Memory Management Using Tab Discard and Reload Prediction

Jon Napper
Michael Giuffrida
Guoxing Zhao
Omri Amarilio
Grace Chung

See next page for additional authors

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Inventor(s)
Jon Napper, Michael Giuffrida, Guoxing Zhao, Omri Amarilio, Grace Chung, and Greg Granito
Memory Management Using Tab Discard and Reload Prediction

ABSTRACT

Browsers and other multi-tab applications discard tabs when there is insufficient memory. When a tab has been discarded, the user is forced to reload the tab to continue interaction. Selection of tabs to discard can be based on simple heuristics; however, such selection can lead to discarding tabs that the user is likely to use. Incorrectly discarded tabs are disruptive to users. This disclosure describes the use of machine learning techniques to generate more accurate predictions to select the tab to be discarded. Selectively discarding tabs in this manner can improve memory management while also providing a better user experience.

KEYWORDS

- Multi-tab application
- Browser tab
- Browser memory
- Tab reload
- Tab discard
- Memory management
- Machine learning

BACKGROUND

Browsers and other multi-tab applications discard tabs when there is insufficient memory. When a tab has been discarded, the user is forced to reload the tab to continue interaction. In certain cases, a tab may not be fully closed out, but its contents may nonetheless be wiped out due to memory constraints. Selection of tabs to discard can be based on simple heuristics, e.g.,
discard the oldest tab, discard the least recently used tab, etc. However, such selection can lead to discarding tabs that the user is likely to use. Incorrectly discarded tabs are disruptive to users.

**DESCRIPTION**

![Diagram](https://www.tdcommons.org/dpubs_series/3035)

**User-permitted Features 104**
- Properties of a tab, and properties of the window the tab is in
  - Does the tab have an input form?
  - Was the tab playing sound?
  - Is the tab pinned?
  - Number of key events to the tab
  - Number of mouse events to the tab
  - Number of touchscreen events to the tab
  - Number of times the tab has been reactivated previously
  - Site engagement score
  - Domain of the URL
  - Most recently used index
- Global device state

**Trained machine learning model 102**

**Predictions 106**
- Likelihood that the user will return to the tab

**Fig. 1: Using machine learning to predict the likelihood that a user will return to a tab**

Per the techniques of this disclosure, illustrated in Fig. 1, a trained machine learning (ML) model (102) determines the probability that the user will reactivate a given tab (106), by the use of user-permitted features (104) that include data about that tab and the global device state. The user is provided with options to choose features that are used for such prediction. The user can deny permission for individual features of user activity, can choose a granularity of data for the feature, and can entirely disable the use of user data for prediction. Further, the user can selectively enable or disable use of prediction for memory management.

The features used by the machine learning model to predict the likelihood of the user returning to a particular tab can include the global device state. Further, properties of each tab and of the window that the tab is in can also be used, as permitted by the user. For example, when the multi-tab application is a browser, such properties can include, for example:

- Whether the tab has an input form.
• Whether the tab was playing sound
• Whether the tab is pinned.
• Whether the window the tab is on is in focus.
• Whether the tab is a bookmarked URL
• The tab position on the window.
• The total time the user has had the tab open.
• The number of key events to the tab.
• The number of mouse events to the tab.
• The number of touchscreen events to the tab.
• The number of times the tab has been reactivated previously.
• Site engagement score.
• The domain of the URL.
• Most recently used index.

The model is trained using one or more of the above user-permitted features as input, and by pairing vectors of input features with previously-observed outcomes, e.g., whether the user reactivated (or not) a closed (or backgrounded) tab. The outcomes also incorporate observations of whether the reactivated tab was closed quickly, e.g., within a couple of seconds. Such an event may be treated as a tab that wasn't reactivated.

When memory or other resource constraints dictate that one or more tabs are to be discarded, a tab manager program generates a list of candidate tabs that can be discarded. The ML model ranks tabs to predict the likelihood that the user has finished with a tab. To perform the ranking, a feature vector comprising the aforementioned features is fed to the model to generate a
score for that tab. The tab manager applies a policy to choose which tab or tabs to discard based on, for example:

- the likelihood that the user will return to the tab, as predicted by the model;
- the amount of memory used by the tab; etc.

The policy can lead to discarding a tab that uses significant amounts of memory, even if there are other tabs that have a greater likelihood that the user won’t return to. Predictions made by the ML model can also be used for other purposes, e.g., session restore, where the tabs to restore first are the ones that the user is most likely to find useful; or tab switching, where the tab switches not to the next one in sequence but the one that would interest the user the most.

The trained machine learning model can be, e.g., a regression learning model, a neural network, etc. Example types of neural networks that can be used include long short-term memory (LSTM) neural networks, recurrent neural networks, convolutional neural networks, etc. Other machine learning models, e.g., support vector machines, random forests, boosted decision trees, etc., can also be used.

Further to the descriptions above, a user is provided with controls allowing the user to make an election as to both if and when systems, programs or features described herein may enable collection of user information (e.g., information about a user’s actions or activities of using a multi-tab application, a user’s preferences, or a user’s current location). In addition, certain data are treated in one or more ways before it is stored or used, so that personally identifiable information is removed. For example, a user’s identity is treated so that no personally identifiable information can be determined for the user. In another example, a user’s geographic location is generalized where location information is obtained (such as to a city, ZIP code, or state level), so that a particular location of a user cannot be determined. Thus, the user
has control over what information is collected about the user, how that information is used, and what information is provided to the user.

CONCLUSION

This disclosure describes the use of machine learning techniques to generate more accurate predictions to select the tab to be discarded. Selectively discarding tabs in this manner can improve memory management while also providing a better user experience.