Image Understanding of GUI Widgets for Test Reuse

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ABSTRACT

UI testing is a crucial but costly activity in software development. Test reuse approaches have recently emerged as a promising solution to reduce the cost of UI testing. These approaches automatically transfer human-designed GUI tests from a source application to a target application with similar functionalities, exploiting semantic similarity among textual information of GUI widgets. However, the success of test reuse approaches hinges on the semantic matching of GUI events. This paper presents the integration of semantic annotation of icons, widgets and images for semantic matching of GUI events. Our findings demonstrate the importance of image understanding of GUI widgets in test reuse and offer practical insights for software developers and researchers. In addition to improving semantic matching, the integration of semantic annotation of icons, widgets, and images can also enhance the interpretability and maintainability of UI tests. By adding semantic information to the test cases, it becomes easier to understand and modify the tests, reducing the overall cost and effort required for UI testing in software development. Furthermore, this approach can potentially improve the overall quality of the software by enabling more comprehensive testing, leading to better user experience and fewer bugs.

1 INTRODUCTION

UI testing is a crucial but costly activity in software development. Test reuse approaches have recently emerged as a promising solution to reduce the cost of UI testing. These approaches automatically transfer human-designed GUI tests from a source application to a target application with similar functionalities, exploiting semantic similarity among textual information of GUI widgets. However, the success of test reuse approaches hinges on the semantic matching of GUI events. This paper presents the first empirical study on semantic matching of GUI events, which involves 253 configurations of the semantic matching, 337 unique queries, and 8,099 distinct GUI events. Our study yields several key findings that shed light on how to improve the semantic matching of test reuse approaches. Additionally, we propose SemFinder, a novel semantic matching algorithm that outperforms existing solutions. Finally, we identify several interesting research directions for future work in this area. Our findings demonstrate the importance of image understanding of GUI widgets in test reuse and offer practical insights for software developers and researchers.GUI test reuse is a promising approach for generating meaningful test cases for GUI applications. By leveraging the observation that many GUI applications share similar functionalities, automatic approaches can migrate GUI tests across apps by mapping semantically similar GUI events. This approach addresses the limitations of current GUI test generators, which often generate semantically meaningless tests and rely on implicit oracles.

Now, in the context of image understanding of GUI widgets for test reuse, it is possible to leverage techniques such as computer vision and deep learning to automatically recognize and match GUI widgets across different applications. By analyzing the visual features and properties of GUI widgets, we can identify semantically similar widgets across different applications and use them to generate meaningful test cases for the target application.

Furthermore, by incorporating image understanding into the GUI test reuse approach, we can potentially address the limitations of current test generators and improve the accuracy and effectiveness of generated test cases. For example, by using image understanding to identify and match semantically similar GUI widgets, we can ensure that the generated test cases properly exercise the relevant functionalities of the target application and reveal faults that might be missed by existing test generators.

Overall, image understanding of GUI widgets for test reuse is a promising research direction that has the potential to significantly improve the quality and efficiency of GUI test generation for software applications.

2. Scope

The scope of this topic is broad and encompasses various aspects of computer science and software engineering. One key area of focus is computer vision, which involves developing algorithms and techniques for analyzing and understanding visual data, such as images and videos. In the context of GUI test reuse, computer vision can be used to automatically recognize and match GUI widgets across different applications.

Another important area of focus is deep learning, which is a subfield of machine learning that involves training artificial neural networks to perform complex tasks, such as image recognition and natural language processing. In the context of GUI test reuse, deep learning techniques can be used to train models that can automatically identify and match semantically similar GUI widgets.

Finally, the scope of GUI testing is also relevant to this topic, as it involves developing techniques and tools for testing graphical user interfaces. In the context of GUI test reuse, this includes the development of methods and algorithms for automatically generating test cases for GUI applications based on existing test cases from other applications. Overall, the scope of image understanding of GUI widgets for test reuse is an interdisciplinary field that involves computer vision, deep learning, and GUI testing to improve the efficiency and effectiveness of software testing.

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3 Objectives

- To develop algorithms and techniques for automatically recognizing and matching GUI widgets across different applications, which can help in reusing existing test cases for new applications.

- To investigate the use of deep learning techniques for automatically identifying semantically similar GUI widgets across different applications, which can help in generating more meaningful and effective test cases.

- To improve the efficiency and effectiveness of GUI testing by developing methods for automatically generating test cases based on existing test cases from other applications.

- To address the limitations of current GUI test generators, which often generate semantically meaningless GUI tests that miss many relevant behaviors of the application under test.

- To explore the reuse of GUI tests across similar applications as an alternative way to automatically generate GUI tests, which can help in generating semantically meaningful GUI tests that properly exercise the functionalities of the target application.

- To develop methods and algorithms for adapting semantically relevant oracle assertions to the target application when reusing GUI tests, which can help in addressing the main limitations of GUI test generators.

4 Software Specifications

As The major components of the system are the dataset used and the framework used for judging the different approaches for suggesting GUI test transfer from one trace of events to another. The dataset used is 'Rico: A Mobile App Dataset for Building Data-Driven Design Applications'[1]. It possesses over 70000 unique UI screens from over 9300 apps. It has defined traces for different UI events. It has also provided semantic annotations to all the GUI elements present in the UI screens along with json files describing the hierarchical relation between the objects. All of these features make it ideal for use.

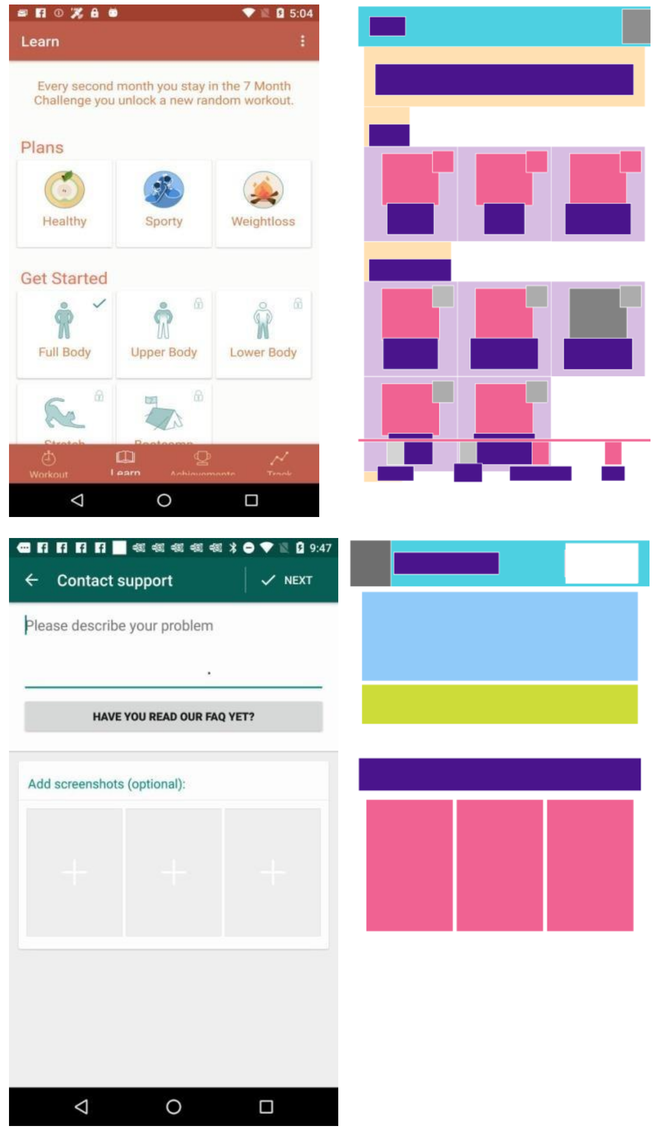


Figure 1: Example of semantic annotation of UI Screen in Rico dataset.

The other component of the system is the framework used in [2]. The framework analyzes the usage of ATM and CraftDroid for test transfer and also proposes a custom algorithm called SemFinder which tries to perform the same task by taking the help of semantic matching of GUI events. The framework was obtained online at [3]. The framework and dataset are implemented using python on Google Colab

5 Methodology and System Architecture

The previous work on semantic matching for GUI event test transfer discusses semantic annotation based only on text. However, including the semantic annotations of GUI widgets and icons could probably boost the performance of certain techniques. The main objective of this work is to integrate semantic annotations of GUI widgets into the existing system for judging the variation in performance caused by it.

I. Dataset

The Rico dataset[1] has a wide array of data samples of UI screenshots and related information such as trace of events, UI layout vectors, semantic annotations and descriptions of hierarchical relationships. The presence of these features in the dataset is essential for the task as information regarding different UI elements need to be collected step-wise as per the trace of the event. Also the semantic annotation of icons and widgets allows for easy integration of semantics of images.

II. Extraction of data

The relevant data was extracted from the dataset. Essential data (event_index, label, type) as well as optional data (text, id, content_desc, hint, parent_text, sibling_text, activity,atm_neighbor, file_name) were all taken from the dataset via mining of the dataset. The extraction of relevant data from the dataset is a critical step in data mining and is essential for obtaining meaningful insights and patterns from the data. By selecting essential data such as event_index, label, and type, the extracted data can be used for a variety of purposes, such as training machine learning models, detecting anomalies, and understanding user behavior.

III. Semantic Matching Framework

The model provided at [3] has readily been trained on various state of the art models like GLOVE, word2vec and so on. The same framework was utilized for testing the earlier obtained data as well after it was adjusted into suitable input format. The framework judged the performance of semantic matching of different events by the different test migration algorithm, descriptor algorithm, training set that was used to train the model and word embedding model.

The use of state-of-the-art models like GLOVE and word2vec in the training of the model provides a solid foundation for semantic matching of different events. By leveraging pre-trained word embeddings, the model can capture the semantic similarity between textual information of GUI widgets, enabling effective transfer of human-designed GUI tests from a source application to a target application with similar functionalities.

The testing of the earlier obtained data after adjustment into a suitable input format provides valuable insights into the performance of the framework. By evaluating the performance of semantic matching using different test migration algorithms, descriptor algorithms, training sets, and word embedding models, it becomes possible to identify the best approach for specific use cases.

The framework presented in [3] provides a robust and flexible solution for UI test reuse, leveraging state-of-the-art models and algorithms to achieve high accuracy in semantic matching. The insights gained from the evaluation of the framework can be applied to various domains, improving the efficiency and effectiveness of UI testing in software development.

IV. Evaluation Metrics

Mean Reciprocal Rank (MRR) has been used for evaluation as a metric which has been used in [2] as well. The advantage of using MRR as an evaluation metric is that it takes into account the order of the results, rather than just whether or not the relevant item was present in the list. In other words, MRR rewards algorithms that place relevant items at the top of the list, and penalizes algorithms that bury relevant items lower down in the list.

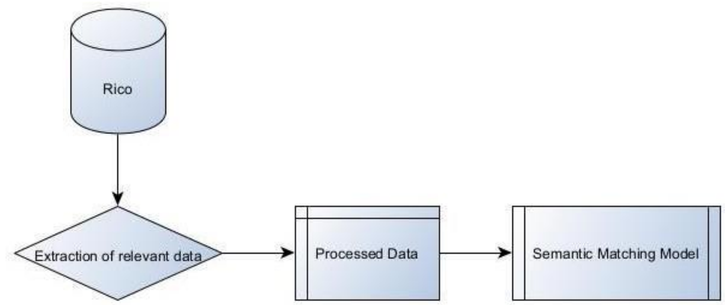
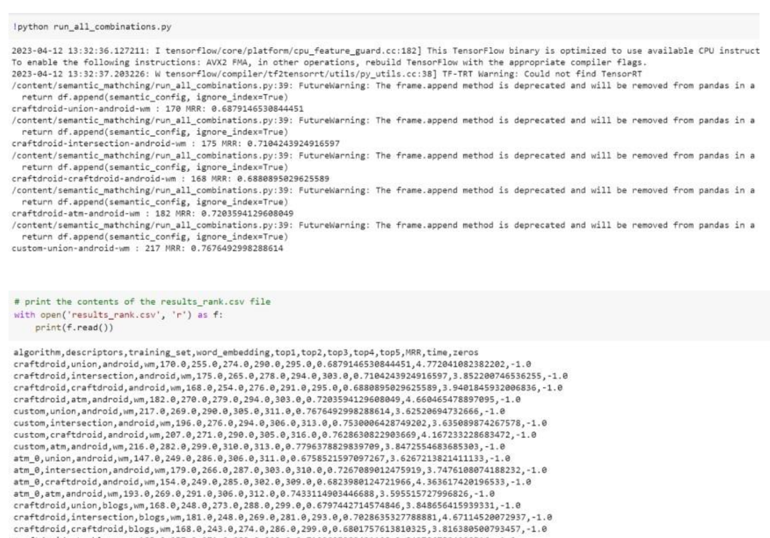


Figure 2 : Generalized architecture of the system

6 Results



```
!python run_all_combinations.py

2023-04-12 13:32:36.127211: I tensorflow/core/platform/cpu_feature_guard.cc:182] This TensorFlow binary is optimized to use available CPU instruct
To enable the following instructions: AVX2 FMA, in other operations, rebuild TensorFlow with the appropriate compiler flags.
2023-04-12 13:32:37.203226: W tensorflow/compiler/tf2tensorrt/utils/py_utils.cc:38] TF-TRT Warning: Could not find TensorRT
/content/semantic_mathching/run_all_combinations.py:39: FutureWarning: The frame.append method is deprecated and will be removed from pandas in a
  return df.append(semantic_config, ignore_index=True)
craftdroid-union-android-wm : 170 MRR: 0.6879146530844451
/content/semantic_mathching/run_all_combinations.py:39: FutureWarning: The frame.append method is deprecated and will be removed from pandas in a
  return df.append(semantic_config, ignore_index=True)
craftdroid-intersection-android-wm : 175 MRR: 0.7104243924916597
/content/semantic_mathching/run_all_combinations.py:39: FutureWarning: The frame.append method is deprecated and will be removed from pandas in a
  return df.append(semantic_config, ignore_index=True)
craftdroid-craftdroid-android-wm : 168 MRR: 0.6880895029625589
/content/semantic_mathching/run_all_combinations.py:39: FutureWarning: The frame.append method is deprecated and will be removed from pandas in a
  return df.append(semantic_config, ignore_index=True)
craftdroid-atm-android-wm : 182 MRR: 0.7203594129608049
/content/semantic_mathching/run_all_combinations.py:39: FutureWarning: The frame.append method is deprecated and will be removed from pandas in a
  return df.append(semantic_config, ignore_index=True)
custom-union-android-wm : 217 MRR: 0.7676492998288614
```

```
# print the contents of the results_rank.csv file
with open('results_rank.csv', 'r') as f:
    print(f.read())
```

```
algorithm,descriptors,training_set,word_embedding,top1,top2,top3,top4,top5,MRR,time,zeros
craftdroid,union,android,wm,170.0,255.0,274.0,290.0,295.0,0.6879146530844451,4.772041082382202,-1.0
craftdroid,intersection,android,wm,175.0,265.0,278.0,294.0,303.0,0.7104243924916597,3.852200746536255,-1.0
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custom,craftdroid,android,wm,207.0,271.0,290.0,305.0,316.0,0.7628630822903669,4.167233228683472,-1.0
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atm_0,craftdroid,android,wm,154.0,249.0,285.0,302.0,309.0,0.6823980124721966,4.363617420196533,-1.0
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```

Figure 3: Sample output of the system

Table : Best combinations as per MRR

	Algorithm	Descriptor	Training Set	MRR
1	custom	atm	Google play	0.795891209
2	custom	atm	standard	0.788772192
3	custom	atm	android	0.779637883

We now discuss the potential implications and limitations of this work.

7 Discussion

The table presented in the results section displays the optimal combinations based on Mean Reciprocal Rank (MRR), which will be listed in the result_rank.csv file. It is worth noting that the top three best combinations are highlighted in the table. According to the results, the combinations obtained from the Google Play, Standard, and Android training sets achieved the highest MRR scores of 0.79, 0.78, and 0.77, respectively. These findings suggest that the aforementioned training sets can effectively enhance the accuracy of the model, thus making them the most suitable choices for the given task.

8 CONCLUSION

In conclusion, UI testing is a crucial but expensive activity in software development. Test reuse approaches have emerged as a promising solution to reduce the cost of UI testing, but the success of these approaches relies heavily on the semantic matching of GUI events. The integration of semantic annotation of icons, widgets, and images can enhance the accuracy of semantic matching, and also improve the interpretability and maintainability of UI tests. This approach has the potential to reduce the overall cost and effort required for UI testing and improve the quality of software by enabling more comprehensive testing. These findings offer practical insights for software developers and researchers, highlighting the importance of image understanding of GUI widgets in test reuse.

Identifying and eliminating inconsequential and contradictory data automatically is an essential task that requires attention in the future. Also the potential of image understanding and semantic matching needs to be further explored to yield better results in the future for this field

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Now, in the context of image understanding of GUI widgets for test reuse, it is possible to leverage techniques such as computer vision and deep learning to automatically recognize and match GUI widgets across different applications. By analyzing the visual features and properties of GUI widgets, we can identify semantically similar widgets across different applications and use them to generate meaningful test cases for the target application.
Furthermore, by incorporating image understanding into the GUI test reuse approach, we can potentially address the limitations of current test generators and improve the accuracy and effectiveness of generated test cases. For example, by using image understanding to identify and match semantically

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ScopeThe scope of this topic is broad and encompasses various aspects of computer science and software engineering. One key area of focus is computer vision, which involves developing algorithms and techniques for analyzing and understanding visual data, such as images and videos. In the context of GUI test reuse, computer vision can be used to automatically recognize and match GUI widgets across different applications.

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3 ObjectivesTo develop algorithms and techniques for automatically recognizing and matching GUI widgets across different applications, which can help in reusing existing test cases for new applications.

To investigate the use of deep learning techniques for automatically identifying semantically similar GUI widgets across different applications, which can help in generating more meaningful and effective test cases.

To improve the efficiency and effectiveness of GUI testing by developing methods for automatically generating test cases based on existing test cases from other applications.

To address the limitations of current GUI test generators, which often generate semantically meaningless GUI tests that miss many relevant behaviors of the application under test.

To explore the reuse of GUI tests across similar applications as an alternative way to automatically generate GUI tests, which can help in generating semantically meaningful GUI tests that properly exercise the functionalities of the target application.

To develop methods and algorithms for adapting semantically relevant oracle assertions to the target application when reusing GUI tests, which can help in addressing the main limitations of GUI test generators.

4 Software SpecificationsAs The major components of the system are the dataset used and the framework used for judging the different approaches for suggesting GUI test transfer from one trace of events to another. The dataset used is 'Rico: A Mobile App Dataset for Building Data-Driven Design Applications'[1]. It possesses over 70000 unique UI screens from over 9300 apps. It has defined traces for different UI events. It has also provided semantic annotations to all the GUI elements present in the UI screens along with json files describing the hierarchical relation between the objects. All of these features make it ideal for use.

Figure 1: Example of semantic annotation of UI Screen in Rico dataset.

The other component of the system is the framework used in [2]. The framework analyzes the usage of ATM and CraftDroid for test transfer and also proposes a custom algorithm called SemFinder which tries to perform the same task by taking the help of semantic matching of GUI events. The framework was obtained online at [3]. The framework and dataset are implemented using python on Google Colab

5 Methodology and System Architecture

The previous work on semantic matching for GUI event test transfer discusses semantic annotation based only on text. However, including the semantic annotations of GUI widgets and icons could probably boost the performance of certain techniques. The main objective of this work is to integrate semantic annotations of GUI widgets into the existing system for judging the variation in performance caused by it.

Dataset

The Rico dataset[1] has a wide array of data samples of UI screenshots and related information such as trace of events, UI layout vectors, semantic annotations and descriptions of hierarchical relationships. The presence of these features in the dataset is essential for the task as information regarding different UI elements need to be collected step-wise as per the trace of the event. Also the semantic annotation of icons and widgets allows for easy integration of semantics of images.

Extraction of data

The relevant data was extracted from the dataset. Essential data (event_index, label, type) as well as optional data (text, id, content_desc, hint, parent_text, sibling_text, activity,atm_neighbor, file_name) were all taken from the dataset via mining of the dataset. The extraction of relevant data from the dataset is a critical step in data mining and is essential for obtaining meaningful insights and patterns from the data. By selecting essential data such as event_index, label, and type, the extracted data can be used for a variety of purposes, such as training machine learning models, detecting anomalies, and understanding user behavior.

Semantic Matching Framework

The model provided at [3] has readily been trained on various state of the art models like GLOVE, word2vec and so on. The same framework was utilized for testing the earlier obtained data as well after it was adjusted into suitable input format. The framework judged the performance of semantic matching of different events by the different test migration algorithm, descriptor algorithm, training set that was used to train the model and word embedding model.

The use of state-of-the-art models like GLOVE and word2vec in the training of the model provides a solid foundation for semantic matching of different events. By leveraging pre-trained word embeddings, the model can capture the semantic similarity between textual information of GUI widgets, enabling effective transfer of human-designed GUI tests from a source application to a target application with similar functionalities.

The testing of the earlier obtained data after adjustment into a suitable input format provides valuable insights into the performance of the framework. By evaluating the performance of semantic matching using different test migration algorithms, descriptor algorithms, training sets, and word embedding models, it becomes possible to identify the best approach for specific use cases.

The framework presented in [3] provides a robust and flexible solution for UI test reuse, leveraging state-of-the-art models and algorithms to achieve high accuracy in semantic matching. The insights gained from the evaluation of the framework can be applied to various domains, improving the efficiency and effectiveness of UI testing in software development.

Evaluation Metrics

Mean Reciprocal Rank (MRR) has been used for evaluation as a metric which has been used in [2] as well. The advantage of using MRR as an evaluation metric is that it takes into account the order of the results, rather than just whether or not the relevant item was present in the list. In other words, MRR rewards algorithms that place relevant items at the top of the list, and penalizes algorithms that bury relevant items lower down in the list.

Figure 2 : Generalized architecture of the system

6 Results

Figure 3: Sample output of the system

Table : Best combinations as per MRR

Algorithm
Descriptor
Training Set
MRR
1
custom
atm
Google play
0.795891209
2
custom
atm
standard
0.788772192

3
custom
atm
android
0.779637883
We now discuss the potential implications and limitations of this work.
7 DiscussionThe table presented in the results section displays the optimal combinations based on Mean Reciprocal Rank (MRR), which will be listed in the result_rank.csv file. It is worth noting that the top three best combinations are highlighted in the table. According to the results, the combinations obtained from the Google Play, Standard, and Android training sets achieved the highest MRR scores of 0.79, 0.78, and 0.77, respectively. These findings suggest that the aforementioned training sets can effectively enhance the accuracy of the model, thus making them the most suitable choices for the given task.
CONCLUSIONIn conclusion, UI testing is a crucial but expensive activity in software development. Test reuse approaches have emerged as a promising solution to reduce the cost of UI testing, but the success of these approaches relies heavily on the semantic matching of GUI events. The integration of semantic annotation of icons, widgets, and images can enhance the accuracy of semantic matching, and also improve the interpretability and maintainability of UI tests. This approach has the potential to reduce the overall cost and effort required for UI testing and improve the quality of software by enabling more comprehensive testing. These findings offer practical insights for software developers and researchers, highlighting the importance of image understanding of GUI widgets in test reuse.
Identifying and eliminating inconsequential and contradictory data automatically is an essential task that requires attention in the future. Also the potential of image understanding and semantic matching needs to be further explored to yield better results in the future for this field
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Project Title Name: Image Understanding of GUI Widgets and Test Resuse

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Submisson proof:

Submission 8740	
Title	Image Understanding of GUI Widgets for Test Reuse
Paper:	(Apr 14, 10:06 GMT)
Author keywords	User Interface (UI) Graphical User Interface (GUI) Testing Test Reuse Semantic Matching
Abstract	UI testing is a crucial but costly activity in software development. Test reuse approaches have recently emerged as a promising solution to reduce the cost of UI testing. These approaches automatically transfer human-designed GUI tests from a source application to a target application with similar functionalities, exploiting semantic similarity among textual information of GUI widgets. However, the success of test reuse approaches hinges on the semantic matching of GUI events. This paper presents the integration of semantic annotation of icons, widgets and images for semantic matching of GUI events. Our findings demonstrate the importance of image understanding of GUI widgets in test reuse and offer practical insights for software developers and researchers. In addition to improving semantic matching, the integration of semantic annotation of icons, widgets, and images can also enhance the interpretability and maintainability of UI tests. By adding semantic information to the test cases, it becomes easier to understand and modify the tests, reducing the overall cost and effort required for UI testing in software development. Furthermore, this approach can potentially improve the overall quality of the software by enabling more comprehensive testing, leading to better user experience and fewer bugs.
Submitted	Apr 14, 10:06 GMT
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ICPCSN 2023 submission 8740

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To: Prajwal Lamsal

Dear authors,

We received your submission to ICPCSN 2023 (3rd International Conference on Pervasive Computing and Social Networking):

Authors : Swarnalatha P, Prithak Gajurel, Yash Mishra and Prajwal Lamsal
Title : Image Understanding of GUI Widgets for Test Reuse
Number : 8740

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Project details in GitHub, Link of URL or App:

https://github.com/mishra-yash/image-understanding