Measuring Code Review in the Linux Kernel
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Introduction
Overview of Linux Kernel Development Process

- A patch is submitted to a relevant mailing list
- Patch is reviewed and integrated into associated git repository by the respective maintainer
- Commit is pulled from maintainer’s integration tree and included in the main repository
- The potential problems about the patch is discovered through integration
The focus for the thesis is the review that happens in the second step of the process. The aim is to measure the review and determine the factors contributing to it. The number of review emails is selected to be the central measure, self-responses are excluded.

Distribution of Number of Responses over Patches
Research Questions

- On patch authors:
  - Does the number of responses increase as the patch developer is more experienced?
  - Do maintainers get fewer or more responses than others, when they author a patch?
  - Do patch developers who have previously been active in some areas of the kernel get more responses than developers who have been active in other areas?

- On characteristics of the patches themselves:
  - Does the number of responses increase or decrease with the number of files a patch proposes to change?
  - Does the number of responses increase or decrease with the number of maintainer sections to which changed files belong to?
  - Does a patch get more responses if it is submitted to more mailing lists?
  - Do some mailing lists or maintainer sections lead to larger numbers of responses than others?
Topics

- Introduction
- Authoring Activity:
  - One Time Committers
- Maintainers
- Patches
- Bots
Authoring Activity
Many of the authors are relatively new in the kernel community. Having been in the community for a longer period of time shows no relation to the number of responses one’s patch receives.
Authoring Activity: Active Months
An alternative measure for developer experience is the number of commits authored. Again, no clear positive relation to number of responses is seen. The histogram shows that one time committers to the kernel make up a large portion of the authors.
Authoring Activity: Commits
• Intel has 34.38% of its developers in the kernel having less than 2 active months.
• 76% Red Hat developers in the kernel has larger than 1 active months, 59% has larger that 24 months.
One Time Committers
One Time Committers’ Popular Sections
One Time Committers: Most Popular Files

Files most frequently changed by one time commit authors

drivers/usb/serial/pl2303.h
drivers/media/video/saa7134/saa7134.h
drivers/usb/serial/pl2303.c
drivers/hid/hidconfig
drivers/usb/serial/pl2303x.c
drivers/media/video/sdc/sdc.x.c
drivers/media/video/sdc/sdc.c
Documentation/video4linux/CARDUST/saa7134
drivers/staging/io/magnetometer/hmc5943.c
drivers/usb/serial/ftdi_sio.h
drivers/hid/hidhidhid_hid-quikks.c
drivers/bluetooth/bluetooth.c
MAINTAINERS
drivers/usb/serial/ftdi_sio.ids.h
sound/pci/hda/hda_patch_realtek.c
drivers/usb/storage/ftdi_unusual_devs.c
drivers/usb/serial/option.c
drivers/media/video/saa7134/saa7134-cards.c
drivers/hid/hid-core.c
drivers/usb/serial/ftdi_sio.c
drivers/hid/hid-ids.h
Maintainers: Authoring and Responses

- Maintainers make up 11.22% of the authors
- Maintainers received a larger portion of the responses than the portion of their authoring activity
• 13.81% percent of patches in linux-kernel@vger.kernel.org authored by maintainers
• The highest percentage of maintainer patches in the list is 25.98% seen on kvm@vger.kernel.org
• The lowest percentage of maintainer patches is 0% seen on 30 mailing lists.
• Among all of these top 20 most active lists, average percentage of maintainer patches is 16.69%
Average Number of Responses per Patch

- The histograms show distributions of average number of responses received per patch by maintainers and by others.
- The distributions for neither maintainers nor others are normal.
- Non-parametric rank sum test is be conducted to check the difference between maintainers and others.
- The Mann-Whitney test rejected the null hypothesis with a 95% confidence.
- There is enough evidence to reject that maintainers get the same average number of responses per patch.

\[ H_0 : \mu_{\text{maintainers}} = \mu_{\text{others}} \quad H_A : \mu_{\text{maintainers}} > \mu_{\text{others}} \]
Maintainer Activity Across Sections

[Bar chart showing the number of upstream commits for different sections.]
Patches
• Many patches change fewer files, only one in most cases
• While there are outliers, the number of files does not have a linear relation with the number of responses
Patches: Number of Files
• Next, whether sending a patch to more mailing lists result in more responses is inspected.
• No relation between overall number of mailing lists and the number of responses is seen.
• What if we look at the effect of individual mailing lists instead of the total number of mailing lists?
Patches: Number of Mailing Lists
• 96.11% of all the emails that were sent to the leading list qemu-devel@nongnu.org were only sent to qemu-devel@nongnu.org.

• 45.48% of all the patches were submitted to linux-kernel@vger.kernel.org 15.16% of them were submitted only here.
The graph shows the average number of responses per patch for each of the mailing lists.

The overall average number of responses per patch is 1.3.

Patch itself is counted as one response.

Highest average is 3.67 on workflows@vger.kernel.org
The positive correlation heatmap of mailing lists are shown in the graph.

A correlation of 1 would indicate that patches are always sent to the corresponding two mailing lists together.
Correlations of selected mailing lists are shown in the graph.

Some mailing lists are observed to be paired together frequently:
- linux-arm-kernel@lists.infradead.org and devicetree@vger.kernel.org lists have 0.37 correlation.
As patches can be sent to multiple mailing lists, measuring the effects of individual mailing lists on the number of responses becomes a challenge.

New approach: Cluster patches together according to the mailing lists they have been sent to, measure the effects of being in a cluster on the number of responses.

Most defining mailing lists are selected with a variance threshold and used for clustering.
Using the selected mailing lists, we form 32 clusters of patches.

Each cluster has its characteristics in terms of frequent mailing lists patches were sent to.
The graph shows the average number of responses a patch receive for each of the clusters.

The overall average is marked by the red line.

The Kruskal-Wallis test rejects the hypothesis of equal means across clusters with 95% significance.

\[ H_0 : \mu_i = \mu_j \ \forall \ i, j \in [0, 31] \quad H_A : \mu_i \neq \mu_j \ \exists i, j \in [0, 31] \]
Bots

Percentage of bot emails

- Other: 92.04%
- Bot: 7.96%
Bots: Activity Over Time
Bots: Most Active Bots

- The patchwork bot has sent all emails to intel-gfx@lists.freedesktop.org
- The bot for Mark Brown is significantly active on alsa-devel@alsa-project.org and linux-kernel@vger.kernel.org lists.
Other than exceptions such as the Patchwork bot and the bot for Mark Brown individual bots have sent very few emails.

The amount of bots existing in a mailing lists may not correspond to increased bot activity in the mailing list.
The graph shows the percentages of emails sent by bots across different mailing lists.

Only the top three of the mailing lists has larger than 30% of their email activity coming from bots.
• The graph shows the mailing list with the highest percentage of bot emails.
• 11.94% of all of the emails sent to kernel development community were sent to the top three mailing lists.
• linux-tip-commits@vger.kernel.org has only 0.83% of all of the emails.
Thank You!
Resources

Backup
Activity Area
Each person has a vector of mailing lists. Each dimension value is the number of emails sent to the respective list.

- Vector is normalized to have the norm of 1.
- More defining mailing lists are selected to be used for clustering people using a variance threshold.

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Authoring Activity: Activity Area
The graphs show the distributions of the number of responses per patch authored by developers in each clusters.

Since the distributions are not normal, a non-parametric test is conducted for differences of means across each cluster.
Kruskal-Wallis test rejects the hypothesis of equal means across clusters and concludes that there is at least two groups with equal means.

We disprove that the author’s area of activity does not make a difference.

\[ H_0 : \mu_i = \mu_j \; \forall i, j \in [0, 25] \quad H_A : \mu_i \neq \mu_j \; \exists i, j \in [0, 25] \]
Each patch has a vector of 1s and 0s according to which mailing lists they have been sent to, dimensions are the mailing lists.

Some dimensions are removed with a variance threshold.

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Using the same sum of distances criteria as the previous clustering, the number of clusters is selected to be 32.
• For clustering, K-means clustering algorithm is used.
• The algorithm works by recursively assigning data points to cluster centers and calculating new cluster centers.
• The algorithm requires to specify the number of clusters.
• Error measure is the sum of distances from data points to corresponding centers.
• The distributions of the number of responses per patch is shown in the graph.
• Since the distributions are not normal, a non-parametric test is conducted for differences of means across each cluster.
Patches: Number of Sections

- The log-scaled histogram shows the distribution of number of sections related to a patch, many has fewer sections.
- In the graph, many patches are clustered in the left side, while no relation to number of responses is observed.
Patches: Individual Sections

- The graph shows the average number of responses per patch for each of the maintainer sections.
• Using the same sum of distances criteria as the previous clustering, the number of clusters is selected to be 18
Patches: Individual Sections

- Coefficients of the center vectors of each cluster is shown below.
• Similar to mailing list case, the distributions of the number of responses per patch within clusters are not normal
• Non-parametric Kruskal-Wallis test is conducted
The graph shows the average number of responses a patch receive for each of the clusters.

The overall average is marked by the red line.

Similar to the mailing lists case, the Kruskal-Wallis test rejects the hypothesis of equal means across clusters with 95% significance.

\[ H_0 : \mu_i = \mu_j \ \forall i, j \in [0, 17] \quad H_A : \mu_i \neq \mu_j \ \exists i, j \in [0, 17] \]
• $x_1$ : the number of mailing lists
• $x_2$ : the number of files
• Simple formula has an R-Squared value of 0.76
• Extended formula has an R-Squared value of 0.78

\[
1.59 \times \frac{1}{x_1} + 1.46 \times \frac{1}{x_2} - 1.82 \times \left( \frac{1}{x_1} \times \frac{1}{x_2} \right) = y
\]

Simple Formula

\[
-2.01 \times \frac{1}{x_1^2} - 0.8 \times \frac{1}{x_2^2} + 3.22 \times \frac{1}{x_1} + 1.41 \times \frac{1}{x_2} - 0.61 \times \left( \frac{1}{x_1} \times \frac{1}{x_2} \right) = y
\]

Extended Formula
The graph shows Reviewed-by tags, most frequently showing up in one time committer commits.
Backup: Average Number of Responses per Patch per Person