

# Collateral Damage of Facebook Applications

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**Abstract:** Third party application providers in Online Social Networks can collect personal data of users through their friends without the user's awareness. In some cases, one or more application providers may own several applications and thus the same provider may collect an excessive amount of personal data, which creates a serious privacy risk. Previous research has developed methods to quantify privacy risks in Online Social Networks. However, most of the existing work does not focus on the issues of personal data disclosure via the user's friends applications and application providers. The aim of this paper is to investigate the need for solutions that can compute privacy risk related to applications and application providers. In this work we perform a legal and technical analysis of the privacy threats stemming from the collection of personal data by third parties when applications are installed by the user's friends. Particularly, we examine the case of Facebook as it is the most popular Online Social Network nowadays.

## 1 INTRODUCTION

Online Social Networks (OSNs) have altered the social ecosystem in a remarkable way. OSNs supports a plethora of applications (Apps) providing games, lifestyle and entertainment opportunities developed by third parties. Such Apps may disclose a user's personal data from their online friends to third party application providers (AppPs) (Chaabane et al., 2012; McCarthy, 2014). In some cases, AppPs may own several Apps, through which they may get access to larger amounts of personal data. As a consequence, personal data disclosure may pose significant privacy risks and prompts serious concerns among the users, the media and the research community (Consumerreports, 2012; Krishnamurthy and Wills, 2008; Wang et al., 2011).

When a user shares information with her online friends in OSNs the user is not aware whether a friend has installed Apps that may access her personal data. Moreover, she is not aware that her personal data are further exposed to the AppPs. We define as collateral damage the privacy issues that arise by: (1) the acquisition of users' personal data by the Apps installed by a user's friends, (2) the acquisition of personal data of a user by the AppPs, who may disclose this data outside the OSN ecosystem.

From a legal point of view, these privacy issues

cause concerns with respect to data protection legislation. Data protection law provides a framework for the protection of the users' fundamental rights and in particular the right to privacy during processing of personal data. Personal data, pursuant to Article 2(a) of the Data Protection Directive 95/46/EC (95/46/EC, 2015) "refers to any information relating to an identified or identifiable natural person (i.e., user)" which in the scope of this paper corresponds to the user's measurable personal data processed by the App. Data protection law may be infringed in relation with two aspects: (1) data processing lacks legitimacy as the user has not given her consent to the App processing her personal data, and (2) data processing lacks transparency as the user may be totally unaware of the data processing that may take place.

There exists a considerable amount of related work regarding the user's privacy in OSNs, including work that investigates installed Apps (Biczók and Chia, 2013; Chaabane et al., 2012; Chia et al., 2012; Huber et al., 2013). However, there is no prior work analyzing the case where a set of AppPs collects the user's personal data via the Apps installed by the user's friends. Moreover, there is no work that estimates the privacy risk of the users in the case of the collateral damage of the Apps in OSNs.

Based on the assumption of privacy as a good practice (Diaz and Gürses, 2012), our research is

motivated by the need to reduce the collateral damage of the Apps in OSNs. Technically, we study how an evaluation of the privacy risk can help the user to better manage her privacy. We define the privacy score of a user as an indicator of her privacy risk. The higher the privacy score, the higher the threat to the user. A privacy risk computation is a Privacy Enhancing Technology. Privacy Enhancing Technologies are able to raise awareness on personal data collection and may support the user's decisions about personal data sharing (McDonnell et al., 2015). From a legal point of view, our solution aims to implement transparency following the principle of Data Protection by Default. Data Protection by Default was introduced in Article 23 (2) of the draft Data Protection Regulation, which requires mechanisms that, "by default ensure that the users are able to control the distribution of their personal data" (Parliament, 2015). Data protection by default intends to mitigate privacy risks stemming from users' asymmetrical information (McDonnell et al., 2015). In the context of this paper, data protection solutions, such as privacy score, raise user's awareness and enhance her empowerment.

The rest of this paper is organized as follows. Section 2 reviews the related work with respect to the privacy issues that Apps introduce in OSNs as well as the existing research related to the user's privacy risk. Section 3 describes the case of Facebook OSN. Section 4 concludes and proposes the future work.

## 2 RELATED WORK

This section describes the related work on privacy issues that arise from the use of Apps in OSNs. Moreover, it describes the existing work on the computation of privacy risk in OSNs.

Currently there exists work related to the privacy issues of Apps in OSNs. Chaabane et al. (Chaabane et al., 2012) showed that the Apps can have tracking capabilities and disseminate the collected information to "fourth party" organizations (Chaabane et al., 2014). Similarly, Huber et al. developed an automatic evaluation tool, AppInspect (Huber et al., 2013), and demonstrated security and privacy leakages of a large set of Facebook Apps. Furthermore, Biczók and Chia (Biczók and Chia, 2013) described the issue of users' information leaked through their friends via Apps on Facebook. This work introduced a game theoretic approach to simulate an interdependent privacy scenario of two users and one App game. Extending the work of Biczók and Chia (Biczók and Chia, 2013) Pu and Grossklags (Pu and Grossklags, 2014) proposed a formula to estimate the payoffs. Fi-

nally, Frank et al. (Frank et al., 2012) showed the existence of malicious Apps that deviate from the generic permissions pattern acquiring more information from the users, while Chia et al. (Chia et al., 2012) showed that certain Apps collect more information than necessary.

To estimate the privacy risk for a user, Maximilien et al. (Maximilien et al., 2009) initially proposed a Privacy-as-a-Service formula. This formula is used to compute the privacy risk as the product of *sensitivity* and *visibility* of personal data. Liu and Terzi (Liu and Terzi, 2010) extended this work (Maximilien et al., 2009) and proposed a framework for computing the privacy risk using a probabilistic model based on the Item Response Theory (IRT). Although, IRT presents interesting results to compute the *sensitivity* of the user's personal data, there is a lack of evaluation for the *visibility*. Moreover, Sánchez and Viejo (Sánchez and Viejo, 2015) developed a formula to assess the sensitivity of unstructured textual data, such as wall posts in OSNs. Their model aims to control the dissemination of the user's data to different recipients of an OSN (Viejo and Sánchez, 2015). Minkus et al. (Minkus and Memon, 2014) estimated the sensitivity and visibility of the privacy settings based on a survey of 189 participants. Finally, Nepali and Wang (Nepali and Wang, 2013) proposed a privacy index to evaluate the inference attacks as described by Sweeney (Sweeney, 2000), while Ngoc et al. (Ngoc et al., 2010) introduced a metric to estimate the potential leakage of private information from public posts in OSNs.

To the best of our knowledge, there is currently no work that considers the case of the *collateral damage* of the Apps for computing the privacy risk. The existing related work is mainly focused on estimating a privacy score as an impact on the dissemination of the user's information to the other members of an OSN. Our work is focused on the privacy impact that arises from the acquisition of users' personal data via the Apps installed by the user's friends and the user itself. These Apps expose the user's personal data to the AppPs, outside the OSN ecosystem, without users' prior knowledge.

## 3 THE CASE OF FACEBOOK APPLICATIONS

This section analyses the collateral damage privacy issues of the Apps for the case of Facebook. Facebook is a popular OSN with more than 1.4 billion monthly active users (Statista, 2015).

Facebook offers a plethora of easy-to-use tools

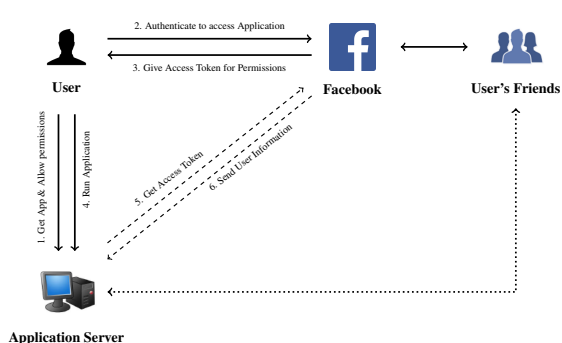


Figure 1: Facebook applications architecture overview.

such as Apps developed by third party application providers (AppPs). Currently, there are over 25,000 Apps available on Facebook (Huber et al., 2013; SBA-Research, 2015). Users on Facebook are able to construct online profiles (Boyd and Ellison, 2008). A user’s profile consists of information that can be stored with the aim to be shared with other entities such as other users and Apps. For instance, on Facebook there is a list of more than twenty attributes in a user’s profile, such as “age”, “birthday”, “gender”, and “location” (Facebook, 2015).

A running App can retrieve information from a user’s profile; this information can subsequently be accessed and stored by the AppPs. For an App to access the user’s profile, an installation process has to be performed. Each App requests from the user a set of *permissions*, that allow the App to access and collect additional information. This is done by an access token provided by Facebook, that requires authorization from the user (steps 1 to 4 in Figure 1). After the user’s approval, Apps can collect the user’s personal data and store these data at the AppPs servers. Therefore, the user’s personal data are stored outside the Facebook ecosystem and out of the user’s control (steps 5 and 6 in Figure 1).

In order to control the visibility of the user’s personal data, Facebook offers a set of *privacy settings* to its users. The set of available *privacy settings* (Facebook, 2015) is broad, and it ranges from restricted to public, with settings such as “only me”, “friends”, “friends to friends”, “custom” and “public”. For the case of Apps on Facebook, the privacy setting “only me” restricts the visibility of the personal data to the user. However, privacy settings of “friends”, “friends of friends”, “custom” and “public” equally expose the user’s personal data to third party AppPs via their friends’ Apps, making them available to external servers.

Moreover, due to the server-to-server communication (steps 5 and 6 in Figure 1), the offline interaction

between Facebook and AppPs makes any protection mechanisms hard to apply (Enck et al., 2014). As a result, the user’s profile information can arbitrarily be retrieved by AppPs without notification or approval of the user.

### 3.1 Users’ information is exposed by their friends

Initially, the API v.1 of Facebook provided a set of permissions to the Apps, such as *friends\_birthday*, and *friends\_location*. Those permissions gave the AppPs the right to access and collect users’ personal data via their friends, such as the user’s birthday and location. However, currently the Facebook API version v.1 is obsolete and the *friends\_xxx* permissions are not present. The updated API version v.2 (Facebook, 2015) replaced the *friends\_xxx* permissions with the *user\_friends*. Although the newer API had to be in line with the regulations of EU and U.S. (95/46/EC, 2015; FTC, 2015), our analysis showed that it discloses up to fourteen user attributes via the user’s friends; maintaining the privacy concerns of collateral damage of the Apps as an open problem. A more detailed view on the available permissions of Apps is given in Table 3 in the Appendix.

Furthermore, Apps can request permissions through strangers (non-friends) who participated in the same conversation group with the user (i.e., personal messages). This is the case, for instance, for the permission *read\_mailbox*. The mere exchange of text messages in a group conversation may disclose user personal data: when the user participates in a group conversation with other users (friends and non-friends) who has installed *read\_mailbox*, the user’s personal data becomes accessible to the Apps. This personal data can be the content of the conversation as well as the time that the communication took place.

To examine the problem, we performed an analysis of the Apps on Facebook. We used the publicly available dataset provided by Hubert et al (Huber et al., 2013; SBA-Research, 2015). The dataset consists of 16,808 Facebook applications between 2012 and 2014. It contains the application name, id, number of active users (daily, weekly and monthly), the requested permissions and the Apps that an AppP owns. For this paper we analyzed the permissions of Apps with more than 10,000 Monthly Active Users (MAU). Among, these Apps we identified the proportion of permissions that cause the collateral damage privacy issue. Moreover, in order to calculate the number of personal data that Apps can collect we considered the number of corresponding permissions to that data such as *friends\_photos* and *user\_photos* to

photos.

Table 1: Facebook most requested permissions for more than 100 and 10,000 Monthly Active Users.

Permissions	≥ 100 Monthly	≥ 10000 Monthly
email	50.5 %	61.8 %
user_birthday	19.4 %	24.5 %
user_likes	14.1 %	12.8 %
user_location	7.3 %	7.9 %
publish_actions	31.1 %	50.3 %
publish_stream	31.4 %	19.3 %
user_photos	10.6 %	8.5 %
friends_xxx	10.23%	10%
read_mailbox	0.9%	0.45%

From the list of 16,808 Apps on Facebook, we identified 2,200 Apps with more than 10,000 monthly active users (MAU). As described in Table 1, we verified that several Apps request permissions for collecting sensitive data, such as birthday 28.7%, photos 12.9%, likes 14.8%, location 9.5%, friend information 10.23%, and, more invasive, private mailbox privileges 0.45%. Among this sensitive data the most commonly requested friends related permissions for the Apps that enable the collateral damage issue, were *friends\_birthday* 4.2%, *friends\_photos* 4.4%, *friends\_likes* 1.8% and *friends\_location* 1.5%.

While the permissions affecting friends’ data seem limited, the lack of transparency and opt-out option (lack of consent) for the user is worrisome. Moreover, although *read\_mailbox* appears to be used by only 0.45% of the Apps the severity of the risks it may entail for the user is significant.

### 3.2 Third party application providers

Third party application providers (AppPs) can be owners of several Apps. As a consequence, one AppP may collect through those Apps several personal data items of each user. The amount of personal data that can be retrieved is equal to the collection of all the acquired personal data under the same AppP. Moreover, every App retrieves the Facebook’s user ID which can identify a user and can be used to accurately correlate the collected personal data from each App. For instance, extending our analysis for the AppPs we identified that there are AppPs with up to 160 Apps with more than 10,000 MAU (see Table 2). Moreover, we repeated our analysis for the Apps and its corresponding AppPs that enable the collateral damage problem. We identified that “Astrologix” and “Social sweethearts GmbH” AppPs have 7 Apps and “Shinezone” 5.

Table 2: Facebook application providers and the amount of its corresponding applications for more than 100 and 10,000 Monthly Active Users.

Application Provider	≥ 100 Monthly	≥ 10,000 Monthly
Vipo Komunikacijos	163	99
Telaxo	136	118
Mindjolt	120	32
superplay!	81	8

### 3.3 Legal issues

From a legal perspective, one of the main challenges of data protection attached to the Apps permissions, as described above, is the fact that personal data processing may lack legitimacy. Article 7 of Data Protection Directive 1995/46/EC (95/46/EC, 2015) provides a limited number of legal grounds aiming to perform personal data processing, such as the “the user’s unambiguous consent”. As enshrined in Article 7a, the data controller, i.e., Facebook or Apps, may collect, store, use and further disclose the data, if the user has given her consent. For the consent to be valid, it has to fulfil certain criteria: it has to be given prior to the data processing, accepted in a “free” way and sufficiently specified and informed (Art. 29 WP 2011) (95/46/EC, 2015).

However, Facebook third party Apps can proceed to the users personal data processing only with the user’s friends’ consent. In other words, consent may be provided only by the user of the App and not by the user, whose data however will be processed in the end. On Facebook Apps settings, users allow by default their data to be used by their friends Apps, unless they manually uncheck the relevant boxes “Apps other use”. One could claim that consent has been theoretically given. However, the U.S. Federal Trade Commission required that Apps cannot imply consent, but this should be rather affirmatively expressed by the users. Despite this requirement, due to the default privacy setting on Facebook, users are totally unaware of the fact that they have to uncheck the boxes in order to prevent such data processing (FTC, 2015).

Further, with regards to the obligation of the data controller (Facebook or Apps) to transparency, it should be noted that in both cases, users have neither sufficient information about the nature and amount of data that will be collected nor about the purposes that the data will be used for. In other words data processing goes far beyond the user’s legitimate expectations. This interferes with the principle of fairness and transparency stemming from Article 10 of Data Protection Directive 46/1995/EC (95/46/EC, 2015). In relation with the same matter, the U.S. Federal Trade Commission stressed the need to keep users informed in case any disclosure exceeds the restrictions imposed

by the privacy setting(s) of the Apps (FTC, 2015). This can be possibly the case of permissions such as *user\_friends*.

## 4 CONCLUSION AND FUTURE WORK

In this paper, we analyse the importance of the privacy issues that arise from the collection of the user’s personal data that can be collected by third party Apps installed by the user’s friends in OSNs. Moreover, we analyse the case where Apps under a minor set of AppPs can collect the users’ personal data and expose them outside of the OSN ecosystem without prior knowledge of the users. To demonstrate the importance of the problem we analyzed the case of the Facebook Apps.

Considering the privacy issues that arise from the installation of third party Apps, this paper performs a privacy risk assessment which is in line with the legal principle of privacy by default. It aims to illustrate how the user’s data disclosure takes place through the acquisition of users’ personal data via Apps installed by their friends in OSNs. A calculation of a user’s privacy risk can be useful to both users and researchers. A privacy risk assessment (Nebel et al., 2013) can help the privacy-aware users to better support their decisions when they install Apps. The increase of awareness on personal data collection is in line with the legal principle of data protection by default, as it can potentially support decisions and foster user control on personal data disclosure. From the researchers’ perspective, a numerical value describing the user’s information exposure would allow statistical inferences and comparisons for better privacy design.

A previous work proposed by Liu and Terzi (Liu and Terzi, 2010; Maximilien et al., 2009) developed a 2-dimensional matrix to compute the privacy risk, considering the sensitivity and the visibility of a user’s personal data to the users of an OSN. Our future work aims to extend this model also to Apps and AppPs. Moreover, our analysis considers the Apps and AppPs that are available at the time of writing. However, since API and Apps are rapidly evolving it would be interesting to update and extend the current dataset with the recent Apps available on Facebook.

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## 6 APPENDIX

Table 3: Facebook application permissions and the corresponding profile items. Permission availability to API v1 (①) and v2 (②)

Permission Group	Permissions	Profile Items
Public profile (default)	public_profile①②	id, name, first_name, last_name, link, gender, locale, timezone, updated_time, verified
App friends	user_friends①②	bio, birthday, education, first_name, last_name, gender, interested_in, languages, location, political, relationship_status, religion, quotes, website, work,
Extended Profile Properties (xpp)*	friends_about_me①, friends_actions①, friends_activities①, friends_birthday①, friends_checkins①, friends_education_history①, friends_events①, friends_games_activity①, friends_groups①, friends_hometown①, friends_interests①, friends_likes①, friends_location①, friends_notes①, friends_online_presence①, friends_photo_video_tags①, friends_photos①, friends_questions①, friends_relationship_details①, friends_relationships①, friends_religion_politics①, friends_status①, friends_subscriptions①, friends_website①, friends_work_history①	about_me, actions, activities, birthday checkins, history, events, games.activity, groups, hometown, interests, likes, location, notes, online_presence, photo_video_tags, photos, questions, relationship_details, relationships, religion_politics, status, subscriptions, website, work_history
Extended Permissions (xp)*	read_mailbox①②	inbox

## REFERENCES

95/46/EC (Accessed April 15, 2015). Directive 95/46/ec of the european parliament and of the council. [http://ec.europa.eu/justice/policies/privacy/docs/95-46-ce/dir1995-46\\_part1\\_en.pdf](http://ec.europa.eu/justice/policies/privacy/docs/95-46-ce/dir1995-46_part1_en.pdf).

Biczók, G. and Chia, P. H. (2013). Interdependent privacy: Let me share your data. In *Financial Cryptography and Data Security - 17th International Conference, FC 2013, Okinawa, Japan, April 1-5, 2013, Revised Selected Papers*, pages 338–353.

- Boyd, D. and Ellison, N. (2008). Social Network Sites: Definition, History, and Scholarship. *Journal of Computer-Mediated Communication*, 13(1).
- Chaabane, A., Ding, Y., Dey, R., Ali Kaafar, M., and Ross, K. (2014). A Closer Look at Third-Party OSN Applications: Are They Leaking Your Personal Information? In *Passive and Active Measurement conference (2014)*, Los Angeles, États-Unis. Springer.
- Chaabane, A., Kaafar, M. A., and Boreli, R. (2012). Big friend is watching you: Analyzing online social networks tracking capabilities. WOSN '12, pages 7–12, New York, NY, USA. ACM.
- Chia, P. H., Yamamoto, Y., and Asokan, N. (2012). Is this app safe? A large scale study on application permissions and risk signals. In *WWW*, Lyon, France. ACM.
- Consumerreports (Accessed on Sept. 6, 2012). Facebook and your privacy: Who sees the data you share on the biggest social network? <http://bit.ly/11WhqWt>.
- Diaz, C. and Gürses, S. (2012). Understanding the landscape of privacy technologies. *Proc. of the Information Security Summit*, pages 58–63.
- Enck, W., Gilbert, P., Chun, B., Cox, L. P., Jung, J., McDaniel, P., and Sheth, A. (2014). Taintdroid: an information flow tracking system for real-time privacy monitoring on smartphones. *Commun. ACM*, 57(3):99–106.
- Facebook (Accessed February 08, 2015). Facebook privacy settings and 3rd parties. <https://developers.facebook.com/docs/graph-api/reference/user/>.
- Frank, M., Dong, B., Felt, A., and Song, D. (2012). Mining permission request patterns from android and facebook applications. In *ICDM*, pages 870–875.
- FTC (Accessed February 08, 2015). FTC and Facebook agreement for 3rd parties wrt privacy settings. <http://www.ftc.gov/sites/default/files/documents/cases/2011/11/111129facebookagree.pdf>.
- Huber, M., Mulazzani, M., Schrittwieser, S., and Weippl, E. R. (2013). Appinspect: large-scale evaluation of social networking apps. In *Conference on Online Social Networks, COSN'13, Boston, MA, USA, October 7-8, 2013*, pages 143–154.
- Krishnamurthy, B. and Wills, C. E. (2008). Characterizing privacy in online social networks. WOSN '08, pages 37–42, New York, NY, USA. ACM.
- Liu, K. and Terzi, E. (2010). A framework for computing the privacy scores of users in online social networks. *TKDD*, 5(1):6.
- Maximilien, E. M., Grandison, T., Liu, K., Sun, T., Richardson, D., and Guo, S. (2009). Enabling privacy as a fundamental construct for social networks. In *Proceedings IEEE CSE'09, 12th IEEE International Conference on Computational Science and Engineering, August 29-31, 2009, Vancouver, BC, Canada*, pages 1015–1020.
- McCarthy, C. (Accessed Apr. 9, 2014). Understanding what Facebook apps really know (FAQ). <http://cnet.co/1k85Fys>.
- McDonnel, N., Troncoso, C., Tsormpatzoudi, P., Coudert, F., and Métayer, D. (Accessed May 04, 2015). “Deliverable 5.1 : State-of-play: Current practices and solutions.” FP7 PRIPARE project. <http://pripareproject.eu/wp-content/uploads/2013/11/D5.1.pdf>.
- Minkus, T. and Memon, N. (2014). On a scale from 1 to 10, how private are you? Scoring Facebook privacy settings. In *Proceedings of the Workshop on Usable Security (USEC 2014). Internet Society*.
- Nebel, M., Buchmann, J., Ronagel, A., Shirazi, F., Simo, H., and Waidner, M. (2013). Personal information dashboard: Putting the individual back in control. *Digital Enlightenment*.
- Nepali, R. K. and Wang, Y. (2013). SONET: A social network model for privacy monitoring and ranking. In *33rd International Conference on Distributed Computing Systems Workshops (ICDCS 2013 Workshops), Philadelphia, PA, USA, 8-11 July, 2013*, pages 162–166.
- Ngoc, T. H., Echizen, I., Komei, K., and Yoshiura, H. (2010). New approach to quantification of privacy on social network sites. In *Advanced Information Networking and Applications (AINA), 2010 24th IEEE International Conference on*, pages 556–564. IEEE.
- Parliament, E. (Accessed May 04, 2015). European parliament legislative resolution of 12 march 2014 on the proposal for a regulation. <http://www.europarl.europa.eu/sides/getDoc.do?pbRef=-//EP//TEXT+TA+P7-TA-2014-0212+0+DOC+XML+V0//EN>.
- Pu, Y. and Grossklags, J. (2014). An economic model and simulation results of app adoption decisions on networks with interdependent privacy consequences. In *Decision and Game Theory for Security - 5th International Conference, GameSec 2014, Los Angeles, CA, USA, November 6-7, 2014. Proceedings*, pages 246–265.
- Sánchez, D. and Viejo, A. (2015). Privacy risk assessment of textual publications in social networks. In Loiseau, S., Filipe, J., Duval, B., and van den Herik, H. J., editors, *ICAART (1)*, pages 236–241. SciTePress.
- SBA-Research (Accessed Sept 09, 2015). Appinspect: A framework for automated security and privacy analysis of osn application ecosystems. <http://ai.sba-research.org/>.
- Sweeney, L. (2000). Simple demographics often identify people uniquely. *Health (San Francisco)*, 671:1–34.
- Statista (Accessed Sept 09, 2015). Leading social networks worldwide as of august 2015, ranked by number of active users (in millions). <http://www.statista.com/statistics/272014/global-social-networks-ranked-by-number-of-users/>.
- Viejo, A. and Sánchez, D. (2015). Enforcing transparent access to private content in social networks by means of automatic sanitization. *Expert Syst. Appl.*, 42(23):9366–9378.

Wang, Y., Komanduri, S., Leon, P., Norcie, G., Acquisti, A., and Cranor, L. (2011). I regretted the minute I pressed share: A qualitative study of regrets on Facebook. In *SOUPS*.