Understanding the Working Time of Developers in IT Companies in China and the United States

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Abstract—We perform an initial study on the working time of software developers by investigating the timestamps of commit activities in IT companies on GitHub across China and the United States. We identify three temporal patterns shown in commit activities among these companies. We find that Chinese companies are more likely to follow long working hours than American companies. In China, developers in large companies are more likely to work overtime than those in small companies. Developers in Chinese companies tend to work more in regular off-hours during the Chinese New Year than in other dates. We also conduct a survey on the trends of, reasons for and results of overtime work. Our study could provide references for developers to choose workplaces and for companies to make regulations.

Index Terms—developer working time, overtime, IT company, China, United States, GitHub.

1 Introduction

Working overtime is a common social problem in modern life. According to American General Social Survey in 2018, over 27% of employees experienced mandatory overtime work in the United States (http://bit.ly/2lWqcjT). In March 2019, a project called "996ICU" was launched on GitHub (https://github.com/996icu/996.ICU) to debunk the infamous work schedule in some Chinese IT companies, called "996". Employees who follow "996" work schedule work from 9 a.m. to 9 p.m. for six days per week. The exposure of the abnormal working hours on the social media quickly caught the attention of the public and was reported by leading news media around the world (http://bit.ly/2krzJPw, https://cnn.it/2lURsiC, https://bbc.in/2m1f3hq).

The heated discussions represent a pressing demand to better understand work rhythm, which is tightly coupled with people's living conditions. Extended working hours are correlated with adverse health [1]. It would cause sleep disturbances [2], predispose to major depressive episodes [3] and lead to an increased mortality [4]. In the domain of software engineering, it is quite common for developers to switch among multiple activities [5] and software projects [6] over the course of a week.

It is important to analyze the different working time across companies. For developers, understanding the general working time of a company could help them learn about the working culture of that company. For managers and executives in industry, knowing the general working time of their employees could help them set expectations and work conditions to achieve higher work efficiency. However, previous studies [7], [8] related to working time in the software engineering domain were mainly project-based or individual-based, which had a limitation for interpreting working time at organizational level. Furthermore, working time are likely to be influenced by local cultures. There is a lack of investigations on the working time of IT companies across different countries.

This paper aims to fill the gap by studying and comparing the working time of software developers in IT companies from two representative countries, i.e., China and the United States. Our goal is to explore both similarities and differences of working time in modern IT companies through valid data interpretation to reflect on the general IT work conditions and the extended impact such as work productivity and societal pressure.

We crawl and use a real-world dataset of code submissions from a leading online developer community GitHub. We apply a machine learning model to cluster the temporal pattern of code submissions and conduct a comprehensive analysis to investigate the data. Further, we carry out a qualitative survey-based study to better understand developers' working time. The major contributions of this paper are that:

- We design a data-driven approach with machine learning techniques and identify three temporal patterns shown in the commit activities among 86 IT companies on GitHub. We find that Chinese companies are more likely to follow long working hours than American companies.
- We present an empirical analysis on the extent of overtime work in these companies. We find that in China, developers in large companies are more likely to work overtime than those in small companies. Also, developers in Chinese companies tend to work more in regular off-hours during the Chinese New Year than in other dates.
- We conducted a survey on 92 developers to understand the situation of, reasons for and results of working overtime. We find that working overtime is prevalent among developers. People tend to work overtime when there are deadlines or emergencies. Developers who work less frequently on weekends are more likely to believe extra working hours could increase their productivity.

2 Background and Related Work

2.1 Background

During the process of software development, developers use Git, a widely-used open-source distributed version control system, to keep track of their working progress. New code is submitted via Git by making "commit", which records the information of the code submission, including author, local time and the codes to be added or removed. The frequency of commits during a period of time to some extent reflects whether developers are actively working on software projects during the period. The temporal distribution of the commit activities could reflect the circadian and weekly work pattern [7].

Online social networks record rich information of user activities, which can be used for understanding human behaviors [9]. Online developer communities are a special kind of social networks [10], which enable developers and organizations to conduct collaborative development and share code. The commit logs can be retrieved from the online developer communities if the projects are uploaded and made public by the companies. GitHub is a leading online developer community, which has a population of 31 million developers and hosts more than 96 million repositories. Figure 1 shows the temporal distributions of commit activities in three companies collected from GitHub in the form of heatmap. They represent three distinct patterns. Developers in company A work overnight during workdays, and those in Company B may work overtime on weekends besides workday nights, while those in Company C follow the typical working hours.

2.2 Related Work

Researchers explored the factors that may influence people's working time. Beckers et al. [11] proposed that the likelihood of working overtime was influenced by gender, age, job requirements and salary. In addition, the situations of working overtime in some domains were studied. It was reported that American scientists were likely to work at night, while most Chinese scientists worked on weekends [12].

In the sector of software development, Claes et al. [7] investigated the timestamps of commit activities of software projects from three organizations to study developers' working hours. They found that two-thirds of the developers typically worked from 10 a.m. to 6 p.m. and did not work during nights and weekends very often. Eyolfson et al. [8] reported that commits made between 12 a.m. and 4 a.m. were most likely to have bugs.

Although some tangential evidence has been found regarding the working hours of individuals and certain projects in the software engineering domain, there is a lack of investigations on interpreting working time at organizational level and comparing working time of IT companies in different countries. In this paper, we conduct a study to understand and compare the working time of software developers in IT companies from two representative countries, i.e., China and the United States.

3 Research Questions

We aim to study the working time of IT companies in China and the United States. Our study is guided by three motives, which yield five subsequent research questions.

First, we define a company's work rhythm as the pattern of its time allocation for code submissions during the weekdays and weekends, which can be explored from its commit logs [7]. We identify representative work rhythms among IT companies and examine general discrepancies between companies of the two countries in terms of work rhythms.

RQ1 What are the representative work rhythms among IT companies in China and the United States?

RQ2 How do work rhythms of IT companies vary across countries?

Second, we seek a deeper understanding of the degree to which work is performed outside of the commonly expected working hours by considering various groups of companies and different time periods. First, we explore if there is a relationship between overtime work and company size. We set 10,000 employees as the boundary between large companies and small companies according to Fortune (http://bit.ly/2TugpPa) and divide companies into two groups. We test whether there is a difference in the amounts of overtime work of large companies and small companies. In addition, we investigate whether developers would make more commits in regular off-hours during holidays. We target Chinese New Year for Chinese companies and Christmas for American companies.

RQ3 Is there a relationship between overtime work and company size?

RQ4 Is overtime work influenced by holidays?

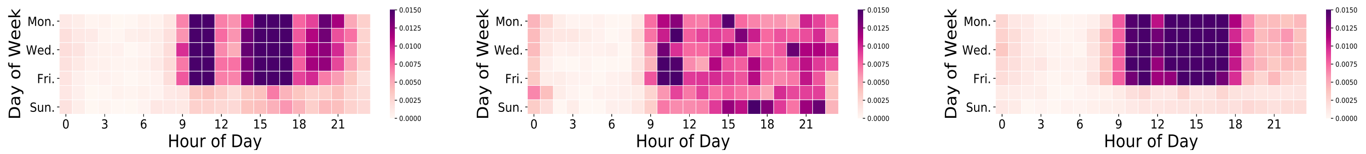
Third, to compensate the results of empirical analysis on the crawled data, we carry out a qualitative survey-based study. We ask developers about the situations of overtime work in their companies and the reasons for working overtime. In addition, to understand the results of overtime work, we ask developers about the frequency of working time on weekends and their perspectives on the productivity during extra working hours.

RQ5 What are the trends of, reasons for and results of working overtime?

4 Empirical Analysis of Work Rhythms of IT Companies

4.1 Data Collection

We used the GitHub API to obtain the commit logs from GitHub. We only collected publicly accessible information. We have consulted GitHub about our work and received their approval for the data collection and analysis in our research. The dataset was collected between May 1 and May 27, 2019, covering the accounts of 101 IT companies and their source repositories on GitHub. They are a combination of Big Techs and Startups in the United States and China. We filter out those commit logs without time zone information and only select companies with at least 30 contributors and 300 commits. Finally, we form our dataset with a total of 86 companies, among which there are 12,041,474 commits from 39 companies in China, and 232,497,720 commits from 47 companies in the United States. We have released the full



(a) Company A (b) Company B (c) Company C

Fig. 1. Temporal distributions of commit activities in three companies. The x axis represents for 24 hours of the day and the y axis represents for seven days of the week. The color bars on the right show the mappings of commit frequency to the darkness of the color. The darker the color of a time slot, the higher commit frequency during the period. Company A is a leading Internet company in China with a history of more than 20 years. Company B is a startup in China which was founded in 2014, maintaining a platform for discovering and sharing technologies. Company C is an American company offering business and employment-oriented services that operates via websites and mobile apps.

list of companies and the repositories in our dataset in the following URL: http://bit.ly/2Tj4NQa.

Notice that our dataset only includes public open source projects on GitHub, which may only reveal the publicly visible work activities. Besides, we can only analyze the commit activities with the dataset which might not reveal the exact working hours since there are other work-related activities such as meeting and project planning. Still, the time distribution of commits could be an important indicator for the working hours.

4.2 Representative Work Rhythms of IT Companies

4.2.1 RQ1: What are the representative work rhythms of IT companies in China and the U.S.?

In order to identify work rhythms of companies, we calculate the commit frequencies in different time periods and use clustering algorithms to analyze the data. For each company, we compute the ratio of the commits in each hour on weekdays to all commits on weekdays. We do the same calculation for weekends. Following the calculations, we get the 24-dimensional vectors for weekdays and weekends respectively, with each element representing the average commit frequency in one of the 24 hours. We concatenate the two vectors as a 48-dimensional vector. Then we apply k-means, a classical clustering algorithm to discover the representative work rhythms.

To select the number of clusters k, we iterate k from 2 to 8 using k-means and evaluate the clustering effects with silhouette analysis. A higher silhouette coefficient score indicates better defined clusters. When $k = 3$, the silhouette coefficient score is the highest. In addition to silhouette analysis, we observe the sizes of the clusters and visualize patterns of each k. We find that when there are more than three clusters, the new clusters have very few individuals and don't show distinct patterns other than time shifting. We choose $k = 3$ based on the results.

Figure 2a and Figure 2b show the average commit frequency of the detected patterns during each hour of the day on weekdays and weekends. The characteristics of each pattern are summarized as follows:

Pattern #1: These companies endure longer working hours on weekdays than those with the other two patterns.

Pattern #2: These companies follow typical working hours (9 a.m. to 6 p.m.) on weekdays. Developers in these companies make more code submissions on weekends than developers in the other two patterns.

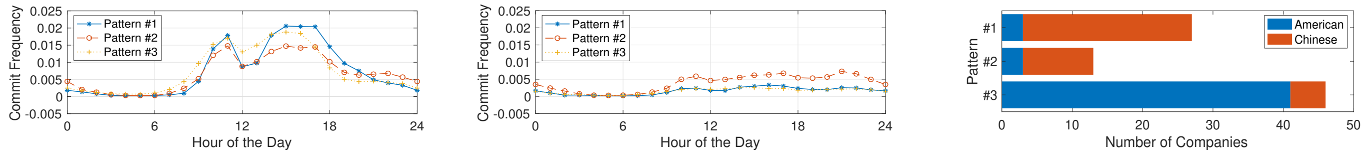
Pattern #3: These companies follow typical working hours on weekdays, from 9 a.m. to 6 p.m.. Developers in these companies rarely submit code changes on weekends.

4.2.2 RQ2: How do work rhythms of IT companies vary across countries?

The number of companies from China and the United States with each pattern is shown in Figure 2c. Patterns #1 and #2 are more prevalent among Chinese companies, while American companies mainly follow pattern #3. To statistically validate the observation, we apply the Fisher's exact test. For each pattern p_i, we assume the null hypothesis H_0 is that Chinese and American companies are equally likely to follow p_i. Since we test three hypotheses simultaneously, we apply Bonferroni correction to limit the family-wise error rate. The significance level is 0.0167, which equals to 0.05 divided by the number of hypotheses. If the p-value is under 0.0167, we could conclude that Chinese companies and American companies are significantly different in terms of pattern p_i. We also report the odds ratio (OR). The distance from 1 of an OR indicates the magnitude of the effect size. An OR greater than 1 indicates that Chinese companies are more likely to follow p_i than American companies; an OR less than 1 indicates that American companies are more likely to follow p_i than Chinese companies. The results indicate that companies in the two countries are significantly different in these three patterns (pattern #1: p-value = 2.706×10^{-8}, OR = 23.47, pattern #2: p-value = 0.0166, OR = 5.06, pattern #3: p-value: 1.359×10^{-12}, OR = 0.02).

4.3 Insights of Working Overtime in IT companies

To investigate the amount of overtime work, first we need to determine working hours of the companies. We follow Claes et al.'s method [7]. Companies are assumed to follow an eight-hour work schedule on work days. For each company, we locate which eight-hour slot has the largest number of commits in a day. Given the timestamps of commit activities of a company, for each starting time t, we compute the number of commits made between t and $t + 8$ hours. We select the interval with the highest number of cumulative commits as the working hours of the considered company. Since companies may change their working hours over time, we restrict the time of commits from 2018 to 2019 to reflect the recent work status of developers in these companies. Still, we remove companies with fewer than 30 contributors or 300 commits. Finally, we get a dataset with 25 companies in China and 39 companies in the United States.



(a) On Weekdays (b) On Weekends (c) Number of Companies in Each Pattern

Fig. 2. Clustering Result. (a) and (b) show the average commit frequency of each detected pattern during each hour of the day on weekdays and weekends. (c) describes the number of companies in each pattern.

4.3.1 *RQ3: Is there a relationship between overtime work and company size?*

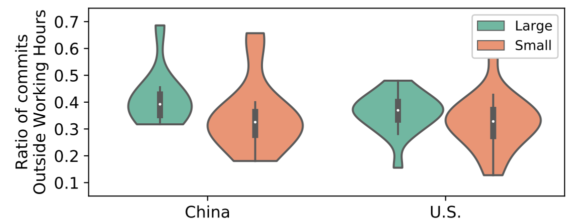
We set 10,000 employees as the boundary between large companies and small companies. For each company, we calculate the ratio of commits outside working hours over commits in total. Figure 3a shows the aggregated results in violin plots. To statistically validate whether large companies have significantly different amount of overtime work than small companies, we performed Mann–Whitney U test. The results of Mann–Whitney U tests are measured by p-values. The significance level is 0.05. We report Cliff's delta (d) for effect size. d ranges from -1 to 1. If d is greater (less) than 0, it quantifies how often the numbers of overtime commits in large companies are higher (lower) than those in small companies. In China, large companies have more overtime commits than small companies (p-value = 0.028, d = 0.53). In the United States, we do not detect significant difference in the amount of overtime commits between large companies and small companies (p-value >0.05).

Since there are more employees in large companies, they may set more comprehensive regulations and standardized workflows than small companies to better manage their employees. On one hand, the regulations for holiday arrangements and benefits for the overtime work may increase employees' willingness to working overtime. On the other hand, due to the standardized workflows, peripheral work of programming, such as waiting for approval or communicating with colleagues in different departments, may take up much time during working hours, so that developers might have to work on their projects after working hours.

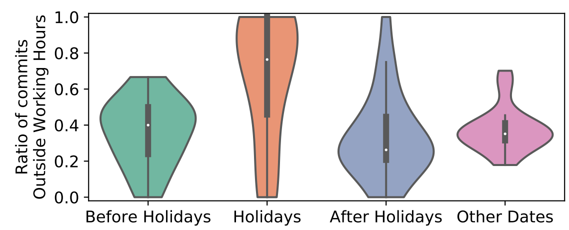
4.3.2 *RQ4: Is overtime work influenced by holidays?*

We compare the overtime commits in four types of time period: before holidays, during holidays, after holidays and other dates. For each type of time period, we only consider those companies which have made at least three commits during that period. The results of Chinese companies and American companies are shown in Figure 3b and Figure 3c respectively. We perform Mann–Whitney U test to validate whether there is a significant difference in the amounts of commits in regular off-hours between before/during/after the holidays and other dates in each country. We apply Bonferroni correction and set the significance level as 0.0167. We also report Cliff's delta (d). d measures how often the numbers of overtime commits during a specific period of time are higher or lower than those during other dates. In Chinese companies, developers work more in regular off-hours during the Chinese New Year than in other dates. (p-value = 0.0044, d = 0.53). We do not detect significant difference in the amounts of overtime commits between the week before or after holidays and other dates (p-value >0.0167). In American companies, we do not detect significant difference in the four types of time periods (p-values >0.0167).

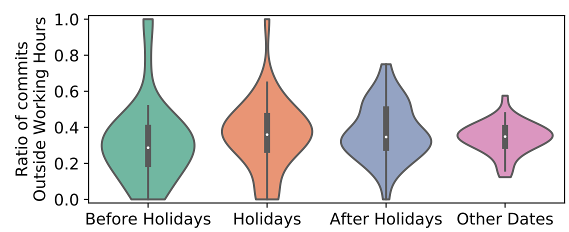
One possible reason is that, during the day time on holidays, people are likely to take part in various activities outside home such as visiting friends, so that they might have to work after they come back home.



(a) The ratio of commits outside working hours over commits in total in large companies and small companies in China and the United States. We set 10,000 employees as the boundary between large companies and small companies.



(b) The ratio of commits outside working hour made by developers in Chinese IT companies before, during and after the Chinese New Year compared with all dates



(c) The ratio of commits outside working hour made by developers in American IT companies before, during and after the Christmas compared with all dates

Fig. 3. The degree to which work is performed outside of the commonly expected working hours. There is a rotated kernel density plot on each side, which shows the distribution of the data. The black bar in the middle represents the quartile range, the extended line represents the 95% confidence interval, and the white point represents the median.

5 Survey Study on Overtime Work

We design a survey study to tackle RQ5 "What are the trends of, reasons for and results of working overtime?". We ask developers about how they and their colleagues are experiencing overtime work; what makes them work overtime; how they think of the productivity during extra working hours. The survey includes multiple-choice and Likert scale questions. Our survey was reviewed and approved by the Research Department of Fudan University. Before releasing the survey, we first conducted a pilot test with seven developers from different companies to fill in the questionnaire, then interviewed them for comments on the survey. We modified the questionnaire according to their feedbacks and then published the survey online. We first sent out surveys to ten developers from selected IT companies (including Big Techs and Startups in China and the United States in our dataset) and then asked them to pass along survey link to other developers. Our online survey has 1516 views and we receive 92 responses. Except for two participants who want to keep their company information confidential, 52 are from Chinese companies and 38 are from American companies.

5.1 Self-reported Experience of Working Overtime

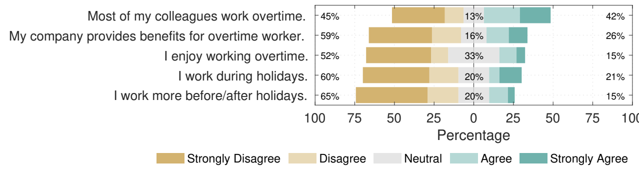
To understand developers' experiences on overtime work, we raise five statements and ask participants how the statements fit with their situations in the form of 5-Likert scale question. For each statement, participants could choose one of the five options among "strongly disagree", "disagree", "neutral", "agree", "strongly agree". We plot a bar chart for the Likert scales as shown in Figure 4a. We find that working overtime is prevalent among developers. Most developers do not enjoy working overtime.

5.2 Reasons for Working Overtime

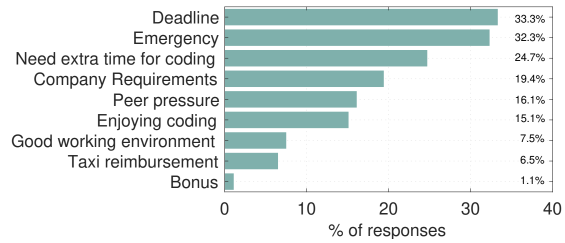
To understand the reasons for working overtime, we set a multiple-choice question and list nine common reasons for extra working hours as options according to the pilot test. Participants could choose one or more options. The responses are shown in Figure 4b. The most common reason for overtime work is the approaching deadlines. The least three voted reasons: "good working environment", "taxi reimbursement" and "bonus" indicate that providing incentives are not that effective to encourage developers to work overtime.

5.3 Extent of Overtime Work on Weekends and Relationship with Productivity

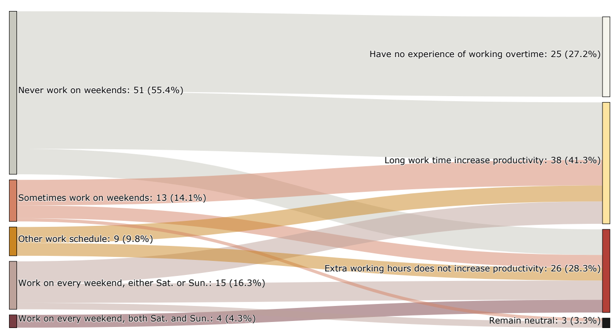
We set a multiple-choice question about the frequency of working overtime on weekends. We ask participants to choose one option among "never work on weekends", "sometimes work on weekends", "work on either Saturday or Sunday every weekend", "work on both Saturday or Sunday every weekend" or "other work schedules". We set another multiple-choice question about whether extra working hours increase productivity. Participants could choose one option among "agree", "disagree", "stay neutral" or "have no experience of working overtime".



(a) Developers' self-reported experience of working overtime. The numbers on the right are the percentage of respondents who agree or strongly agree with the statements. The numbers on the left are the percentage of respondents who disagree or strongly disagree with the statements. The numbers in the middle are the percentage of respondents who stay neutral.



(b) Reasons for working overtime. The numbers on the right are the percentage of respondents who choose the reasons.



(c) The frequency of working overtime on weekends and developers' perspectives on whether extra working hours increase productivity. The number and percentage of respondents who agree with each statement are displayed next to the label.

Fig. 4. Results of the qualitative survey

We cross check the frequency of overtime work on weekends and their perspectives on the productivity of extra working hours. We plot a Sankey diagram as shown in Figure 4c to display the responses. All four people (100%) who work on both Saturday and Sunday every week think extra working hours do not increase productivity. Among the 15 people who work on either Saturday or Sunday during weekend, there are seven (46.67%) support extra working hours increase productivity, six (40%) support the opposite, and two (13.33%) stay neutral. Among the 13 people who sometimes work on weekends, eight (61.54%) think extra working hours increase productivity, while four (30.77%) believe extra working hours do not increase productivity, and one (7.69%) stay neutral. Among the 26 people who never work on weekends (but they work overtime on weekdays), 18 (69.23%) believe extra working hours increase productivity, while eight (30.77%) believe they do not.

Weekend recovery is helpful for improving work performance in the weekdays [13]. Too much work occupied in weekends may cause fatigue and decrease productivity.

6 Conclusion and Future Work

In this paper, we cross check the working time of developers at IT companies in China and the United States. We identify three representative work patterns in our dataset and find significant differences in companies in the two countries. The findings indicate that Chinese companies are more likely to follow longer working hours, which affirmatively acknowledge the "996" phenomenon in Chinese IT industry. Our results show that in China, developers in large companies are more likely to work overtime than those in small companies; developers tend to work more in regular off-hours during the Chinese New Year than in other dates. Further, according to the results of our survey, working overtime is prevalent among developers; the most common reason for overtime work is the approaching deadlines; developers who work less frequently on weekends are more likely to believe extra working hours could increase their productivity. We provide suggestions for both developers and managers. For developers, we suggest that they should be aware of the difference in work time culture between Chinese companies and American companies or large companies and small companies in China when choosing workplaces. For managers and executives, we suggest that if their employees are experiencing overtime work, they should ensure that their employees have adequate rests on weekends.

Acknowledgement

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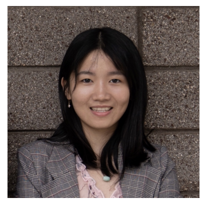

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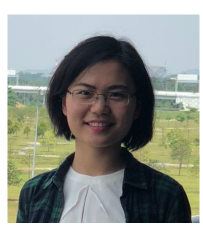

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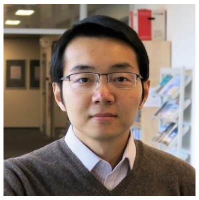

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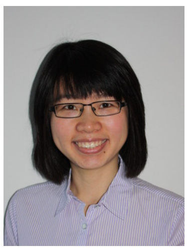

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