Analysis on Human-Display Interaction on TV Features of Rotating Display

Newman Lau, Mengru Liu, Kelly Tang, Yun Hei Chak, Trudy Cheung,
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Abstract—**With the development of information technology and human-display interaction (HDI), smart TV is gradually becoming one of the integral segments of daily life. Smart TVs serve as a core part of the smart home and have a wide range of user groups. However, manufacturers cannot fully anticipate their customers to develop a more engaging smart TV experience. Researchers believe that HDI on rotating display related to smart TV features can provide a better home environment for entertainment along with the full-size screen compared to the mobile phone, which can effectively enhance the user interaction with the smart TV and attract the user to engage in the smart life. In this study, quantitative analysis methods are used to analyze user behavior data which were collected by the features of TCL XESS rotating TV A200S and A200PRO. The findings were discussed in various usage factors, including the feature ranking by all users, the frequency of use, and most and least usage. To conclude, the intelligent design approach on HDI and TV features will support the way to suggest user preference in the next phase of smart TV development.**

Index Terms—**Human-display interaction (HDI), smart TV, rotating display, user behavior, intelligent design approach**

I. Introduction

HUMAN-DISPLAY interaction (HDI) has been a vital element of living in an information and communication technology environment since electronic display devices became a viable and cost-effective approach to improve the display experience decades ago. HDI is the research in the design on the use of display technology, which focuses on the interaction between user and screen displays [1]. The development and advancement of information technology have provided an advanced technology platform for home entertainment, as well as opportunities for HDI innovation in the home environment. The smart home is built with electronic devices integrated with the Internet. These devices serve as communication channels using various machine learning techniques to control the digital home and interact with users to perform various tasks [2]. The integration of HDI and electronic display allows the creation and development of a more intelligent home with cognitive intelligence, hence improving the quality of life and creating a more pleasant living environment [3], [4]. Additionally, the global COVID-19 pandemic has created a new stay-at-home norm, which provides additional synergy for the large-scale implementation of HDI (telecom/home screen) [5].

In this paper, we study and analyze HDI through the way human interacts with rotating displays in a home environment, and also the design techniques that allow human to interact with displays in novel ways. Specifically, we propose the novel observation and analysis of data on the effect of HDI-enabled TV features on the engagement of TCL rotating displays in a home environment. The data were collected on TCL rotating displays from the consumer market and analyzed under two different models. The results based on the data analysis and visualization show that TCL XESS rotating TV A200S and A200PRO are beneficial to understand user preferences on the design and development of smart homes with cognitive intelligence to improve the living environment and user engagement. The contributions of this paper address the investigation on the relationship between HDI and rotating displays in relation to specific home TV functions and features in a smart home environment, and finally propose an innovative use of the fusion of HDI and rotating displays to extract key elements of user behavior patterns based on the TV functionality of rotating displays in a home environment.

II. Literature Review

We live in a world where information processing is confined to multiple computing and display devices, it is being an integral part in our daily life and home activities [6]. In such an environment, based on the LED screens and rear projection, consumer marketing has been growing during recent years [7]. Research on the development of display interaction that can be used to identify human activities and

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behaviors has been further developed [8]. For example, human hand gesture can be utilized in smart display interaction to allow users to command a machine to achieve specific tasks, which develops seamless interaction between intelligent devices and users [9].

Researchers have shown an increased interest in exploring the use of multi-modal interaction technologies or applications to provide more intuitive human-display interaction [10], [11]. The emergence of new electronic devices (NED) brings flexible input and output capabilities to existing living environments, such as flexible display, multiple displays, cross-platform display, mobile display and intelligent devices [12]. These applications have been integrated into activities, environments, and products every day. In such an environment, the attraction and distraction of user attention with NED are more complex and affecting life satisfaction to a large extent [13].

Sensor-based, multi-modal, and touchless approach have also been designed as the requirement for remote interaction with screen displays [14]. Take an example, by processing user hand gestures, this paradigm removes physical contact constraints and permits natural interaction with tangible digital information [15]. This kind of touchless interaction can be multi-modal, exploiting the visual, auditory, and olfactory senses [16]. Researchers have explored HDI technologies for pervasive display environments and found that remote interaction with screen displays requires a sensor-based, multi-modal, touchless approach [4]. Similar research proposed the concept of the active display system. The active display system recognizes consumers' presence and location and offers them a clean screen view. The passive infrared sensor detects the people when they step into a region [17]. Emanuel *et al.* [8] build a human action recognition system based on deep learning models. They have tested the prediction accuracy of four classifiers from real-time video and images. The result shows that the comprehension ability of computer image and video can be enhanced by the detection and tracking of human action recognition.

Human-centric technologies such as artificial intelligence (AI), machine learning, application-oriented sensing, and recent advances in the internet of things (IoT) and machine-to-machine (M2M) networks enable a cognitive artificial intelligence experience in smart homes [18]. Unlike traditional smart home solutions that achieve limited interaction from users to indoors appliances, the evolution of smart homes develops on the relation between users and the extensive smart home system [19], [20]. The machine automatically attempts to understand the content based on the video and human behavior tracking without manual inspection [21]. Research findings conclude a number of discussions leading to future possibilities and challenges of a smart home environment [22]. It is also noted that the consumers' immediate surroundings have substantial impacts on satisfying user needs and are a significant challenge [23]. However, we recognize that the relationship between the HDI in rotating display and user experience under the home environment is unclear. Therefore, in this study, we attempt to explore the impact of HDI on rotating home TV displays on user experience. Furthermore, the quantitative analysis method reveals the critical criteria for extracting user behavior patterns based on TV features of rotating display in the home setting.

III. Data and Research Method

In this section, the dataset under two different rotating display models is introduced, followed by a description of the research method in detail. In the rotating display, the Home Screen serves as the point of entry to other features since the Home Screen is always displayed when the screen rotates. Furthermore, a person may watch television more than once a day, a single user can be accounted for multiple times per day.

A. Collection of Consumer TV Data

Data are generated by two different rotating smart screen TV models of the TCL·XESS: A200S and A200PRO, which can automatically rotate the screen by 90° and quickly switch between landscape and portrait. The primary difference between both models is the rounded corners in the display. The data record includes the number of 84,402 participants in China who spend about 36 weeks in a home TV environment. The dataset contains 13 feature applications (Table I) of different categories which are built into the TV.

TABLE I
THE TV FEATURES

1	Home Screen	8	Motion-detecting Shooting Game
2	Movie Streaming	9	Clip Streaming
3	Fitness Coach	10	Live TV "Huashu"
4	Screen and Mobile	11	Daily Briefing
5	Built-in Camera	12	Photo Album
6	Video Call	13	Live TV
7	Videogame Channel		

B. Features of Rotation

The user behavior data are generated by the above 13 different application features. As shown in Table II, Table III, Figure 1 and Figure 2, user behavior data includes the total users, a sum of accumulated rotations, and the average rotation per day are then calculated. Although the data are collected from two different TV models, there is no significant difference between the two sets. Therefore, the final dataset is a combination as a whole collection for analysis.

Certain features were released at different months. Most features started to get tracked from January, 2020, but some features, such as the Built-in Camera (March), the Motion Game (March), or Clips Streaming (June) started at a later date. Due to the different release times of different applications, the application cannot get aligned to the same starting date. To facilitate the data for comparison, a window period is set to 36 weeks. The data are collected from the first and the last 14 weeks within the window period, ensuring that each application is recorded for the same length and period of time.

IV. Result and Discussion

This section discusses the results in terms of the HDI on rotating TV in relation to specific home TV features and analyzes user behavior in order to support an intelligent

TABLE II
THE INITIAL DATASETS RECORDED IN THE FIRST 14 WEEKS

	Features	Total Users	Accumulated Rotation	Average Rotation Per Day
1	Built-in Camera	5376	700411	5.45
2	Huashu Cable	4273	485734	5.15
3	Motion Game	2203	166508	3.26
4	Home Screen	1687	599495	15.90
5	Fitness Coach	1310	149288	10.94
6	Live TV	1045	146627	10.94
7	Screen and Mobile	875	771871	24.55
8	Video Call	361	138194	8.52
9	Photo Album	170	28437	4.77
10	Movies Streaming	108	49867	5.79
11	Daily Briefing	70	6067	1.17
12	Clips Streaming	35	81297	4.86
13	Video Game Channel	16	3974	0.45

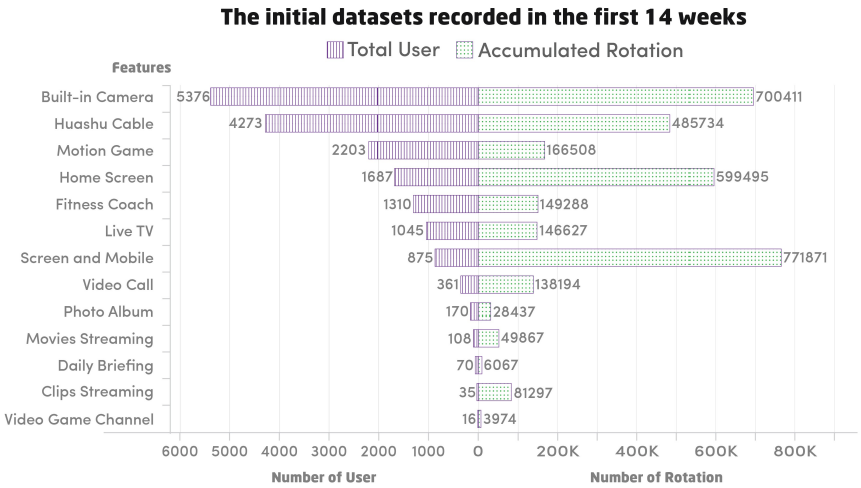

Fig. 1. The initial datasets recorded in the first 14 weeks.

TABLE III
THE INITIAL DATASETS RECORDED IN THE LAST 14 WEEKS

	Features	Total Users	Accumulated Rotation	Average Rotation Per Day
1	Home Screen	74161	42731526	12.67
2	Built-in Camera	36288	7629366	4.95
3	Screen and Mobile	36218	16160874	6.68
4	Motion Game	18151	2237190	2.61
5	Fitness Coach	11041	1132544	1.50
6	Photo Album	7764	3988325	9.61
7	Video Call	4626	2407975	6.53
8	Huashu Cable	4411	485659	5.09
9	Live TV	1230	1065689	1.98
10	Daily Briefing	420	32061	0.84
11	Clips Streaming	35	81297	5.09
12	Movies Streaming	9	136918	0.20
13	Video Game Channel	1	5110	5.09

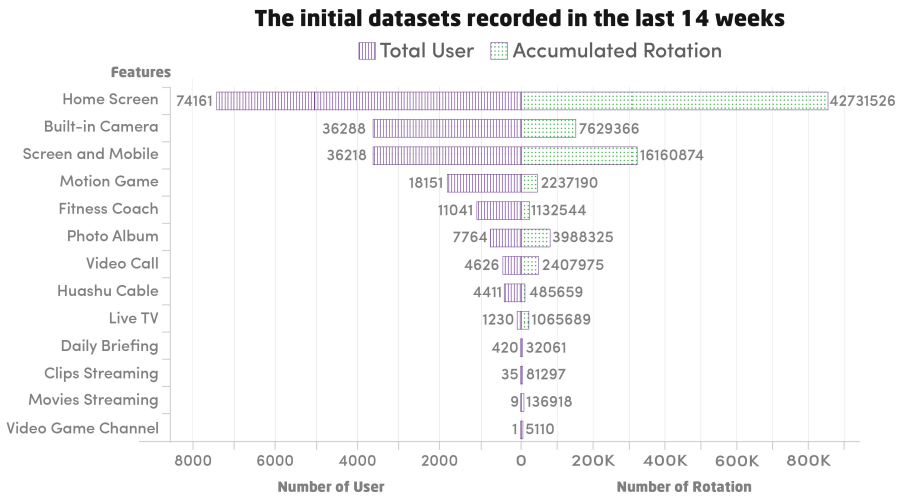

Fig. 2. The initial datasets recorded in the last 14 weeks.

design approach that attempt to satisfy the needs of the smart life for consumers.

A. Features Ranking

As shown in Table IV and Figure 3, the most used features by all users are Screen and Mobile, Built-in Camera, Motion Game, Fitness Coach, and Photo Album, which consists a total of 6790 unique users. The ranking is made based on the percentage of the total number of unique users who have engaged in the usage of the features. The Home Screen is the landing page of the whole application set. Therefore, it composes of all 100% of unique users. On average, about the usage of Home Screen, a user uses vertical functions of the display almost 14 times during the period of the experiment. The most frequently used features are the Screen and Mobile and Built-in Camera, which includes almost 84% and 81% of total users. The design of these two features is based on the usage behavior of mobile phones. The rotating TV has one of the major features in connecting the TV display to the mobile as used for the larger screen to enjoy the usage of mobile phone at home. With the vertical screen format, this larger display gives comfortable and relaxing enjoyment while browsing through the mobile content. The next most frequently used feature is the Motion Game, which has an average of 3.07 rotations per day, covering half of the consumer population. All in all, these five features cover almost half of the unique consumer population.

B. Frequency of Use

Considering the total duration of the tracking period, Table V and Figure 4 show the findings on the feature of rotation,

TABLE IV
HOME SCREEN AND RANKING OF TOP 5 MOST USED FEATURES

	Features	Total Unique Users	Percentage of Total Users	Average Rotation Per Day
1	Home Screen	6790	100.00%	13.89
2	Screen and Mobile	5696	83.89%	14.29
3	Built-in Camera	5495	80.93%	5.19
4	Motion Game	3604	53.08%	3.07
5	Fitness Coach	3601	53.03%	5.83
6	Photo Album	3168	46.66%	8.36

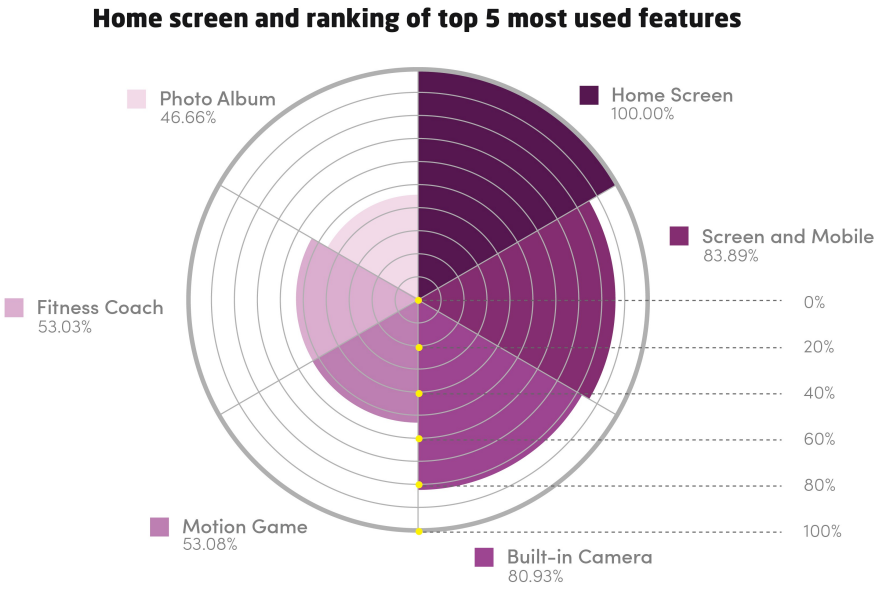

Fig. 3. Home screen and ranking of top 5 most used features.

TABLE V
FREQUENCY OF USE OF FEATURES

	Features	Frequency of Use (in Days)	Frequency of Use (in Weeks)
1	Home Screen	7.15	1.02
2	Built-in Camera	12.10	1.73
3	Screen and Mobile	12.10	1.73
4	Motion Game	17.19	2.46
5	Fitness Coach	25.79	3.68
6	Photo Album	32.67	4.67
7	Video Call	39.20	5.60
8	Huashu Cable	33.79	4.83
9	Live TV	21.78	3.11
10	Daily Briefing	20.42	2.92
11	Movies Streaming	36.30	5.19
12	Clips Streaming	42.61	6.09
13	Video Game Channel	98.00	14.00

based on the Home Screen, is used once every week (7.15 days). The Built-in Camera and the Screen and Mobile are used once every one and a half week (12.10 days), and the Motion Games once every two and a half weeks (17.19 days). The remaining features, such as the Motion Game, the Fitness Coach, the Photo Album, and the Video Call, are used on average once every month (28.7 days). These data reveal that the overall usage rate of these features is low. The low usage rate may also be the result of averaging effect of large customer groups. On the other hand, people may either not aware of these new features, or the benefit of the usage and engagement. Therefore, Smart TV manufacturers still need to explore the promotion and branding of features for increasing the development potential of smart TVs to improve user usage, so that smart TV features can play a significant role in attracting consumers and providing them with a more satisfying and long-lasting HDI experience.

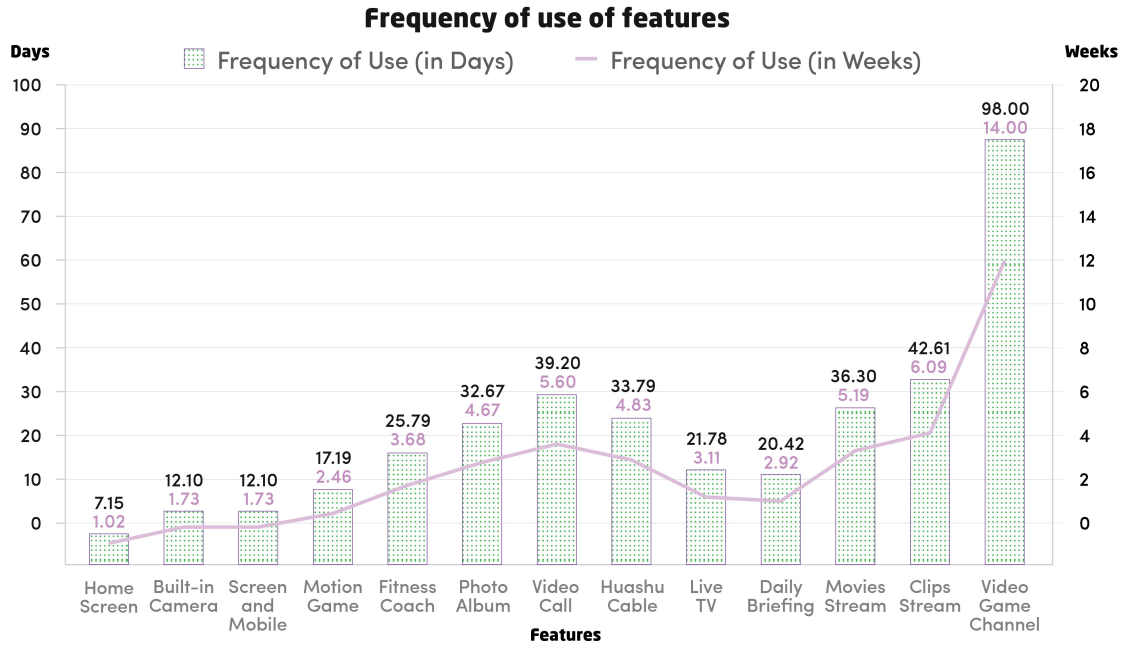

Fig. 4. Frequency of use of features.

TABLE VI
SUMMARY OF THE TOTAL TRACKING DATA OF DAY LEAST USED

	Features	Day of Week	Average Rotation	Average User
1	Home Screen	TUE	14.66	11054
2	Screen and Mobile	MON	39.11	5690
3	Built-in Camera	MON	11.01	5115
4	Motion Game	TUE	2.96	2292
5	Fitness Coach	TUE	3.60	1685
6	Photo Album	MON	7.92	1090
7	Video Call	MON	24.61	751
8	Huashu Cable	MON	7.00	545
9	Live TV	MON	4.29	372
10	Daily Briefing	THU	1.75	65
11	Movies Streaming	SUN	0.46	3
12	Clips Streaming	SAT	3.29	2
13	Video Game Channel	SAT	0.00	0

TABLE VII
SUMMARY OF THE TOTAL TRACKING DATA OF DAY MOST USED

	Features	Day of Week	Average Rotation	Average User
1	Home Screen	SUN	9.74	13365
2	Screen and Mobile	SAT	25.00	6713
3	Built-in Camera	SAT	7.55	6760
4	Motion Game	SAT	2.88	3625
5	Fitness Coach	SAT	6.23	2174
6	Photo Album	SAT	6.77	1466
7	Video Call	THU	18.48	919
8	Huashu Cable	SUN	3.12	749
9	Live TV	FRI	5.09	426
10	Daily Briefing	SAT	0.77	84
11	Movies Streaming	TUE	5.32	33
12	Clips Streaming	TUE	10.58	10
13	Video Game Channel	THU	0.44	5

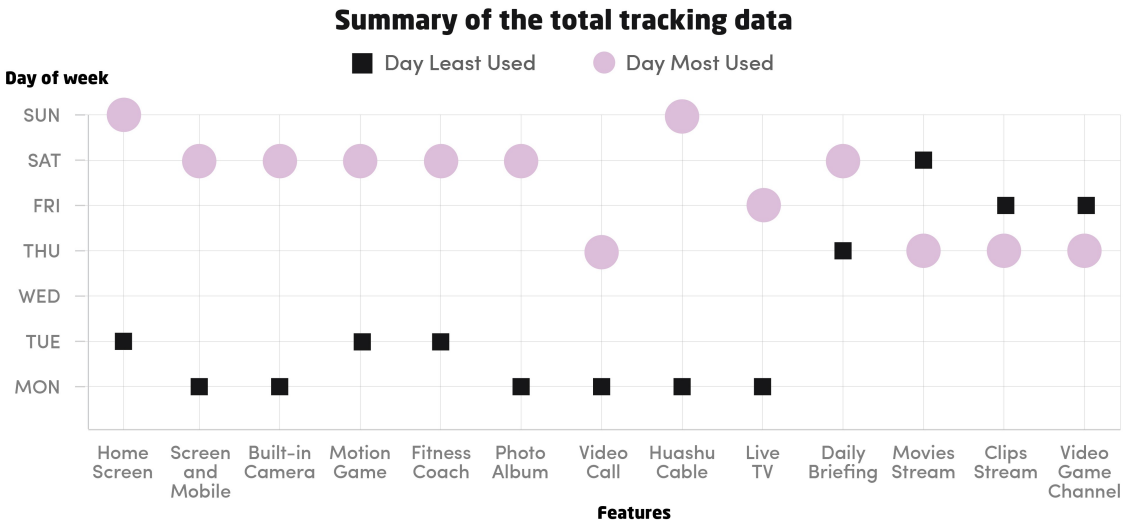

Fig. 5. Summary of the total tracking data.

C. Most and Least Usage

Analyzing the total tracking data from Table VI, Table VII and Figure 5, the most used days for the rotation feature is on Sundays with 13365 average users, while the least used days is on Tuesdays with 11054 average users. Particularly, Saturday is the most used day across these features, while Mondays and Tuesdays are the days with the least number of users for the top 5 features. This shows that people like to enjoy more their smart TV life and explore the rotating or vertical screen display features during the weekends.

D. Intelligence Design Approach on HDI and TV Features

There is a potential in exploring further the technical features offered by the rotating TV. In this case, the challenge is about creating contents that invites the customers to engage more frequently or provide them with features not available in the user's mobile phone. Features, like, Movie Streaming, Clip Streaming and Video Game Channel have a huge share in the consumer market, and however, this phenomenon is not well reflected in the consumer data analysis on the smart TV displays here.

The Motion Capture Game results suggest the potential of motion tracking technology and features in smart TV innovations, or possibly the integration into the natural navigation with the TV display interface.

V. Conclusion

In this paper, the consumer usage data of features based on two TV models contribute to the investigation on the relationship between smart rotating TVs with HDI and user behavior. With the collected data, the research method and analysis model are formulated and achieved in order to understand the key factors of user behavior for smart rotating TVs based on the HDI. The results from the data analysis confirm that smart TV user experience determines user satisfaction and usage intention. Moreover, the data results indicate that the identified factors, such as ranking features, are all distinct and important aspects of the smart TV user experience. These factors contribute significantly to form the overall smart TV user experience. This paper is a quantitative study that formulates from the raw data to examine the user experience and behavioral factors associated with the TCL smart rotating TV. The findings have both practical and theoretical implications for smart TV manufacturers and service providers, as well as for HDI researchers.

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