





























### 4.3 测试任务设计和分配

众包软件测试任务的设计和分配,是众包软件测试中的一个核心问题.我们注意到:已有相关工作把测试任务游戏化(gamify)<sup>[25,95,96]</sup>.同时,有部分研究者开始关注如何高效、经济地分配测试任务<sup>[57,58,97]</sup>.我们认为,这一方向的未来工作可以围绕以下几个方面展开.

#### (1) 提高测试任务的吸引力

测试任务设计的好坏,直接影响了众包测试任务的吸引力.特别是在测试经费预算有限的情况下,无法简单采用加大任务回报的方式来吸引更多众包工人,此时,提高测试任务的趣味性成为一种可行的方式.例如,一种提高众包任务趣味性的方式是将众包任务游戏化或比赛化.由此可见:如何设计测试任务、进一步提高众包任务的趣味性,是一个非常有意思的研究课题.

#### (2) 协同化的任务分配和完成机制

当前,众包任务的分配和完成主要采用独立任务“发布-执行-完成”的模式,即:任务之间关联性较弱,同时,执行任务的众包工人之间的关联也相对较弱.我们认为,后续的研究可以围绕如何建立协同化的任务分配和完成机制展开.一方面,在众包任务的设计过程中,将任务之间的关联关系纳入考虑范畴,将传统的“独立任务”模式转化为“任务链”模式;另一方面,在任务的分配和完成过程中,不再局限于众包工人个体完成,可以基于众包工人之间的关联关系,以众包团队的形式来完成任务,从而发挥每位众包工人的技能特点和优势.

### 4.4 测试报告处理

测试报告处理包括重复 bug 报告检测<sup>[98-100]</sup>、bug 分配<sup>[101-106]</sup>、bug 报告摘要<sup>[107,108]</sup>等,是软件测试中的重要问题.针对传统测试报告,研究人员已提出了多种解决方法并研发了配套工具<sup>[109-111]</sup>,然而,众包软件测试的特性使得测试报告的处理面临新的挑战.相对于传统测试报告以文字描述为主,众包测试报告完成过程中会产生多种类型的信息,例如文字、图片、视频、日志等,但目前仅有部分原始信息反映在测试报告中,且信息的呈现方式较为单一,给大量众包测试报告快速审查带来了困难.同时,由于众包软件测试力求通过群体智能来弥补当前自动化测试技术的不足,众包测试过程中必将产生大量的测试报告.因此,如何高效地处理大量的测试报告变得尤为关键,测试报告的多元化信息,也为软件缺陷的复现提供了更多可能.

基于当前众包软件测试报告处理技术的研究进展<sup>[59-62]</sup>和传统测试报告处理技术的分析总结<sup>[84]</sup>,我们认为,未来的研究主要将围绕以下几个要点展开.

#### (1) 众包测试报告的设计

测试报告模板的质量直接关系到众包工人反馈的质量和审核人员对测试报告的处理效率.相对于传统的测试报告,众包测试报告应较为简练且能够精确地反映问题.这主要是因为:相当一部分众包测试工人不具备软件工程的专业知识,他们期望在较短时间内完成测试报告的填写,而且测试报告的填写应该可以在各类平台上完成.因此,需要开展相关调研以明确针对不同测试任务最有效的测试报告字段,从而完成针对不同测试任务的测试报告模板的设计.

#### (2) 众包测试报告的合并

已有针对传统测试报告的研究表明,重复的测试报告对于软件缺陷的定位和修复具有积极意义<sup>[98-100]</sup>.在众包测试过程中,众多众包工人将提交大量的测试报告,其中必将包含较多的重复数据.因此,对于描述了类似或者相同错误的测试报告信息进行合并,将为后续的缺陷定位和修复提供更多有益的信息.该方向主要的研究内容包括:如何自动化地识别相似的测试报告、如何有效地管理描述相似问题的测试报告、如何提取并呈现反映软件缺陷的关键信息.

#### (3) 众包测试报告的内容摘要

针对信息量较大的测试报告进行内容摘要,是一个必要的工作.内容摘要可以帮助报告审核人员关注测试报告中的关键信息.已有研究学者针对传统的测试报告,给出了针对文本信息的自动摘要技术<sup>[107,108]</sup>.然而与传统的测试报告不同,众包测试报告含有的信息类型更为丰富,可能包含文本、图像、视频、音频等.因此,需要研

究针对多类型信息的内容摘要技术.例如:可将关键帧提取技术应用到测试过程截屏录像中,提取本次测试过程中最具有代表性的帧或错误发现帧;从图片中提取关键错误信息块的技术,则可以帮助审核人员快速地从大量截图信息中确认最有效的错误截图.

#### 4.5 测试行为的自动化回放

测试行为的自动回放对程序员定位错误和修订错误具有重大的意义.在众包测试领域,目前使用最为广泛的回放方法包括:要求众包工人使用录屏或者拍摄工具对操作过程进行全程录制,然后提交所录制的数据;通过客户端记录工具记录众包工人的操作行为并生成相应的脚本,然后将脚本提交至服务器端.然而,上述两种方式都在不同程度上降低了众包任务的执行效率.同时,由于软硬件环境存在着差异,这两种方式都可能会遗漏实际执行过程中的关键信息.研发自动记录后台系统日志的工具,将有效解决测试行为自动回放的难题<sup>[112]</sup>.一方面,日志信息的记录相对于现有的两种主流录制方式,可以获得更加丰富的数据信息;另一方面,日志信息的记录过程更加轻量,对待测对象的行为和执行效率的影响更小.尽管日志记录工具的研究已较为成熟,但是如何从日志中实现测试行为的自动回放,这方面的研究还处于较为初步的阶段.

## 5 总 结

本文从学术研究现状和工业研究进展两个方面,对众包软件测试技术做出了比较全面的概述.我们收集并最终汇总了众包软件测试领域的 52 篇文献,并简要描述了这些文献的技术、策略和实验验证情况.此外,我们分析对比了当前应用最广泛的 20 个众包测试平台,并从多个角度讨论了众包测试平台的特性.在此基础上,详细讨论了众包软件测试技术的未来研究方向.众包软件测试技术有着良好的应用前景,但仍然存在大量的研究问题尚待解决,它必将成为软件工程领域的一个新兴研究热点.

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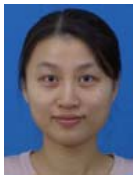
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