silhouettes of people in front of not only on-site displays but also remote displays are superimposed. According to their field experiment, the degree of attention is increased by the overlapping silhouettes of remote people. This phenomenon is called the remote honey pot effect.

**Gesture and Facial Expression.** Michalis and Müller\textsuperscript{49} developed MagicalMirror in downtown Berlin; the MagicalMirror system displays mirror images of passers-by on a public display with visual effects in response to gestures of the passers-by. The gesture is detected using background subtraction from the camera image. Exeler et al.\textsuperscript{28} developed eMir, an experimental system that alters the displayed human faces to match the audience’s emotion as recognized from their facial expressions; they showed that this effect promoted viewer interaction.

### 4. Context Sensing and Aggregation

This section outlines research works on context sensing and aggregation related to DS with classification by means of sensors and information sources.

**Sensor.** There are many studies that use sensors, such as Bluetooth, RFID\textsuperscript{18},\textsuperscript{85}, WiFi, and infrared sensor\textsuperscript{48} for context sensing. In particular, many experimental systems employ Bluetooth for audience presence detection\textsuperscript{67},\textsuperscript{74} as it is present in most smartphones. Bluetooth device name is used as a control command for a DS system to retrieve the interest profile of the user\textsuperscript{44}.

There are some approaches that analyze Bluetooth IDs collected at multiple locations instead of one location. Mikusz et al.\textsuperscript{50} proposed viewer-centric physical analytics, which captures the viewer’s experience across multiple displays, e.g., data about how many times and on which display a viewer saw the same content. Müller et al.\textsuperscript{54} constructed a topological model of displays, including travel time between displays and the number of people moving in set directions as attributes.

**Camera.** There are many research and commercial products that use cameras installed on signage displays for recognizing the number of people, gender/age, face orientation, facial expression, gaze, pointing, and so on. Companies such as Intel\textsuperscript{41}, NEC\textsuperscript{62}, OMRON\textsuperscript{66} have commercial software products mainly designed for measuring advertisement effectiveness; they provide functions such as face detection, viewing direction detection, gender and age estimation, smile detection by processing as input video signals from ordinary cameras. VisionKiosk\textsuperscript{70} uses a stereo camera (two cameras) to track a person using color features. By calculating the
distance between the display and the camera, the orientation of a CG face (DECFace) was controlled and presented on the display. Vogel and Balakrishnan\textsuperscript{31} used motion tracking system (MoCAP) to estimate the direction of the body and the distance from the display for proximity based interaction as mentioned in the previous section.

**External Information Sources** Contextual information may come from external sources such as weather and news information providers\textsuperscript{31}. Emergency signals or manually generated triggers in response to some event can also be thought of external sources.

**Multi-Modal Integration.** Gillian et al.\textsuperscript{31} analyzed and integrated data obtained from 100 sensors including RFID, a depth camera, and an RGB camera, to collect the context information of the viewer's presence, location, and identity.

**Framework.** Several frameworks and middleware have been developed for integrating context information and developing context-aware applications. Strohbach and Martin\textsuperscript{46} developed context management framework (CMF) that manages various sensors, such as cameras and RFID, and provides a context access language called CALA. Based on the framework, they developed an interactive display wall for retail stores, and a targeted advertisement distribution application. Satoh\textsuperscript{76} implemented content display and context collection functions in a mobile agent instead of centralized processing to support large-scale context-aware systems. Cardoso and José\textsuperscript{31} presented a framework of context-aware DS by defining the concept of digital footprints as clues for the characterization of context; digital footprints are categorized as follows: presence detection, presence classification, presence identification, presence self-exposure, suggested content, and actionables. It is noted that footprints are not limited to the information from sensors but include interaction logs and information from viewers, e.g., contents posted by users.

5. Future challenges

This section discusses future research challenges to advance networking and the context-awareness capabilities of DS and to make DS more effective as an information medium.

5.1 Supporting User-Generated Contents

As DS networking progresses, DS applications are expected to expand from unidirectional information distribution (broadcast type) to information sharing like social media such as Facebook and twitter, or like community bulletin boards for a local region or organization. Even now, contents for DS operating within universities or companies are not professionally authored but are created by employees in each department. As an example of the advanced projects, José et al. developed Instant Places\textsuperscript{25} which allows ordinary users to post items called “Posters”. Ten displays were experimentally deployed in a university, city hall, school, and library. The content posted by the user consisted of information from football supporters, event announcements, etc.

Trying to incorporate user-generated content into a DS system raises the following challenging issues: a) easy content posting mechanism, b) efficient content moderation, and c) efficient content scheduling.

a) Easy content posting mechanism. In the DS network running under the advertisement model, high quality is required for advertisement contents to keep brand reputation. In the case of user-generated content, on the other hand, it is more important to be able to create content easily and quickly than to maximize quality. Coutinho et al.\textsuperscript{15} analyzed the contents of a long-running DS in a university. There were few fancy contents, simple contents like just images, or some combination of text and images accounted for 60%.

b) Efficient content moderation. Since posted contents must be assumed to be displayed in public or semi-public spaces, manual content moderation is required for deleting contents inappropriate or not suitable for the place. It is important to reduce the cost of moderation and improve the efficiency. Elhart et al.\textsuperscript{25} proposed a post-moderation mechanism that allows for remote or online monitoring of posted contents and the removal of inappropriate content. Content analysis technologies could be applied to facilitate content moderation, as they are used in Web services.

c) Efficient content scheduling. Automated scheduling to reduce the latency from posting to display is needed more than is true in conventional DS systems. The two main reasons are: i) immediate information distribution is required in emergencies, e.g., a lost child or lost items\textsuperscript{17}; and ii) ordinary users are likely expect their contents will be displayed immediately upon posting.

A different scheduling mechanism would be required to deal with user-generated content. The reason is that: i) there are no constraints such as advertisement budget and impression because the business model is different,
ii) the communication goals of ordinary people are diverse, iii) a novel way and metaphor are necessary to allow general users to intuitively specify conditions for content display.

5.2 Attracting Attention without Disturbing Viewers’ Actions

The first step to increasing the effectiveness of DS is to have as many people as possible become aware of the display and its content. Mülêr et al. discussed the “display blindness” effect, in which displays are often ignored if users expect content to be uninteresting (e.g., unappealing advertisements).

Many efforts have been made to raise the attention paid to displays by making DS screens large, high definition, and interactive. In particular, there are many studies on interactive DS, and it has been demonstrated that the number of people paying attention is actually increasing. This is probably due to the fact that the users of interactive applications, a recent innovation, stay longer and trigger the honey pot effect.

Interactive DS is not always effective because: i) there are places where prolonged standing is prohibited; for example, stations, airports, crowded aisles are places for walking, and from the aspect of safety assurance, it is necessary that the contents be easily perused without difficulty while walking, ii) as interactive contents cannot be stopped halfway, there are cases where advertisement contents cannot be displayed on time or the number of times stipulated by the advertisers. In some cases, advertisers dislike this situation.

For the above reasons, I believe that it is necessary to explore mechanisms that convey useful information to viewers without disturbing the viewer’s main actions. The following are examples of possible approaches.

a) Presentation of content considering location characteristics. As is already well-known, the position, size, number of displays, especially the characteristics of place have a big influence on the degree of attention. Huang et al. described knowledge derived from field studies; as an example, to draw viewer’s attention, it is important to install the display at eye level. In Shinagawa station, see Fig. 3, multiple displays are set along the concourse and the content is simultaneously displayed, so that passers-by see the content for a long time while walking. Abeja developed the Fukidam system which recognizes a pedestrian passing through a specific area, and displays information or exclusive advertisements that chase the moving pedestrian. It is said that this has the effect of attracting attention of not only the pedestrian but also the people around them.

b) Content adaptation based on estimates of viewers’ intention. Presenting content useful for the next action could be effective as it does not significantly disturb the current behavior. Taking retail shops as an example, approaches to estimate interest in products have been studied by analyzing the stay time in front of shelves, the direction of gaze, customer behavior such as extending hands towards products and picking up products. In recent years, computer vision-based technologies have been making great progress. Applying these technologies would improve the performance of human behavior recognition. To recognize such shopping behavior, computer-vision techniques such as non-frontal face recognition, crowd analysis, and human pose estimation could be employed. It goes without saying that privacy protection will become more important with advances in the personalization of contents and technologies for recognizing behavior of people. Davies et al. pointed out the problem caused by displaying personalized content on a large screen display. Geiger proposed that the digital signage privacy standard should be based on internationally accepted Fair Information Practices (FIPs).

6. Conclusion

In this paper, we focused on the following two directions of DS development: networking and context-aware DS. Specifically, the outlines of published research were described for automated content scheduling, real-time content adaptation, and context sensing and aggregation. Based on the above survey, some future challenges were discussed, specifically, the support of user generated contents and attracting attention while not disturbing the viewer’s behavior.
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