

Research and Applications in Context Awareness

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In recent years, the phrase “context aware” has frequently appeared as a keyword in informatics-related literature. When understood literally, “context aware” means to “notice context or logical connections.” However, in the IT world, it connotes how “computers perceive future states and changes.”

The intended meaning of “context aware” is detailed in NISTEP's materials¹, but therein, context broadly refers to resource context and user contexts. “Resource context” means the categories and properties of contents, which are information resources, while users' contexts can be further categorized into “user context”—the user's attributes, intentions, and goals—and “situation context”—the environment, location, and time in which the user is placed. When computers understand this information, it creates the potential to develop a variety of services.

Context awareness is likely to be an essential concept in future IT-related services, but as its meaning is somewhat vague, it is unclear what is meant by “context awareness” in the present environment. Therefore, we gathered academic citations related to context awareness, using the bibliographic database operated by the publisher Elsevier. We conducted an analysis of the complete picture of context awareness research and its potential future applications, using a cluster analysis.

The academic citations used for our analysis were articles originally published in English that include “context aware*” (the asterisk indicates a wild card) in their titles, abstracts, or keywords. There were roughly 3,000 relevant articles.

¹ http://www.nistep.go.jp/achiev/ftx/jpn/stfc/stt077j/0708_03_featurearticles/0708fa02/200708_fa02.html

Macro Trends in Context Awareness Research

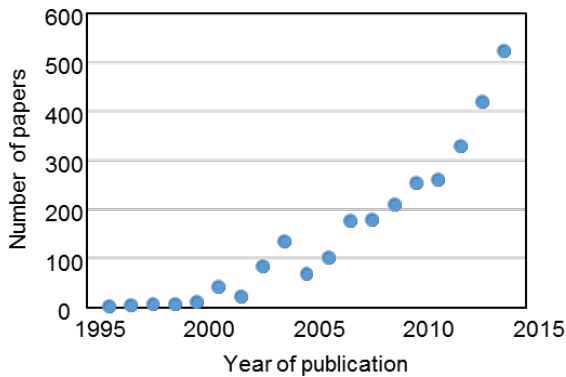


Figure 1 - Number of Context Awareness-Related Articles

Figure 1 shows the number of research papers on context awareness published over time. Academic citations began using the phrase “context aware” in around 2000, followed by a particularly rapid increase in 2007.

Figure 1 shows only peer-reviewed articles, but if we add conference papers, which are more time-sensitive than peer-reviewed articles, then there have been roughly 13,000 reports to date.

Figure 2 shows the number of articles published on context awareness by the key research institutes in each country, while Figure 3 shows the changes in the numbers of articles published in the top four countries and Japan.

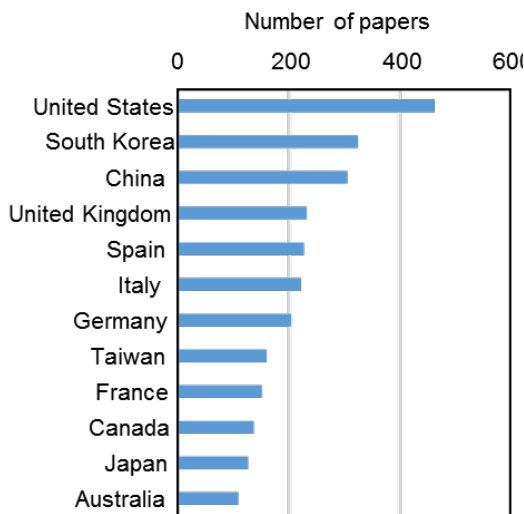


Figure 2 - Key Countries in Context Awareness-Related Research

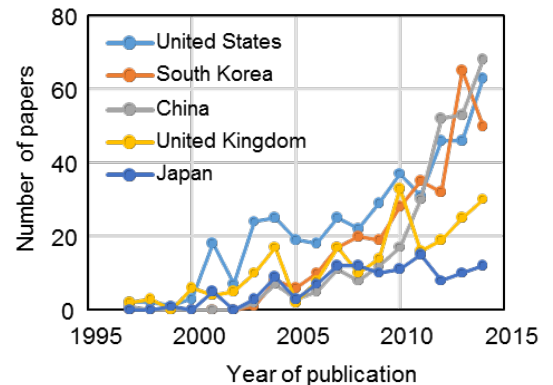


Figure 3 - Numbers of Articles from the Leading Four Countries and Japan

The US has published the most articles cited, followed by South Korea and China. Japan appears in 11th place in terms of the number of articles published, while just in terms of this indicator, it is falling behind not only the West but also South Korea and China. Looked at annually, the US and the UK were first to publish greater numbers of articles than other countries, while South Korea, China, and Japan have been publishing more

articles since 2005. The most remarkable difference in the number of articles published has been since 2007, when the US, South Korea, and China rapidly increased their numbers of articles published, while Japan has seen little growth. The figure shows that the differences in this research field between Japan and the other leading countries stems from the growth in the number of articles among them since 2007.

PANORAMIC VIEW ANALYSIS

Cluster Analysis of Context Awareness-Related Articles

Articles related to context awareness began to surface in around 2000, which was followed by a particularly rapid increase in 2007. So we wondered what the complete picture looked like. In order to elucidate the key research fields and these trends, we conducted a cluster analysis of related academic citation data. We used tf-idf values to evaluate the feature quantity of documents gathered for our cluster analysis, which provides a visualization of this data based on the degree of similarity among documents. We used the titles and abstracts of gathered articles to evaluate their degree of similarity. The results of this analysis are shown in Figure 4. Each blue dot in Figure 4 represents the data from one article.

From the results of our context awareness cluster analysis, we find multiple regions with densities higher than their surroundings. The articles included in these concentrated regions share (multiple) specific terms in their titles or abstracts, exhibiting a commonality in research content. Using these shared specific terms, we assigned names to the concentrated regions, providing an outline of research that is shown in the chart.

Context awareness-related research can be broadly categorized into research related to **hardware, processing, and applied research**. There is considerably more applied research.

Research related to hardware is mostly aggregated in the upper left of the cluster analysis chart, and we find research related to **sensor networks, RFID, and the IoT** in this region. Research related to processing includes topics such as **access controls, service discovery, service selection, and search queries**. Applied research covers a wide range of topics, including **driving behavior and modeling, activity recognition at hospitals and in health care, music selection, robotics applications, augmented reality, learning, and smart homes**.

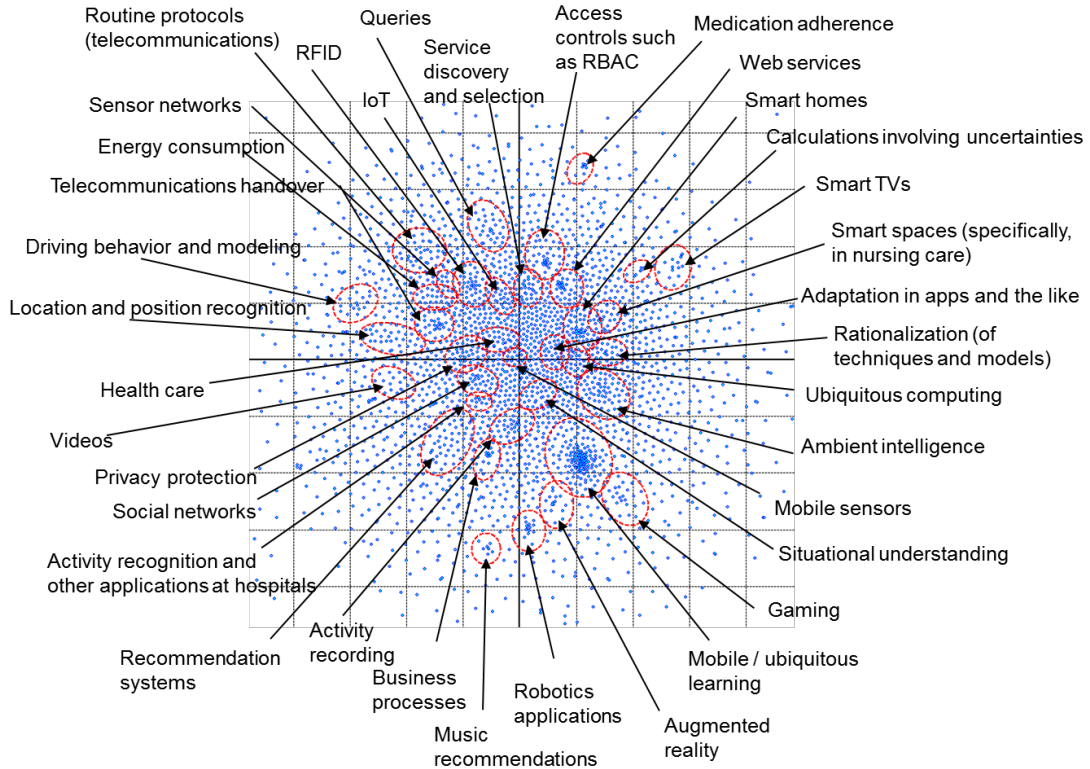


Figure 4 - Cluster Analysis Results for Context Awareness-Related Articles

Macro Research Trends

Research related to context awareness became active in 2000, followed by particularly rapid growth since 2007. We created visualizations of how the research trends have changed during this period—found in Figure 5—using our cluster analysis data.

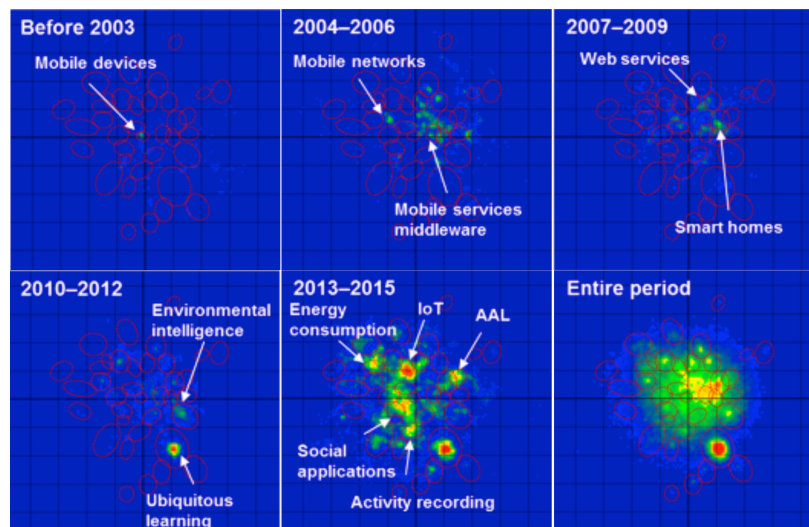


Figure 5 - Changes Over Time in Context Awareness-Related Research

In the research conducted prior to 2003, we find concentrations of research related to mobile devices. Thereafter, research related to mobile services, especially middleware and mobile networks, increased. **The rapid growth in articles since 2007 coincided with the growth in research related to web services and smart homes.** Since 2010, there has been a marked increase in research related to ubiquitous learning and environmental intelligence. **Taiwan leads the world in its research in ubiquitous learning.** Research fields have shown even more diversification since 2013, with a multifaceted expansion into energy consumption, ambient assisted living (AAL), the IoT, and social applications, as well as the previously mentioned ubiquitous learning. From this rapid expansion of research related to context awareness since 2013, we can see a remarkable expansion of mainly applied fields.

Focal Regions for Key Research Countries

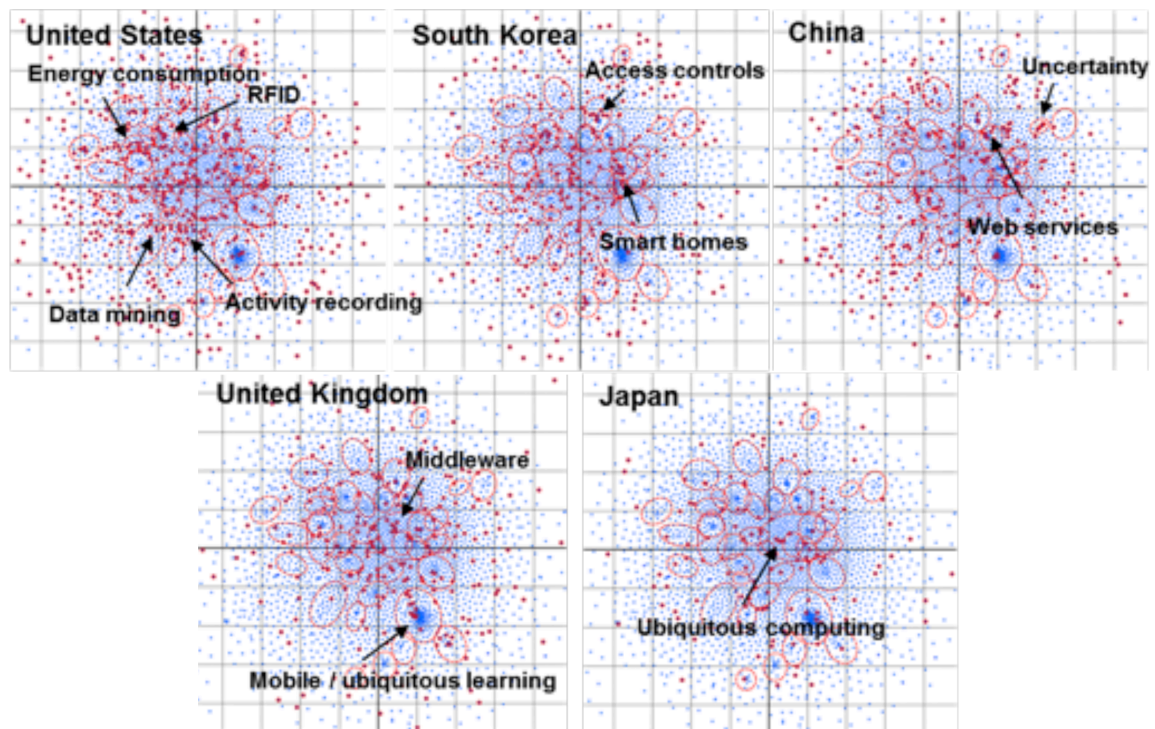


Figure 6 - Research Fields for the Key Countries

Figure 6 shows the focal regions for each of the key countries in context awareness-related research. On the chart, articles in which the relevant countries are included in the authors' affiliated institutions are marked in red. As the chart exhibits, research conducted in each of the countries covers all technology regions. Nevertheless, **the US** publishes most of its articles on topics such as energy consumption, RFID-related research, activity recording, and data mining. **South Korea** offers a high proportion of research on smart homes and access controls; **China**, on web services and computing with uncertainty; and **the UK**, on middleware and mobile / ubiquitous learning.

Participation by Private Companies

As shown in the cluster analysis results, we find much of context awareness-related research focused on applied research. In such an environment, we wondered what research fields private companies were committed to.

Figure 7 shows the research articles that are jointly authored by private companies in red.

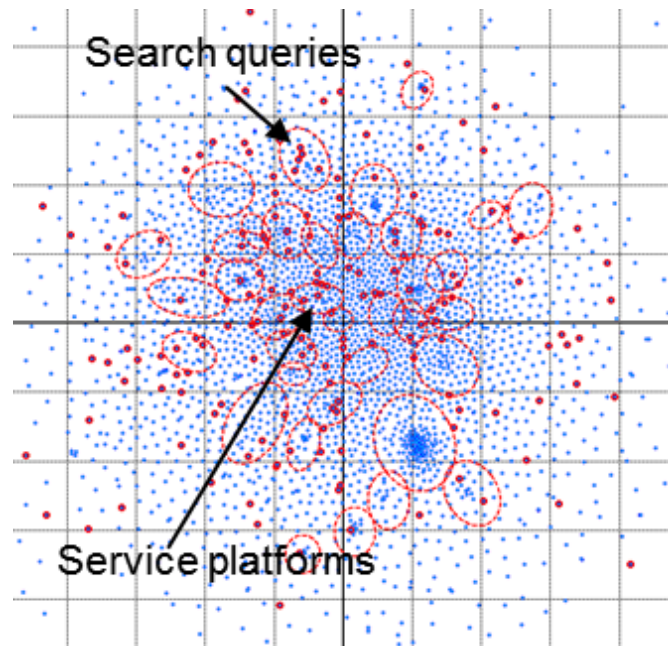


Figure 7 - Participation by Private Companies

There were roughly 180 articles published that were coauthored by private companies, or 6% of the total articles published (approximately 3,000). Research from private companies also exhibits a broad distribution, but when looking at the cluster analysis results, it is clear that a relatively high volume of such research is just above the center of the chart, mostly interested in research related to **topics such as telecommunications and web services**. In contrast, regions in the lower right corner of the analysis results contain few articles coauthored by private companies. Their presence is particularly insignificant in research fields such as mobile / ubiquitous learning, ambient intelligence, augmented reality, and situational understanding. That said, readers should note that the total efforts of private companies are not necessarily revealed through academic citations.

CONCLUSION

We performed a cluster analysis of academic citations related to context awareness and created a panoramic overview of the key research fields and players.

Research related to context awareness has grown at an accelerating rate since 2007, and much of the research and development is based on applied research. Specifically, since 2013, numerous research papers have been published in applied fields deeply related to daily life, such as **energy consumption, social applications, AAL, and activity recording**. Meanwhile, the focal regions by country do not show any major distinguishing characteristics, and it can be said that there are not many articles coauthored by private companies.

Just by looking at the annual trends and the cluster analysis results, we can expect context awareness-related research to become more active in the future. Therefore, it is likely that we will see researchers sift through their results to **find more effective applications and research techniques**. Now, when we are seeing this growth of research, could be a **crucial stage for conducting advanced engineering by accurately understanding which research fields will be active in the future** and, from a business-based perspective, which technologies will be worthy of attention.

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