VisABAC: A Tool for Visualising ABAC Policies

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Abstract: Authoring and editing access control policy can be a complex and cognitive demanding task, especially when dealing with a large number of rules and attributes. Visualisation techniques are known to be helpful to users analysing intricate data, and can, in some contexts, help decreasing the cognitive load. In this paper, we propose a new tool, VisABAC, which enables the visualisation of attribute based access control policies using the Circle Packing method. We used a participatory design, following a survey of existing visualisation methods in access control. VisABAC is designed as a web-page component, developed in Javascript using the D3.js library, and as such is easily usable without requiring any particular setup. In addition to presenting VisABAC, we demonstrate its usability by conducting a controlled experiment with 32 participants, asking them to change some attribute values in order to obtain a given decision for a policy, and measuring the time taken by participants to conduct these tasks (the faster, the better). We show a small to medium effect size ($d = 0.44$), thus indicating that VisABAC is a promising tool for authoring and editing access control policies.

1 INTRODUCTION

An *access control policy* can be seen a compendium of authorisations that regulate the use of a particular set of resources. They are defined by *security administrators* and are processed by a trusted software module called *access control mechanism* or *reference monitor* (Benantar, 2005).

The first access control model is often considered to be the Access Matrix (Lampson, 1974), where each row indicates a subject, each column an object, and each cell the access rights granted to the corresponding subject over the corresponding object. This approach can be cumbersome for systems requiring a large number of subjects and objects, and can lead to policy misconfigurations (Bauer et al., 2008). Many access control models have been introduced[1], providing more suitable methods for designing access control policies in specific contexts.

General policy languages have subsequently been created, including, but not limited to, *ExPDT* (Sackmann and Kähmer, 2008), *EPAL* (Ashley et al., 2003) and the standard XACML (eXtensible Access Control Markup Language) (Standard, 2005). The latest version, XACML 3.0, was released in 2013, and standardizes *Attribute-based Access Control*, within which an *access request* can be seen as a set of attribute values, an *access rule* as a decision (e.g., permit or deny) returned when a boolean expression (i.e., target and/or condition) holds for a request, and an *access policy* as combining the decisions returned by a collection of rules using a composition operator (e.g., deny-overrides or permit-overrides).

Although XACML is a very general and powerful framework, its underlying format is XML, which makes XACML policies machine readable, but arguably harder to author and edit by hand. The need for including human factors in security is recognised as an important problem: in the UK, for instance, 50% of the worst breaches were caused by "inadvertent human error" (up from 31% in 2014) (PwC, 2015), and there has been an increasing effort on *usable security* (see, e.g., (Alavi et al., 2014; Lacey, 2009; Trudeau et al., 2009; Kirlappos and Sasse, 2014)). The need for regulatory mandates in computer security have increased the number of policies and its complexity far beyond human cognitive capacity (Barrett et al., 2004). Security Administrators cope with such entanglement by obviating irrelevant data, causing inadvertently security risks in the process (Vaniea et al., 2008). Recent privacy breaches along with experiments, such as Trudeau et al. (Trudeau et al., 2009)

[1] See for instance (Barker, 2009) for an account on the variety of access control models introduced over the past decades.

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corroborates this, showing that users (including experienced policy engineers) easily oversee details. There is therefore a clear case to build tools helping security administrators author and edit access control policies.

Reducing complexity is an essential stage in any kind of analysis and it is perfectly possible to simplify a system without loosing essential functional properties. *Information visualisation* (Card et al., 1999) comprises techniques that allow humans to understand and manipulate huge quantities of abstract data by simplification and it is being actively investigated by security researchers (Vaniea et al., 2008; Becker et al., 2014; Stepien et al.,). Languages such as `Mir6` (Heydon et al., 1990) have demonstrated that it is even possible to specify security visually, albeit with very limited complexity. In particular, visualisation techniques have been proposed in the context of access control (Rosa, 2009; Heydon et al., 1990), including the tools ALFA[2] (Axiomatics Language for Authorization), which proposes a much simplified textual syntax for describing XACML policies, or VisPE (Nergaard et al., 2015), which proposes a Sratch-based interface. However, these approaches tend to enhance the textual representation of the policy, rather than offer a visualisation of the evaluation of a policy.

This paper contributes to solving this problem by proposing a new tool, VisABAC, which provides a visual interface for the evaluation of an attribute based access control policies using the Circle Packing method. More precisely, we provide two main contributions in this paper:

- We introduce the tool VisABAC, which is a client-side browser application, and, given an attribute-based access control policy, provides a textual representation of that policy (inspired by XACML 3.0 and ALFA), a graphical visualisation using the Circle Packing method, and an interface allowing a policy designer to change policy and attribute values. VisABAC is, to the best of our knowledge, the first visualisation tool to support the XACML 3.0 extended decision set, which includes multiple indeterminate decisions (indicating missing information).
- We conduct a controlled experiment with 32 participants, asked to interact with two versions of VisABAC: the control group would only see the textual representation, while the tested group would see both the textual and graphical representations. Participants were given a series of questions, each question containing a policy and asking the participant to modify attribute values in order to obtain a specific decision. We show that the tested group was, in average, faster to answer the questions (with an effect size of $d = 0.44$ over the monitored questions), and more likely to interact with the tool (subjective preferences measured at the end of the test showed that 76.47% of participants who tested the visualisation tool manifested they felt more confident operating the policy.)

To the best of our knowledge, there is no standard benchmark for evaluating the efficiency and usability of policy authoring/editing tool, and we believe the results of the controlled experiments could pave the way towards establishing such a benchmark. In addition, VisABAC focuses on the visualisation of the evaluation of policies, rather than on the structure of the policy itself, and therefore is complementary to several existing approaches, described in Section 2.

The rest of this paper is structured as follows: we first introduce in Section 2 the background on Attribute-Based Access Control, and related work on the visualisation of access control. We then present VisABAC in Section 3, the experiment in Section 4, and the results are discussed in Section 5.

2 BACKGROUND AND RELATED WORK

In this section, we first describe the notion of Attribute Based Access Control (ABAC) policies, after which we go through existing approaches, leading to our selection of the Circle Packing method.

2.1 ABAC

As briefly described in the Introduction, ABAC consists in considering an access request as a set of attribute values. Following for instance the approach adopted for PTaCL (Crampton et al., 2015), we therefore consider a set of attribute names $\mathcal{A}$ and a set of attribute values $\mathcal{V}$, such that the set of requests is denoted by $Q = \wp(\mathcal{A} \times \mathcal{V})$.

We assume here that the sets $\mathcal{A}$ and $\mathcal{V}$ are known and fixed, and, in order to model missing information (which is a key aspect of XACML 3.0), we consider a request as a function $q : \mathcal{A} \times \mathcal{V} \to \{1, 0, \perp\}$, such that, given an attribute a and a value v, $q(a, v) = 1$ indicates that a has the value v in q, $q(a, v) = 0$ indicates that a does not have the value v in q, and $q(a, v) = \perp$ indicates that we do not know whether a has the value v in q or not.

An atomic target is defined as a pair (a, v), and a composite target is defined as a proposition of atomic

[2] https://www.axiomatics.com/pure-xacml.html

Table 1: Evaluation of the healthcare policy example on some selected values for each atomic target.

Targets				Rules		Policy
t_1	t_2	t_3	$t_2 \vee t_3$	r_1	r_2	p
1	1	1	1	Deny	Permit	Deny
0	1	1	1	NA	Permit	Permit
0	0	0	0	NA	NA	NA
0	$\perp$	0	$\perp$	NA	Indet(P)	Indet(P)
$\perp$	1	1	1	Indet(D)	Permit	Indet(PD)
$\perp$	0	0	0	Indet(D)	NA	Indet(D)

targets. Since, in the controlled experiment presented in Section 4, we targeted participants with no specific knowledge of access control, we only considered simple conjunction ($\wedge$) and disjunction ($\vee$) operators, corresponding to the XACML AllOf and AnyOf elements, respectively. We leave the study of more complex logical operators for future work.

Given a request q, the evaluation of an atomic target $t = (a, v)$ is equal to $q(a, v)$. Here, we interpret 1, 0, and $\perp$ as the XACML elements Match, NoMatch and Indeterminate, respectively. We use a strong Kleene interpretation for the logical operators, following the PTaCL and XACML semantics: given a request q, and two targets t_1 and t_2, the target $t = t_1 \wedge t_2$ evaluates to 1 if both t_1 and t_2 evaluates to 1, to 0 if either t_1 or t_2 evaluates to 0, or to $\perp$ otherwise. Similarly, the target $t = t_1 \vee t_2$ evaluates to 1 if either t_1 or t_2 evaluates to 1, to 0 if both t_1 and t_2 evaluates to 0, or to $\perp$ otherwise.

An access rule is defined as a tuple (d, t), where d is a decision (either Permit or Deny) and t is a target. Given a request q, a rule (d, t) evaluates to d if t evaluates to 1, to NA (Not-Applicable) if t evaluates to 0, to Indet(P)[3] if $d =$ Permit and t evaluates to $\perp$, or to Indet(D) if $d =$ Deny and t evaluates to $\perp$.

An access policy is a collection of rules, composed together with a composition operator. We implemented in VisABAC the six main XACML operators: permit-overrides (POV), deny-overrides (DOV), permit-unless-deny (PUD), deny-unless-permit (DUP), first-applicable (FA), only-one-applicable (OOA). We refer to the main documentation of XACML or for instance to (Morisset and Zannone, 2014) for the full definitions of these operators.

For instance, let us consider a health-care policy, regulating the access to a medical record, where intuitively, access is permitted when there is no explicit disagreement from the patient and when either the hospital or the concerned surgeon agrees for the access, and access is denied otherwise. There are therefore three possible attribute values/atomic targets: $t_1 =$ (patient, disagree), $t_2 =$ (hospital, agree) and $t_3 =$ (surgeon, agrees). We then define two rules, $r_1 = (\mathsf{Deny}, t_1)$ and $r_2 = (\mathsf{Permit}, t_2 \vee t_3)$, and the policy $p = DOV(r_1, r_2)$. The evaluations of these elements are presented in Table 1. It is worth observing that this simple policy can in practice evaluate to every possible XACML decision, depending on the values of the atomic targets.

A straight-forward machine readable textual representation of this policy is presented below. We use this format in VisABAC, in addition to the graphical representation.

```
R1: Deny if PATIENT_disagrees
R2: Permit if OR(HOSPITAL_agrees,
                 SURGEON_agrees)
P: DOV(R1,R2)
```

2.2 Visualisation for Access Control

We now present visualisation techniques, some of them actively applied into access control, that were considered in the process of building VisABAC. Although there is a rich literature for visualisation in security, few approaches deal with Attribute-based Access Control, and these approaches tend to work on the structure of the policy itself, such as VisPE (Nergaard et al., 2015), rather than on policy evaluation.

There is a limited literature studying trees as a way to visually find conflicts inside access policies; this seems surprising since trees are used to create XACML policies itself and it is the preferred method for explaining XACML policies in the OASIS specification (Rissanen et al., 2009). Rosa (Rosa, 2009) explore this approach for very light graphs in its XACML Viz prototype. Pina Ros et al. (Pina Ros et al., 2012) uses trees (Matching tree and Combining Tree) to optimise the evaluation of applicable rules in an access policy engine called XEngine. The tool is not aimed at visualisation, however, the paper shows how policies are organised in a tree structure than can be directly match to a tree representation. Rao et al. (Rao et al., 2009) propose multi-level grids to visualise results of multiple types of access control policy analysis and authoring. Although this approach is simple to implement, it can be very space consuming.Semantic Substrates (Card et al., 1999) use spatial representation to group common attributes by regions. Pan and Xu (Pan et al., 2013; Pan and Xu, 2012) propose a visualisation toolkit called “Policy Visualisation Framework (PVF)” which extends XACML to support RBAC aiming to provide a clearer representation than conventional role-permission tree graphs. They further propose in (Pan and Xu, 2012) to use treemaps (Johnson and Shneiderman, 1991)

[3] For the sake of compactness, we abbreviate the XACML Indeterminate extended decisions to Indet.

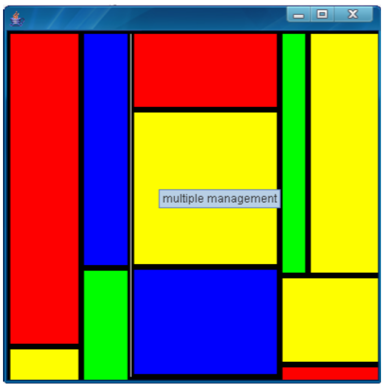


Figure 1: Tree-maps as a visualisation tool for analysing conflict detection for multi-domain policies (Pan and Xu, 2012).

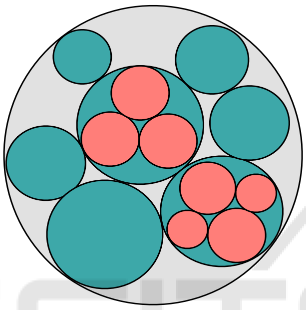


Figure 2: Circle Packing Diagram (Wang et al., 2006). Level 0,1 and 2 painted light grey, green and red respectively.

to complement Semantic Substrates instead of adjacency matrices to form macro and micro vision respectively. Treemaps visualise hierarchical tree structures using a root rectangle that contains all nodes of a given tree. Each subsequent level of the tree structure divides the above square according to a particular attribute of a node, such as size. They are used in (Pan and Xu, 2012) to analyse RBAC access control polices when multi-domain information is exchanged (Figure 1).

Circle Packing (Wang et al., 2006) is very similar in concept to Treemaps, as it was inspired by them. As a marked difference, it uses circles instead of rectangles which give them a lower space efficiency ratio; however they express more clearly the hierarchy they represent. Figure 2 shows a very simple Circle Packing diagram which has three levels. Wang et al. (Wang et al., 2006) have shown with a file visualisation tool (FVT) that it is possible to handle efficiently thousands of nodes with this method. However, to the best of our knowledge, Circle Packing has never been used in the context of access control.

3 VisABAC

In this section, we first explain the process with which we have designed VisABAC, after which we describe the tool itself[4].

3.1 Participatory Design

In general, visualisation is not only a set of techniques but also a process (Meyer, 2011) therefore, in order to achieve a successful representation, it is important to work closely with users affected by the shortcomings of traditional analysis. Hence, we work closely with 5 members of our research group using a *participatory design* (Ritter et al., 2014). That expertise targeted essential usability aspects and the feedback acquired (*heuristic approach* (Ritter et al., 2014)) was complemented by *heuristic evaluation* and informal/formal evaluation by recruited participants.

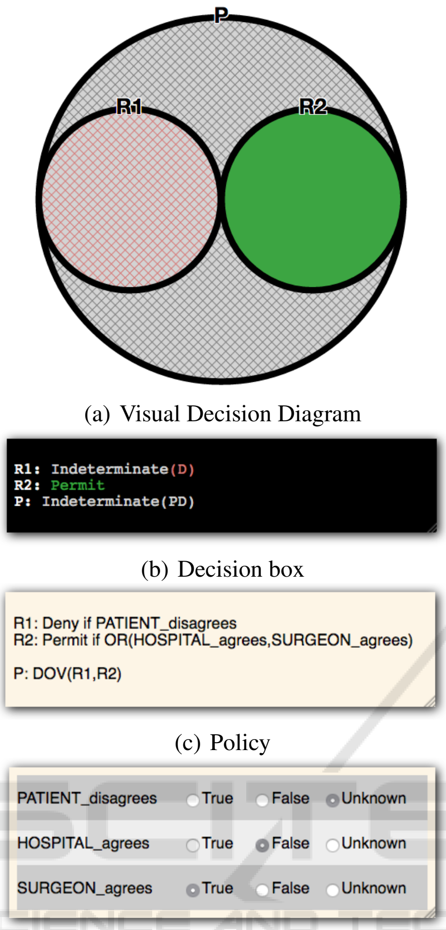
Some approaches, such as: graphs, hierarchical graphs, hypergraphs, Euler diagrams, and binary decision diagrams (BDD), have already been identified as too complex to implement, visualise or unsuitable to be of any practical use (Fisler et al., 2005; Heydon et al., 1990; Montemayor et al., 2006; Fisler et al., 2005; Kolovski, 2007). Some candidates, on the other hand, were particularly promising, including trees and treemaps, which have been applied previously to security visualisation. However, some limitations were found during the participatory process, even after trying to refine those ideas using *zoomable treemaps* and *collapsible trees*:

- In particular, the relationship between screen state utilisation and navigability has been highlighted as very important by the participants. Screen utilisation for collapsible trees, for example, was very low (more than 50% is background)[5] but users easily navigated inside the access control policy; on the other hand, zoomable treemaps proposed a full screen state utilisation but users got lost inside the policy quickly.
- Treemaps made clear that once navigating inside a policy users easily forgot the evaluation result of the particular policy they were inspecting, having to go a level back again to remember what the outcome was.

A tradeoff between efficiency and usability was found in *circle packing*, a visualisation technique crit-

[4] VisABAC is available for demonstration at http://homepages.cs.ncl.ac.uk/charles.morisset/visabac

[5] A prototype version of VisABAC with collapsible trees is available alongside the main tool, illustrating the poor screen utilisation.



(a) Visual Decision Diagram

(b) Decision box

(c) Policy

(d) Attribute Values

Figure 3: Figure 3(a) and Figure 3(b) show the evaluation of the policy P, represented in 3(c), when attributes are set as 3(d) (fifth row of Table 1). The largest circle (P) is filled in with a grey pattern, since it evaluates to Indet(PD), the circle for R1 is filled in with a red pattern, since it evaluates to Indet(D), and the circle for R2 is filled in green, since it evaluates to Permit.

icised (Wang et al., 2006) for not being as space efficient as treemaps but praised for providing a better hierarchy illusion than those obtained by, for example, treemap representations.

3.2 VisABAC Interface

The VisABAC interface is designed as a web page component and, as such, runs on any web browser. The interface consists of four main components, which we now detail, using the visualisation of the policy described in Section 2.1 as an example (Figure 3).

The *Policy component* (Figure 3(c)) is a textual box, directly editable from the browser, which contains the definition of the policy following the syntax described in Section 2.1. This definition can either be typed in, loaded from a set of existing samples, or loaded from a file. These rules are automatically parsed into JavaScript Object Notation (JSON), where the text of each rule is identified by its name. For instance, the policy described in Section 2.1 would correspond to the object:

```
policyRules=
{"R1": "Permit if PATIENT_disagrees",
 "R2": "Permit if OR(HOSPITAL_agrees,
                      SURGEON_agrees)"
 "P": "DOV(R1,R2)"}
```

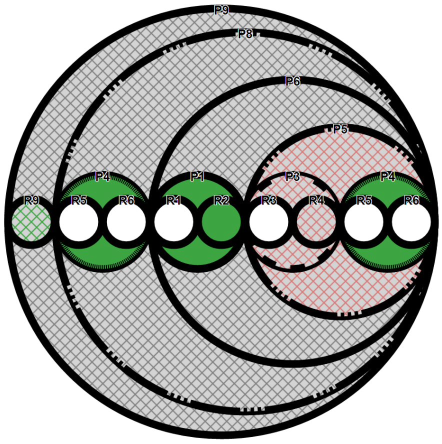
The *Attributes component* (Figure 3(d)) allows the user to set the value for each attribute value: true, false, or unknown. For instance, Figure 3(d) corresponds to a request where we do not know if the patient disagrees to the access, we know that the hospital does not agree to the access, and that the surgeon agrees, which corresponds to the fifth row of Table 1.

The *Decision component* (Figure 3(b)) lists, for each rule in the Policy component, the decision obtained for that rule. These decisions are obtained by iterating through the `policyRules` object, following the evaluation rules established in (Crampton et al., 2015). The evaluation returns an object with the same structure, but where each rule has been replaced by its decision. In the case where a rule is not well-formed (e.g., missing reference, syntax error), it evaluates to Indeterminate(PD). Note that cycles in rule definitions are not currently detected, and an error would occur.

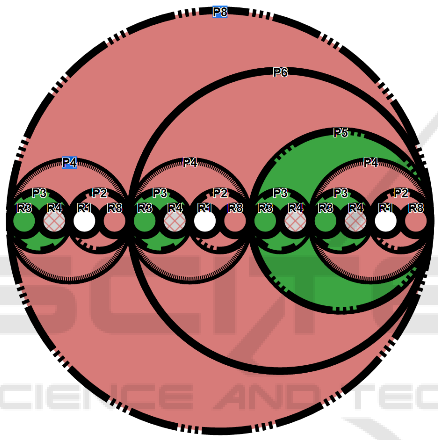
Finally, the *Visual component* (Figure 3(a)) uses Zoomable Circle Packing to visually explore access control policies, using the D3.js library[6]. The zoomable aspect is a crucial one, as it allows the space occupied by the visualisation to remain constant. A *circle* is either a rule or a composition of rules grouped by a composition operators. As a consequence, a policy comprised of sub-policies is represented by circles containing sub-circles in a similar hierarchy as the given policy. The visual diagram is dynamic, and is updated when the policy or the attributes are updated and a new evaluation is calculated. Each circle is defined by two characteristics:

- The colour, which matches the result of the policy/rule they represent: green is for Permit, red for Deny, white for NA, patterned-green for Indet(P), patterned-red for Indet(D), and patterned-grey for Indet(PD). We have also developed a colour deficiency mode, which caters for different types of colour deficiencies. In addition, since these

[6]https://d3js.org



(a) Policy with 9 atomic rules and 9 binary policies.



(b) Variation of 4(a) with sub-policies used multiple times.

Figure 4: Circle packing visualisation of arbitrary complex policies in VisABAC.

colours are set through a simple CSS (Cascading Style Sheet), they could be user configurable.

- The line pattern which matches the operator used. In particular, we use full lines for Deny-overrides and dashed lines for Permit-overrides. The lines for the other operators can be found in the online help of the tool.

For instance, Figure 3(a) shows that *Level 0* (P) represents the whole policy by the most outer circle line; *Level 1* (R1 and R2) represent the first level of the tree policy with smaller circles inside. A zoom on the inner circles would display their respective targets, since they are atomic policies. Figure 4 illustrates more complex examples of ABAC policies.

4 EVALUATION

VisABAC, presented in the previous section, is relatively easy to use, since it is defined as an in-browser application. The input language for policies is relatively straight-forward from an Attribute-based Access Control perspective. More importantly, the D3.js library for Circle Packing is particularly fluid, making the tool very responsive. Our participatory design elicited Circle Packing as the preferred visualisation technique, compared with other techniques such as foldable trees or treemaps. However, we are also interested in understanding whether VisABAC is effectively *usable*, i.e, whether its proposed graphical representation could help users in their tasks.

Nielsen and Levy argue that usability should be measured according to *subjective user preferences* and *objective performance measures*, since, in some cases, users have favoured interfaces that are measurably worse for them (Nielsen and Levy, 1994). Similarly, MacLean et al. (MacLean et al., 1985) found that subjects inclined towards a proven slower data entry method would still prefer it as long as it was not 20% slower than the faster method.

Hence, in addition to a subjective user preference questionnaire, we want to design an objective performance measure for using VisABAC. To the best of our knowledge, there is no standard benchmark for the usability of tools for access control policies, and therefore we define a new method in this paper. Roughly speaking, we give the user a fixed policy, a valuation for the attributes, and ask the user to change this valuation in order for the policy to evaluate to a specified decision. Our hypothesis is that the faster the user is able to do this task, the more they understand the policy, and thus the better is the tool with which the user interacts. We now describe this experimental settings, and we discuss the limitations of our approach in Section 6.

4.1 User Interface

We conduct a controlled-group experiment, where users in different groups see a different user interface. We define two different user interfaces (UI):

- The *Graphics UI* is an extension of the VisABAC interface, described in Section 3.2, with the addition of two main elements: the *context* box, which introduces the context of the policy, in English; and the *question* box, which specifies the expected decision. The boxes for the policy, the attributes, the decision box, and the visual decision diagram, are as described in Figure 3[7].

- The *Text UI* is similar to the Graphics UI, as the notable exception that the visual decision diagram box is missing. However, the user still has access to the evaluation of the policy with the decision box.

4.2 Policy Question

The aim of either UI described above is to answer a question, given a context and a policy. Ideally, we would like to ask questions related to any aspect of the editing or maintenance of a policy. However, we believe that this would introduce too many different dimensions to control, and we focus instead on questions related to policy evaluation. We leave for future work the study of more complex questions. The context is a simple description of the motivation behind the policy, for instance, for the policy described in Section 2.1 and Figure 3, the context is:

> *Releasing medical records in a certain hospital requires compliance with an access control policy. The system checks events with statements that return True or False if the forms have been filled and validated by the corresponding departments.*

The attribute values are initially set so that the policy evaluates to $\mathsf{Indet(PD)}$, and the question is:

> *Can you change the radio buttons so that PC evaluates to Deny ?*

The user can change any radio button, and then click on a button *Evaluate*, which refreshes the different boxes with the new policy evaluation. There is no limit on the authorised number of evaluation per question, and they can go to the next question by clicking on the *Submit* button. They were also instructed they could go to the next question at any time if they did not wish to submit an answer for the current question, and this would be recorded as a wrong answer.

The experiment consists of a total of 32 sub-questions, grouped in 8 main questions. All sub-questions within a single main question have the same context, and only differ on minor details. For instance, a sub-question in the same group than the policy above use the First-Applicable (FA) operator to combine R1 and R2 instead of the Deny-Overrides (DOV). The main questions are denoted from Q1 to Q8, the sub-questions for the main question Q_i are denoted from Q_ia to Q_id.

[7]The full test with both interfaces is available from the front page of the tool.

4.3 Protocol

Each recruited participant P_i goes through the following steps:

1. After reading and signing the participant consent form, P_i is randomly assigned to either the *Text group* (the control group) or the *Graphics group* (the tested group).
2. P_i is presented with a short introduction about ABAC, going through a simple policy example (similar to that described in Section 2.1). At this stage, they can use the Text UI on the introduced example (the Graphics UI is only introduced in Step 4 for the Graphics group) and ask any question. They are also explained what is expected of them and informed that their time will be recorded. They are also informed that some policies are on purpose hard to analyse, and that we are measuring how the interface helps them, rather than assessing them. This step takes in average 10 minutes.
3. Once they feel confident about using the tool, they start answering the first series of main questions, Q1 and Q2 (8 sub-questions in total), using the Text UI, regardless of their assigned group.
4. After Q2, if P_i is in the Text group, they keep answering Q3 to Q8 (24 sub-questions in total); If P_i is in the Graphics group, they switch to the Graphics UI, and they are briefly introduced with the specifics of the Circle Packing representation; They then answer Q3 to Q8 using the Graphics UI.
5. After Q8, P_i is debriefed, and explained the purpose of the experiment. According to recommended practices (Nielsen, 1993), a £10 Amazon voucher is given as compensation for their time.

The entire protocol was designed to take, in average, between 30 to 45 minutes, including 20 minutes of actual assessment. The time to answer each question was visible to the participant, and although there was no strict countdown, to avoid adding time pressure, participants were encouraged to move on to the next question if they were spending more than 5 minutes on a sub-question (which happened in only one instance). The experiment took place in the same office and the same computer (a 27” iMac), in order to control environmental changes. Participants were asked about colour deficiency, but none was indicated in our experiment.

4.4 Objective Performance Measure

Intuitively, we want to compare the time taken by users in the two different groups, in order to evaluate whether the Graphics UI was beneficial. However, performance measure among different individuals varies according to the capabilities of each one, and the nature of the experiment makes it hard to ensure the distribution of the users in the groups is consistent with user capabilities. As a consequence, a procedure of normalisation had to be performed in order to compare data.

The selected normalisation value was the inverse of the number of seconds each participant spent on solving Q2 (i.e., the total time spent on subquestions Q2a, Q2b, Q2c and Q2d). We denote this as the *normalisation coefficient* α_i, for each participant P_i. Subsequently, the time taken by P_i to answer each question is normalised by multiplying it by α_i. If this value is lower than 1, this implies the subject performed a particular question faster than Q_2 while a larger value represents the opposite. For instance, if P_1 took 4 seconds to complete Q2 ($\alpha_1 = 0.25$) and 6 seconds to complete Q3, their normalised time for Q3 is 1.5; If P_2 took 16 seconds to complete Q2 ($\alpha_2 = 0.0625$) and 23 seconds to complete Q3, their normalised time for Q3 is 1.4375. In other words, even though, absolutely speaking, P_2 was slower than P_1 for Q3, they were comparatively faster.

This choice for the normalisation function comes from the fact that we have designed different questions with different levels of difficulty, Q7 being the most difficult. Hence, we expect that all users will spend more time to answer Q7 than Q2, and we want to measure this difference, rather than measuring directly the difference between users. Q2 was selected as the normalisation value since all participants, regardless of their group, had to do it with the Text UI, and it was assumed some familiarity was already gained by the user after performing Q1, since Q1 and Q2 have a similar complexity level.

4.5 Subjective User Preferences

Subjective Testing was performed on users who were exposed to the visualisation technique. A relatively standard questionnaire was presented to collect their impressions using a *Likert scale* (Nielsen and Levy, 1994) after finishing the objective testing.

5 RESULTS

We recruited 32 participants over 4 weeks, mostly among undergraduate Computer Science students, with no formal knowledge of ABAC, and randomly assigned to the groups (16 participants each). The aim of this study was to assess the impact of circle

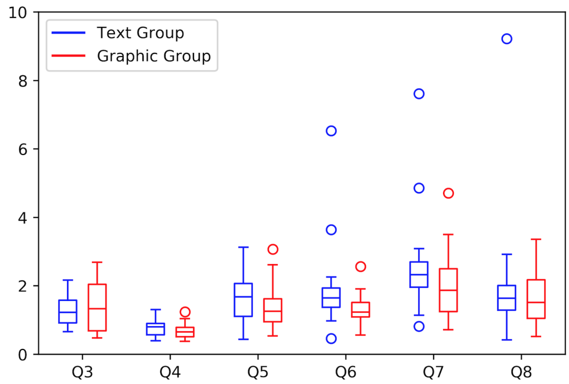


Figure 5: Boxplots comparison of normalised times for questions Q3 to Q8 between the Text and Graphics groups (lower is better). The body of each box represents the intervals between the first (q_1) and third quartiles (q_3), the bar represents the mean, the whiskers represent the maximal and minimal values between $q_3 + 1.5(q_3 - q_1)$ and $q_1 - 1.5(q_3 - q_1)$, fliers represent points outside of this range.

packing, so we targeted a relatively uniform group in terms of prior knowledge, rather than experts in Access Control. Figure 5 shows the normalised time average of participants for each question, including wrong answers (there are 8 wrong answers in each group). The mean for the Graphics group is lower (i.e., better) from Q4 to Q8 (comparatively to the time taken for Q2) compared to the Text group. The mean of Graphics group is higher for Q3, which could indicate a small learning curve with the Graphics UI.

Altogether, the normalised mean time for participants in the Text group to answer all questions from Q3 to Q8 is $m_t = 10.38$ (with a confidence interval of $[7.88, 12.88]$ and a standard deviation of $\sigma_t = 5.10$). In comparison, the normalised mean time for participants in the Graphics group is $m_g = 8.58$ (with a confidence interval of $[7.33, 9.83]$ and a standard deviation of $\sigma_g = 2.55$). This allows us to conclude that the effect size[8] is 0.44, which is traditionally seen as a small to medium effect size (Cohen, 1988). In addition, the results of the user preferences survey showed that 82.35% of participants described the presence of the visualisation as useful; 76.47% of participants felt more confident operating the policy with the presence of the graph and 47.06% agree (35.39% agree to some extent) that the presence of the graph makes them feel they understand the policy better. Some questions were however very conclusive, e.g. if complex mental operations were needed, which could indicate this question was not well formulated.

[8]Cohen's effect is computed as $(m_t - m_g)$ divided by $\sqrt{(\sigma_t^2 + \sigma_g^2)/2}$

6 CONCLUSIONS

VisABAC: A Usable Tool. VisABAC presents a way to visually overview an access control policy, where composition operations seems to be adequately represented and details are disclosed on demand thanks to the zooming and progressive disclosure of tags. VisABAC also provides interactivity to the user and increments the exploring of the policy in a graphical manner. The response was overall positive, both during the participatory design and with the subjective user preferences survey. Most users liked the concept very much, found it intuitive and easy to use, although they remarked that some training could have decrease their response time. Furthermore, the experiment showed a small to medium effect size, allowing to conclude that VisABAC improves the handling of attribute-based access control policies for a population with no formal training. Of course, at this stage, it is not yet clear whether VisABAC can provide a significant contribution to access control experts, but we believe the tool as presented here and our results pave the way towards an experiment at a larger scale.

Comparison with Other Visualisation Techniques. Although the experiment focuses only on the circle packing technique, it is worth recalling that VisABAC was designed using a participatory design, where other techniques were rejected as less effective compared to circle packing. Furthermore, most approaches described in Section 2 do not focus on attribute-based access control, which is now considered to be standard. We believe that a wide-ranging comparison of different visualisation techniques would require a strong benchmark and a clear methodology, and we designed our approach to be a first step in that direction.

Extensions. Since VisABAC is designed as a webpage component, using HTML (for the basic interface), JSON (for the encoding of the policies), and Javascript (for the evaluation of policies and the visualisation elements), additional visualisation techniques can be added. The collapsible tree approach (see Section 2.2) has received some positive response during the participatory design phase of VisABAC (policies tend to be naturally seen as trees). If the space occupation issue could be fixed, they could be an interesting candidate to integrate into VisABAC. In particular, navigating large networks with hierarchies and zooming has been explored in authors such as Eick and Wills (Eick and Wills, 1993) with thorough discussion about node placement algorithms. In addition, we could also embed the visualisation framework into a more capable tool that could parse directly XACML policies, making it possible to compare real XACML cases against their visualisation (and not synthetic ones), and include authoring tools such as VisPE (Nergaard et al., 2015). This would facilitate the deployment of VisABAC for realistic experiments with field experts.

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