

## A Survey of Time Series Data Visualization Methods

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**Abstract:** In the era of big data, the general public is more likely to access big data, but they wouldn't like to analyze the data. Therefore, the traditional data visualization with certain professionalism is not easy to be accepted by the general public living in the fast pace. Under this background, a new general visualization method for dynamic time series data emerges as the times require. Time series data visualization organizes abstract and hard-to-understand data into a form that is easily understood by the public. This method integrates data visualization into short videos, which is more in line with the way people get information in modern fast-paced lifestyles. The modular approach also facilitates public participation in production. This paper summarizes the dynamic visualization methods of time series data ranking, studies the relevant literature, shows its value and existing problems, and gives corresponding suggestions and future research prospects.

**Keywords:** Dynamic visualization; historical ranking of time series data; video; big data

### 1 Introduction

In recent years, "big data" has been regarded as the new "oil" [1] in the information age, it has also become a new focus of attention from all walks of life. Data visualization is a visual representation of data. It extracts the intrinsic information of data in a summary form, realizes accurate and effective expression by means of graphical visual expression [2]. Ben Fry pointed out in his book <Visualizing Data> that the creation of information visualization includes seven stages: acquisition, analysis, filtering, mining, presentation, practice and interaction [3]. The most important step in visualization is to select the appropriate type of visualization chart for different input data and different visualization tasks. Different types have a great impact on user perceived data [4]. All kinds of signs show that the world has entered the era of big data [5], and the era of big data visualization is also flourishing.

When "big data" encounters visualization, visualization is endowed with more connotations, and data visualization is refreshed. Gregory called visualization in scientific computing [6] scientific visualization in his masterpiece <Visualization in scientific computing>. Big data visualization analysis [7] aims to use the computer's automated analysis capabilities to fully exploit people's cognitive ability of visual information, organically integrate their respective strengths, use human-computer interactive analysis methods and interactive technologies. Help people understand the information, knowledge and wisdom behind big data more intuitively and efficiently.

The development and maturity of large data visualization technology (2013-2014). The Internet of Things, Visual Analysis, Cloud Computing, Information Technology Processing and Information Visualization in 2013, the Big Data Era, Visual Management, Information Technology, Visual Processing,



Data Acquisition and Visualization Effect in 2014 are all the cornerstones of the development of Big Data Visualization technology. In this stage, big data visualization technology is more abundant, forming a big data visualization analysis technology based on text visual analysis, network visual analysis, spatiotemporal data visual analysis, and multidimensional data visual analysis [8].

Big data visualization application stage (2015-present). According to the search results of Cnki (A Chinese Knowledge Index website), big data visualization technology is more widely used in visual news, libraries, knowledge maps, educational big data and so on. At the same time, this period puts more emphasis on visual design and visualization methods and pursues the development of big data visualization to the direction of intelligence and wisdom. With the advent of the era of big data and the popularity of cloud computing platforms, specialized big data analysis software and network acquisition systems of big data have emerged, such as Google Charts, D3, R language, which can generate various graphs such as network, flow, hierarchy and so on [9-11]. Visualization research tools have also been enriched, such as cave5d, Data Desk for statistical theory and citation researchers, Gephi for network analysis, Tableau, which provides intelligent visualization of data self-help analysis for operators or businessmen, Trendalyzer for vivid display of economic, social and other statistical trends and so on.

The era of big data visualization [12] is becoming the main direction after the information visualization era [13,14]. People are beginning to get more and more contact with and understand big data visualization. The object of big data visualization has also changed from a professional researcher to a general public.

In the wave of big data, the way people get information has also changed “The mass media is no longer exist,” said Bob Leodis, the CEO of the National Association of Advertisers. Prof. Guoming Yu from Renmin University of China further elaborated on this statement: “Fragmentation” is reflected in the field of communication: on the one hand, the market share of traditional media has shrunk, the authority of discourse and communication efficiency has been declining; on the other hand, the prosperity of new media, the proliferation of communication channels, the accumulation of massive information and the diversity of opinions expressed—This is the construction of communication power at this stage facing with the social context [15]. The “individual” who has been marginalized by mass media discourse hegemony will become the real master of the media: They are not only consumers and users, but also active producers, creators and builders—and everyone has the ability and possibility to use the media to publish information [16].

The development of information technology makes it easier to generate and consume data. For example, every minute a video with a length of 72 hours is uploaded to the Youtube server [17]. Short video adapts to the characteristics of mobile social media fragmentation, and also promotes the Internet industry. From the perspective of development process, the emergence of short video originally originated from traditional portals and online video sharing websites. With the rapid development of social networks, short videos have more direct communication advantages, and the number of users has increased significantly [18].

The brilliance of modern mobile internet terminal technology has made media technology return from a remote and high independent technology form to the initial state that everyone can use, publish, communicate and transmit information. The scope and quantity of information transmission are unprecedented [19]. This also means that video has become one of the main ways for people to get information.

Sequential data is a complex type of data, which consists of sequence values or events that change over time. Time is a measure of measurement and a special dimension. When visualizing time series data, the role of time must be specifically considered to establish a direct, visual association with the time axis [20,21]. In <A Task by Data Type Taxonomy for Information Visualizations> [22], Shneiderman regards time as a very important dimension, and he regards time series data as one of the seven basic data types [23]. People analyze time series data over a long-time span, which is conducive to discovering and mastering the law. For example, when the enterprise manager analyzes the production process of the

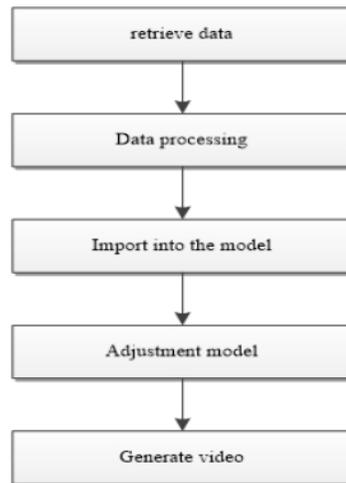
product, it needs to analyze the time series data such as operation data and quality inspection data of the entire production process (the time span can be up to one month or even longer).

There is a better combination of time-axis video and time-series data. It can be found in various video websites that more and more visual videos have appeared in recent years. In Bilibili (A Chinese barrage video website), the total number of visual videos played has already exceeded tens of millions.

In this background, how to combine time series data visualization with video is studied in this paper. This paper studies several current time-series data visualization templates, and introduces the detailed data requirements, usage methods, effects, etc. of each template, and presents the problems at the current stage and gives its development direction.

## 2 General Method of Time Series Data Dynamic Visualization

With the rapid development of digital devices, a large number of images are generated and shared [24]. In online induction, the idea of dynamic histogram comes from Abacaba on Youtube. At present, the number of open source templates for visualization of temporal data ranking is not much, only three. The emergence of these templates greatly reduces the use threshold of such videos and improves production efficiency, making it easier for users without programming experience to produce ranking visualization videos. Usually, the steps of making visual video of temporal data can be summarized as five steps, as shown in Fig. 1.



**Figure 1:** Time series data dynamic visualization

There are various ways to obtain data, which can be crawled through Python or directly obtained from professional data websites. However, different visual templates have different format requirements for data.

### 2.1 Template Based on D3.js

This template is provided by Jannchie, which we can download from <https://github.com/Jannchie/Historical-ranking-data-visualization-based-on-d3.js>. This template is the earliest open source visualization template, and is also a widely used version, based on the D3.js architecture, consisting of three parts: html+js+css.

The HTML part mainly refers to JS and CSS files, while the CSS part sets color classes, various element widths, text edges and coordinate styles. JavaScript is the core of dynamic visualization, which organizes and updates tags. D3 provides a method to bind data by index, enumerates data array, returns data under the corresponding time and binds new data continuously to achieve the effect of dynamic update.

The part of the code:

```

function getCurrentData(date) {
  rate = [];
  currentData = [];  indexList = [];
  data.forEach(element => {
    if (element["date"] == date && parseFloat(element["value"]) != 0) { if
      (element.name.length > config.bar_name_max) {
        tail = "...";
      } else { tail = "";
      }
      element.name = element.name.slice(0,  config.bar_name_max  - 1)  +  tail;
      currentData.push(element);
    }
  });
  rate["MAX_RATE"] = 0;
  rate["MIN_RATE"] = 1;
  currentData.forEach(e => {
    _cName = e.name; lastData.forEach(el =>
    { if (el.name == e.name) {
      rate[e.name] = Number (Number(e.value) - Number(el.value));
    }
  });
  if (rate[e.name] == undefined) { rate[e.name] =
    rate["MIN_RATE"];

  } else if (rate[e.name] < rate["MIN_RATE"]) {
    rate["MIN_RATE"] = rate[e.name];
  }
});
currentData = currentData.slice(0, max_number); dataSort ();
d3. transition ("2")
  . each (redraw)
  . each (change); lastData = currentData;
  The template can read data in CSV format, which is shown in Fig. 2.

```

	A	B	C	D
1	name	type	value	date
2	条目	Chinese	11243	2019/1/1
3	条目	Chinese	11243	2019/1/2
4	条目	Chinese	41243	2019/1/3
5	条目	Chinese	41743	2019/1/4
6	条目	Chinese	41543	2019/1/5
7	エントリ	Japanese	12412	2019/1/1
8	エントリ	Japanese	43343	2019/1/2

Figure 2: Sample data (条目: item)

The “name” appears on the left side of the histogram as the Y axis, while the “type-name” appears on the histogram as additional information. Types are related to the color of the histogram. It is recommended to name Chinese and English characters that do not contain spaces or special symbols. Values bound to the length of a histogram must be integers or floating-point numbers.

This template can be easily customized. With Notepad or other text editors, you can modify some parameters by opening the config. JS file. You can change the maximum number of items displayed at each time point, reverse order, so that the shortest item is at the top, define the value of the field and its corresponding color value, color gradient, define the length and spacing of the coordinate axis, define the thumbnail of each item and other personalized definitions. The top left corner shows the current first name, and the top right corner shows the number of consecutive days in the first place.

Open the bargraph.html file in the SRC folder and select the CSV data file (Sample data) to run. Running result. Let’s use the sample data and run it as shown in Figs. 3–5.

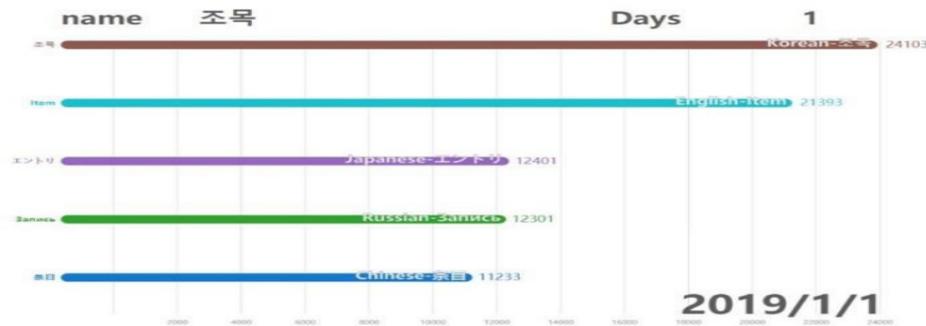


Figure 3: Sample data dynamic visualization-1

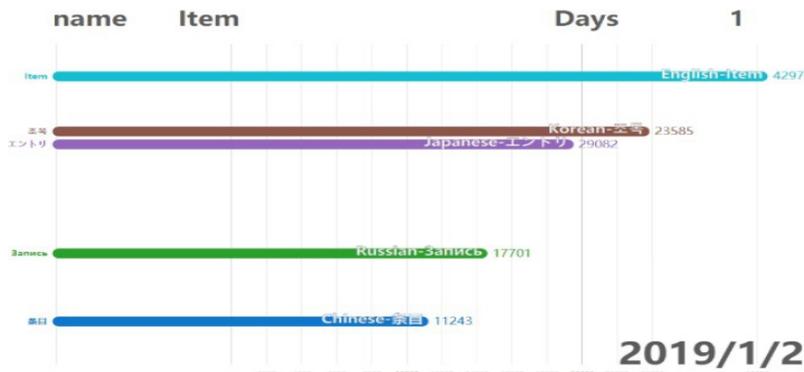


Figure 4: Sample data dynamic visualization-2



**Figure 5:** Sample data dynamic visualization-3 (条目:item)

As can be seen from the graph, the template can achieve the effect of dynamic ranking well, and the X-axis automatically matches the size of the data. The color comparison makes the historical ranking of each data clear at a glance.

## 2.2 Template Based on Pygame

This template is provided by Moying-moe and can be download from [https://github.com/Moying-moe/python\\_ranking\\_Visualization\\_based\\_on\\_pygame](https://github.com/Moying-moe/python_ranking_Visualization_based_on_pygame) download. This project is written by python, based on Section 2.1 data template, which is a python reproduction version of Jannchie visual template. Because of the use of game engine rendering, there may be a carton in the display process.

The requirement for data is consistent with Section 2.1. When reading, date is arranged in a string-based order, so the data source can be disordered. It is recommended to use YYYY-MM-DD format. The compiled EXE file (main.exe) exists in the root directory. Double-click to open it, enter the path of the CSV file or drag the CSV file directly into the root directory, and press Enter to start the output image. The function of the template is less and imperfect, and it cannot output pictures.

The part of the code:

```
store = BarList([])
data_date = sorted(list(data)) # Get ascending date
index = 0
max_index = len(data_date) fadev = 0
lastk = None frame = -1
temp = sorted(data[data_date[0]],key = lambda x: x['value'],reverse=True) lastmaxv =
temp[0]['value']
store.update(data[data_date[0]],lastmaxv) top1 = 0
lasttop1 = "while True:
    for event in pygame.event.get(): if event.type
        == QUIT:
            pygame.quit() sys.exit()
    if index == -1: clock.tick(60)
        continue
```

```

screen.fill(WHITE) frame += 1
if frame == DATE_INTERVAL+1 and index != -1: frame = 0
    index += 1
if frame == 0: # update data top1 += 1
    if index == max_index:
        store.update(data[data_date[max_index-1]],store.data[0].ivalue) else:
        store.update(data[data_date[index]],store.data[0].ivalue)

```

Since the template is reproduced in 2.1, the result is consistent with that in 2.1, which is not demonstrated here.

### 2.3 Template Based on ActionScript

This template is provided by LePtC and can be downloaded from <https://github.com/LePtC/FlashAni>. This is a combination of templates, including stacked columns + graphs, bar graphs + champion bars, bar graphs + particle walks, bar graphs + graphs, and the scenes used are more abundant. This template was created using Flash/Animate, and now the bar chart + champion bar has a compiled version, just need to prepare the data. It greatly reduces the cost of visualization.

The template can read data in csv format, and the data is indexed by date. The format is as shown in Fig. 6.

	A	B	C	D	E	F	G	H
1		1	2	3	4	5	6	7
2	Date	Chrome	Safari	UC Browse	Android	Opera	Nokia	Samsung I
3	2009年1月	0	35.96	0	1.92	24.69	17.78	0
4	2009年2月	0	36.43	0	2.06	23.15	18.25	0
5	2009年3月	0	39.6	0	2.18	21.45	17.95	0
6	2009年4月	0	41.91	0	2.02	21.08	16.77	0
7	2009年5月	0	37.32	0	1.86	24.64	17.9	0
8	2009年6月	0	35.85	0	0.13	25.79	18.49	0
9	2009年7月	0	34.2	0	2.21	24.9	18.71	0.18
10	2009年8月	0	33.91	0	2.28	25.47	18.68	0.69
11	2009年9月	0	31.13	0	2.32	26.49	20.43	0.77
12	2009年10月	0	30.5	0	2.56	26.92	20.84	0.8
13	2009年11月	0	31.56	0	3.31	26.57	19.32	0.86
14	2009年12月	0	32.05	0	4.06	26.39	18.98	0.88
15	2010年1月	0	33.13	0	4.54	25.53	18.53	0.85
16	2010年2月	0	33.92	0.02	5.35	25	16.99	0.9
17	2010年3月	0	30.13	1.23	5.84	26.1	16.45	0.89
18	2010年4月	0	29.39	1.13	6.18	26.14	15.52	0.85
19	2010年5月	0	29.06	1.21	6.3	26.68	14.69	0.78
20	2010年6月	0	26.71	1.16	6.84	25.89	15.98	0.97
21	2010年7月	0	25.87	1.02	8.32	23.55	16.5	0.94
22	2010年8月	0	25.49	0.99	8.95	23.52	16.3	0.95
23	2010年9月	0	22.66	0.9	9.48	24.82	16.77	0.98

**Figure 6:** Mobile browser market share data (年:year 月:month)

The Pic column is linked to the picture, for example, 1 refers to the image named 1.png.

The compiler-free version does not need to install Flash ontology. It prepares the data (and pictures) in the same directory, and then opens the compiled adaptive histogram, .swf file with any SWF player (Flash Player, Potplayer, etc.). The SWF file has been embedded in the whole set of Siyuan boldface fonts, eliminating the need to find font. The template adopts the variable speed algorithm for long-span motion, and the short- distance motion is switched to the uniform motion algorithm to adapt to the jumping data and normal data at the same time. The background reference system shrinks with the maximum value but does not zoom in when the data strip is reduced, so as to accommodate both single-increased data and

increased or decreased data. Various position, size, and speed parameters can be adjusted through the configuration file (config.csv). All code is loaded from the outside ('.as' file), and the source code can be studied without installing Flash/Animate, which greatly reduces the cost of use.

Using an object-oriented approach, update in real time using bubble sorting, tell each object how many i are, and then let each object move to the target at a fixed speed.

The core code shows:

```

var RKmax = RKcon.numChildren-1;
if(t%2==1){ // Update every 2 frames to save calculations
  for(i = RKmax; i >= 0; i--) {
    bar1 = RKcon.getChildAt(i) as rankBar; for(j = i + 1; j
    <= RKmax; j++) {
      var bar2: rankBar = RKcon.getChildAt(j) as rankBar; if(bar1.fan >
      bar2.fan) {
        bar1.rank = RKmax-j;
      }else{ break; } }
      RKcon.setChildIndex(bar1, RKmax-bar1.rank); } }
    bar1 = RKcon.getChildAt(RKmax-int(cfg[75][1]-1)) as rankBar;
    maxr += (Number(cfg[51][0]) / userfunc(bar1.fan, maxfan, cfg[53][0] == "1") - maxr) /
    Number(cfg[7][0]);
    if(Math.abs(maxfan) < Math.abs(bar1.fan)) { maxfan =
      bar1.fan;
    } else {
      maxfan += (bar1.fan - maxfan) * Number(cfg[54][0]); } absmaxr =
      Math.abs(maxr);
  for(i = 0; i < RKcon.numChildren; i++) { bar1 =
    RKcon.getChildAt(i) as rankBar; bar1.rank = RKmax-i;
    bar1.updatey(bar1.rank, absmaxr); //bkggrid.scaleX } for(i = 0; i <
    BKcon.numChildren; i++) {
      bk = BKcon.getChildAt(i) as bkgL;
      bk.updatex(absmaxr); }

```

A single bar chart dynamic ranking cannot know the duration of the first place, so the design of the championship bar is added. Particle Walk + Champion Template runs as shown in Fig. 7 and Fig. 8.

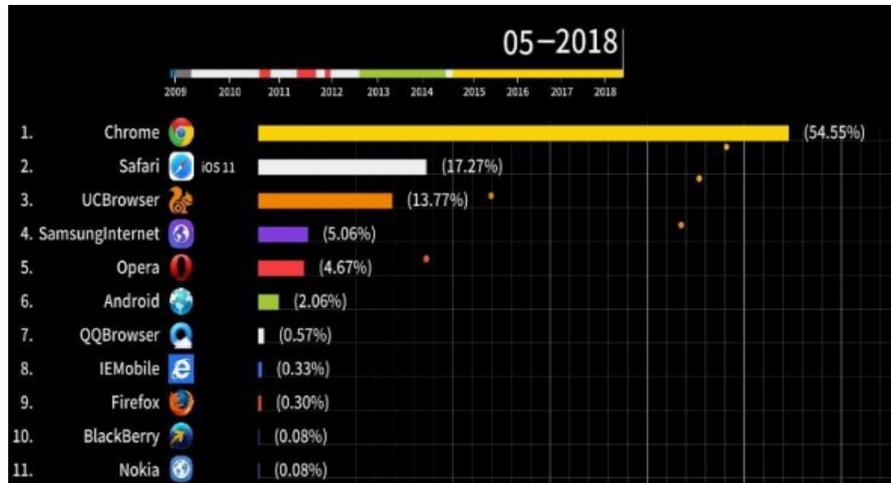


Figure 7: Mobile browser market share dynamic visualization-1

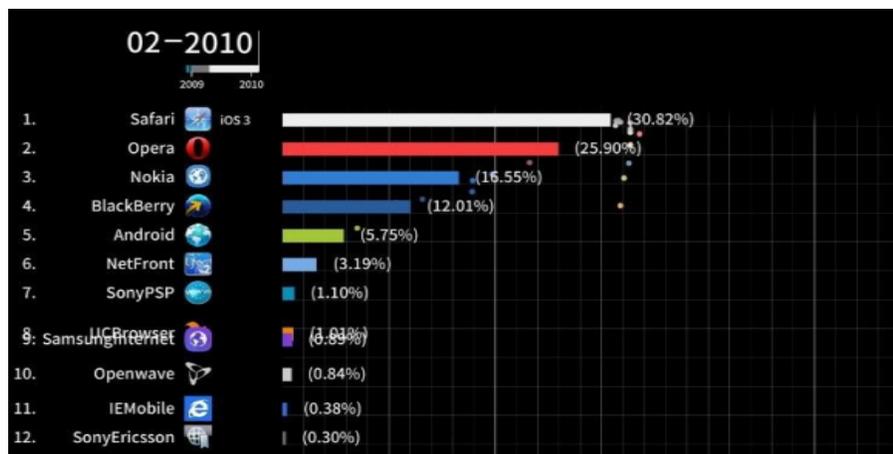
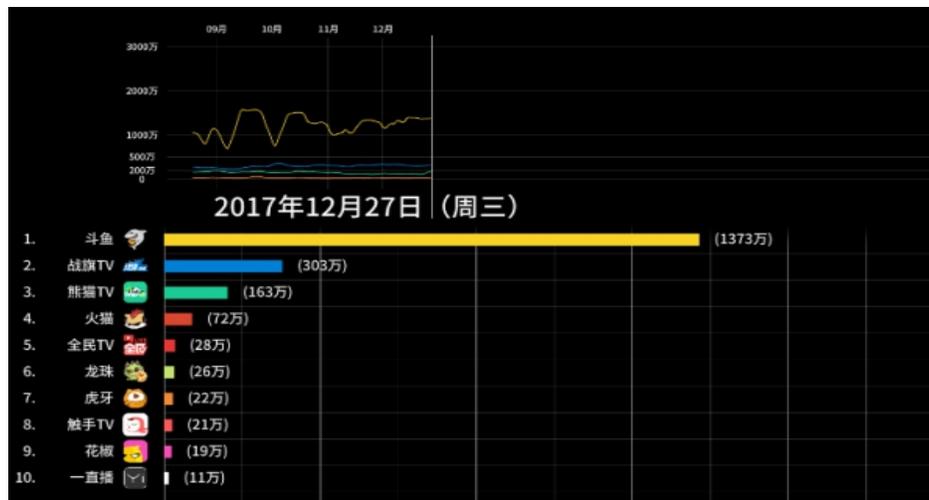


Figure 8: Mobile browser market shares dynamic visualization-2

The data used is the market share of major mobile browsers over the years. Particle migration effect is applicable to the data with mutual increase or decrease. The number of particles represents the number of data increase or decrease, which shows the data increase or decrease more obviously. The top Championship bar shows the duration and distribution of hegemony. It can be clearly seen that Chrome browsers continue to engulf the market share of other browsers and become the dominant market in mid-2014 and continue to this day.

The compiled version currently has more functions, but it needs to download Flash/Animate for compilation, and Sublime for data preprocessing. If you need to change the elements in the template, you need to open the FLA file with the compiler to make code changes.

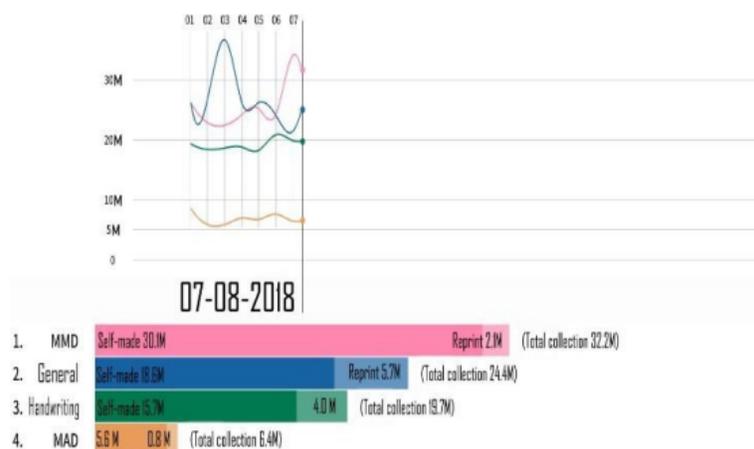
Bar graph cannot show the overall trend of data very well, so the function of polyline graph is added to the template. The effect of bar graph + line graph template is shown in Fig. 9 below.



**Figure 9:** Dynamic Visualization of the Number of Chinese Live Platforms. 年: year; 月: month; 日: day; 周三: wednesday; 斗鱼: Douyu; 战旗 TV: ZhanqiTV; 熊猫 TV: PandaTV; 火猫: Huomao; 全民 TV: QuanminTV; 龙珠: Longzhu; 虎牙: Huya; 手 TV: ChoushouTV; 花椒: Huajiao; 一直播: Yizhibo

The data used is the number of live-streaming platforms in China over the years. The addition of line graphs shows the local change rate and the overall change trend of data. It can be clearly seen from video that Douyu TV has been in an absolute dominant position in all periods, but there has been a huge loss of personnel in some periods, while the number of people on other live-streaming platforms has basically not changed much.

When a data is divided into whole and part, the bar graph cannot meet the demand, and the dynamic stacking column is designed. The template effect of stacked column + curve is shown in Fig. 10.



**Figure 10:** Dynamic visualization of Bilibili animation plate collection

The stacked bar chart takes full advantage of the intuitive and contrasting nature of the bar chart [25], which provides a visual representation of the collection and the overall situation. This template will be very effective when you need to distinguish between parts and the whole. It is natural to see the comparison between the reprinting of each section of the animation area and the self-made, and the proportion of the reprinted in the total collection.

If the data has different states in different periods, we need to refer to the idea of the heat map and bind the color depth of each column to the state to reflect the different states of a certain period. Color change column effect is shown in Fig. 11 and Fig. 12.

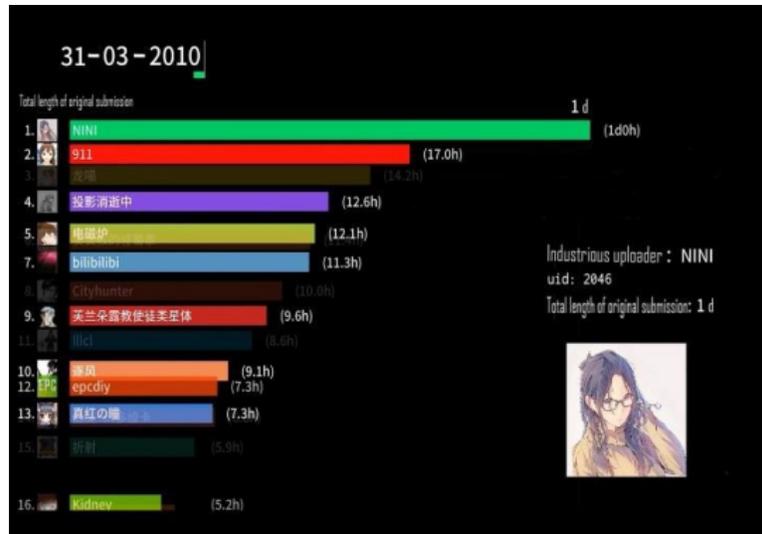


Figure 11: Dynamic visualization of bilibili's video producer's original manuscript total time history ranking-1

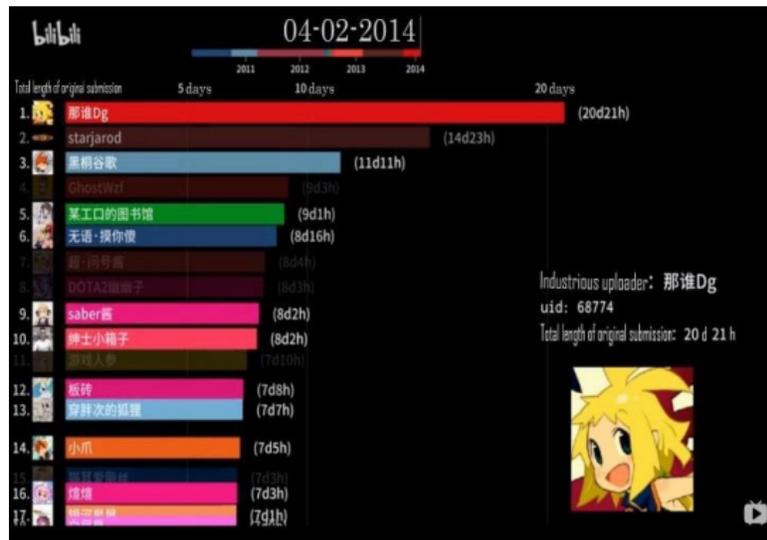


Figure 12: Dynamic visualization of bilibili's video producer's original manuscript total time history ranking-2

In this case, a darker color means that the video author hasn't submitted for a long time, and a new submission will light up. It can be clearly seen the contribution status of the UP masters who are in the top 20 of the total length of the original contribution at that time. The bottom right corner can also automatically introduce the detailed information of the top of the list.

### 3 Summary Outlooks

At the end of the 18th century, there appeared many chart types, such as histogram, time series graph, contour map, scatter plot and so on, which are widely used in time series data processing [26]. The line graph used by William Playfair for the visualization of time series data is considered to be the default choice type for time series data visualization [27]. After all the line segments in the line chart are removed, the line chart becomes a scatter chart. There are a series of data points in the graph which cannot express the local change rate of data, but still show the overall change trend of data [28]. Bar graph is the most common icon type, which is suitable for many types of data. The information expressed by stacked bar

graph and grouped bar graph in bar graph is more intuitive and abundant, especially for discrete time series data. Therefore, bar graph and polyline graph are the preferred graph types for time series data, and dynamic visualization cannot be separated from the basic framework of bar graph and polyline graph.

With the birth of new media, audiences are not satisfied with the form of expressing the deducing results through traditional data and text [29]. The function of visual video is to convey information to the audience. A good visual video can convey more information without boring the viewer. There are many factors influencing a good visual video, such as whether the theme is novel, whether the color matching is eye-catching, whether BGM fits the theme, and so on. These belong to the category of design.

At this stage, the dynamic visualization of time series data ranking has not formed a complete system, and there is no functionally perfect software [30]. There are still many problems in visualization template, such as the lack of personalized customization, the need to master a certain programming language to be more in-depth customization, the data between different templates cannot be universal, and so on. High customizability, data universality, simplified operation and high integration will be the future development direction. People live in the era of big data, which is inseparable from big data. In the future, more and more people will devote themselves to data visualization, and the visual video will be diverse.

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