Metrics-based Evaluation of Slicing Obfuscations

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Obfuscation

- An obfuscation is a functionality-preserving transformation.
- The goal of obfuscation is to keep something secret within a program.
- Barak et al proved that perfect obfuscation is impossible for their model.
- We aim for transformations that are *difficult* but not *impossible* to reverse engineer.

Program Slicing

- Slicing is a reverse engineering technique often used to aid program comprehension.
- A slice consists of the program parts that potentially affect the values computed at a particular point.
- We will restrict ourselves just to backwards slices and output statements.

Experimental Design

- We would like to restrict the usefulness of slicing for program comprehension.
- Use CodeSurfer to slice our programs.
- CodeSurfer uses system dependence graphs (SDGs) to compute slices.
- We slice our unobfuscated program and use this information to create obfuscations that are targeted to restrict the effectiveness of slicing.

Adding dependencies

- Consider the nodes from the SDG that are left behind after slicing – called *orphans*.
- Add in obfuscations that create dependencies between the slicing variable and the variables contained within the orphans.
- Forthcoming PhD will explore dependencies in more detail.

Slicing Metrics

Tightness measures the number of statements common to every slice: $T(M) = \frac{|SL_{int}|}{|M|}$

Minimum Coverage is the ratio of the smallest slice in a method to it's length: $Min(M) = \frac{1}{|M|} \min_i |SL_i|$

Coverage compares the length of slices to the length of the entire method: $C(M) = \frac{1}{|V_O|} \sum_{i=1}^{|V_O|} \frac{|SL_i|}{|M|}$

Maximum Coverage is the ratio of the largest slice in a method to it's length: $Max(M) = \frac{1}{|M|} \max_i |SL_i|$

Overlap is a measure of how many statements in a slice are found in all the other slices: $O(M) = \frac{1}{|V_O|} \sum_{i=1}^{|V_O|} \frac{|SL_{int}|}{|SL_i|}$

Aims

We are going to add simple obfuscations to our programs which:

- add dependencies between variables
- increase the size of the slices
- increase the metric values
- do not increase the code size significantly

Suitable Obfuscations

We will restrict ourselves to only using the following obfuscations:

- Adding a bogus predicate
- Variable encoding
- Adding to the guard of a while loop

These transformations have been chosen because they enable us to add dependencies between variables.

A Particular Example

As an example, consider the program *wc* which counts the number of lines (*nl*), words (*nw*) and characters (*nc*) in a file.

```
wc() {
  int c, nl = 0, nw = 0, nc = 0, in;
  in = F;
  while ((c = getchar())! = EOF) {
    nc ++;
    if (c ==' ' || c ==' \n' || c ==' \t')
      in = F;
    else if (in == F)
      {in = T; nw ++;}
    if (c ==' \n') nl ++;          }
  out(nl, nw, nc);    }
```

A Particular Example

As an example, consider the program *wc* which counts the number of lines (*nl*), words (*nw*) and characters (*nc*) in a file.

The backwards slice from *nl*.

```
wc() {
  int c, nl = 0, nw = 0, nc = 0, in;
  in = F;
  while ((c = getchar())! = EOF) {
    nc ++;
    if (c ==' ' || c ==' \n' || c ==' \t')
      in = F;
    else if (in == F)
      {in = T; nw ++;}
    if (c ==' \n') nl ++;          }
  out(nl, nw, nc);    }
```

A Particular Example

As an example, consider the program *wc* which counts the number of lines (*nl*), words (*nw*) and characters (*nc*) in a file.

The backwards slice from *nl* …

Our goal is to include these orphans in the slice.

```
wc() {
  int c, nl = 0, nw = 0, nc = 0, in;
  in = F;
  while ((c = getchar())! = EOF) {
    nc ++;
    if (c ==' ' || c ==' \n' || c ==' \t')
      in = F;
    else if (in == F)
      {in = T; nw ++;}
    if (c ==' \n') nl ++;
  }
  out(nl, nw, nc);
}
```

An Example Obfuscation

As an obfuscation, we add bogus predicates to create dependencies.

```
wc-obf1() {
  int c, nl = 0, nw = 0, nc = 0, in;
  in = F;
  while ((c = getchar())! = EOF) {
    nc ++;
    if (c ==' ' || c ==' \n' || c ==' \t')
      in = F;
    else if (in == F)
      {in = T; nw ++;}
    if (c ==' \n') nl ++;          }
  out(nl, nw, nc);    }
```

An Example Obfuscation

As an obfuscation, we add bogus predicates to create dependencies.

These predicates use the invariant:

$$nc \geq nw \ \wedge \ nc \geq nl$$

```
wc-obf1() {
  int c, nl = 0, nw = 0, nc = 0, in;
  in = F;
  while ((c = getchar())! = EOF) {
    nc++;
    if (c ==' ' || c ==' \n' || c ==' \t')
      in = F;
    else if (in == F)
      {in = T; nw++;}
    if (c ==' \n') {if (nw <= nc) nl++;}
    if (nl > nc) nw = nc + nl;
    else {if (nw > nc) nc = nw − nl;} }
  out(nl, nw, nc);    }
```

An Example Obfuscation

As an obfuscation, we add bogus predicates to create dependencies.

The backwards slice from nl.

Now we've included all of the orphans in the slice for nl.

```
wc-obf1() {
  int c, nl = 0, nw = 0, nc = 0, in;
  in = F;
  while ((c = getchar())! = EOF) {
    nc++;
    if (c ==' ' || c ==' \n' || c ==' \t')
      in = F;
    else if (in == F)
      {in = T; nw++;}
    if (c ==' \n') {if (nw <= nc) nl++;}
    if (nl > nc) nw = nc + nl;
    else {if (nw > nc) nc = nw - nl;} }
  out(nl, nw, nc);   }
```

An Example Obfuscation

As an obfuscation, we add bogus predicates to create dependencies.

We have also included the orphans of the slices for the other two output variables.

```
wc-obf1() {
  int c, nl = 0, nw = 0, nc = 0, in;
  in = F;
  while ((c = getchar())! = EOF) {
    nc++;
    if (c ==' ' || c ==' \n' || c ==' \t')
      in = F;
    else if (in == F)
      {in = T; nw++;}
    if (c ==' \n') {if (nw <= nc) nl++;}
    if (nl > nc) nw = nc + nl;
    else {if (nw > nc) nc = nw − nl;} }
  out(nl, nw, nc);    }
```

Results for *wordcount*

Method M	$\|M\|$	$\|Vo\|$	Size of nl	Size of nw	Size of nc	$\|SLint\|$
wc	36	3	15	20	10	7
wc-obf1	42	3	30	30	30	28

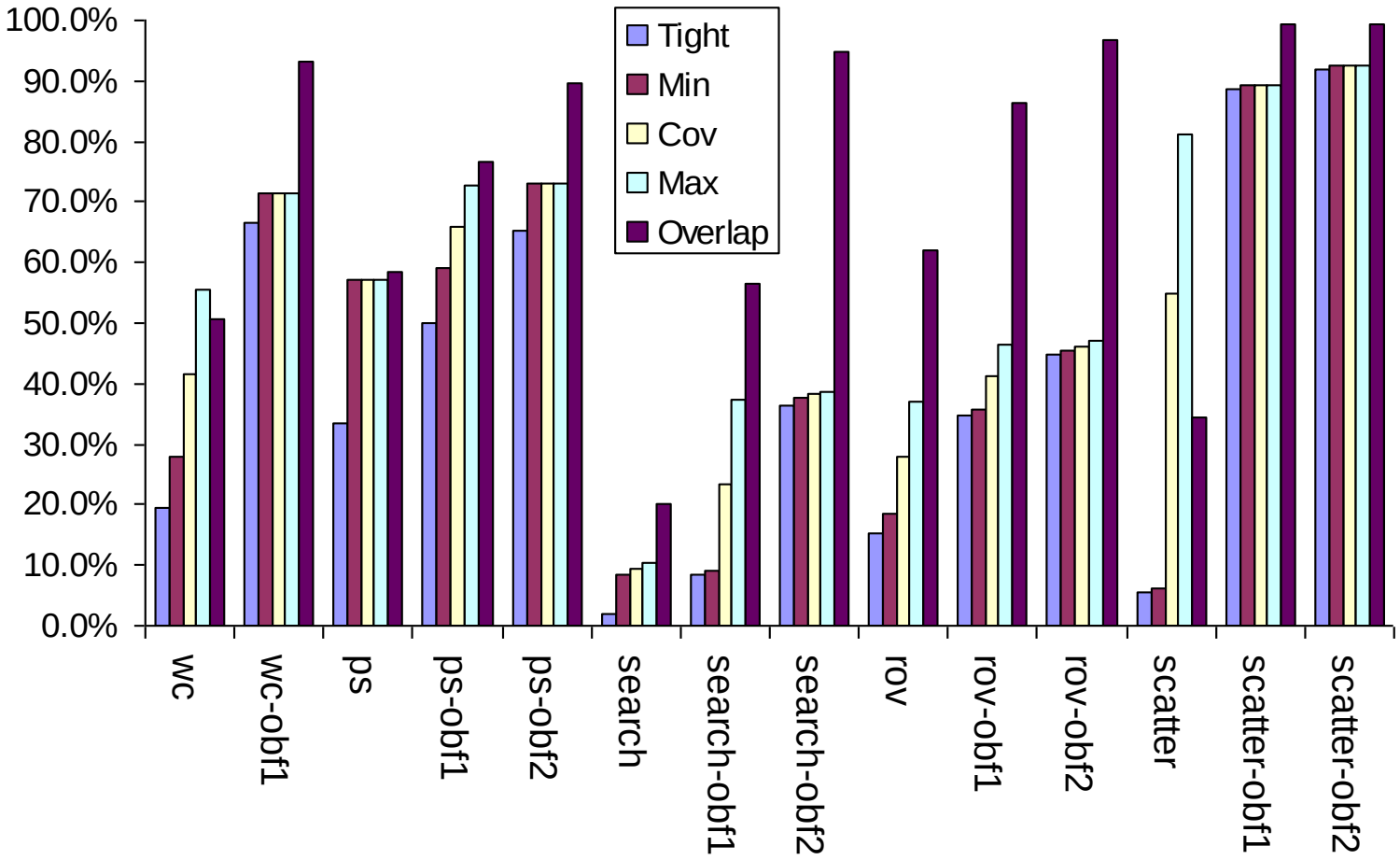
	$T(M)$	$Min(M)$	$C(M)$	$Max(M)$	$O(M)$
wc	19.4%	27.8%	41.7%	55.6%	50.6%
wc-obf1	66.7%	71.4%	71.4%	71.4%	93.3%

Measurements obtained from CodeSurfer

Table of Results

Method M	$\|M\|$	$\|V_O\|$	For each v_i the slice size $\|SL_i\|$						$\|SL_{int}\|$	$T(M)$	$Min(M)$	$C(M)$	$Max(M)$	$O(M)$
wc	36	3	*nl*	15	*nw*	20	*nc*	10	7	19.4%	27.8%	41.7%	55.6%	50.6%
wc-obf1	42	3	*nl*	30	*nw*	30	*nc*	30	28	66.7%	71.4%	71.4%	71.4%	93.3%
ps	21	2	*prod*	12	*sum*	12			7	33.3%	57.1%	57.1%	57.1%	58.3%
ps-obf1	22	2	*prod*	16	*sum*	13			11	50.0%	59.1%	65.9%	72.7%	76.7%
ps-obf2	26	2	*prod*	19	*sum*	19			17	65.4%	73.1%	73.1%	73.1%	89.5%
search	107	2	*n*	9	*secs*	11			2	1.9%	8.4%	9.3%	10.3%	20.2%
search-obf1	120	2	*n*	45	*secs*	11			10	8.3%	9.2%	23.3%	37.5%	56.6%
search-obf2	127	2	*n*	49	*secs*	48			46	36.2%	37.8%	38.2%	38.6%	94.9%
rov	124	2	*fuel*	23	*dist*	46			19	15.3%	18.5%	27.8%	37.1%	62.0%
rov-obf1	129	2	*fuel*	60	*dist*	46			45	34.9%	35.7%	41.1%	46.5%	86.4%
rov-obf2	132	2	*fuel*	62	*dist*	60			59	44.7%	45.5%	46.2%	47.0%	96.7%
scatter	143	3	*si*	116	*ru*	111	*i*	9	8	5.6%	6.3%	55.0%	81.1%	34.3%
scatter-obf1	148	3	*si*	132	*ru*	132	*i*	132	131	88.5%	89.2%	89.2%	89.2%	99.2%
scatter-obf2	150	3	*si*	139	*ru*	139	*i*	139	138	92.0%	92.7%	92.7%	92.7%	99.3%

Graph of Results



Discussion

- Managed to increase the slice sizes for all our obfuscations and so we increased the metric values.
- Slightly increase the code size.
- Important to increase the slice intersection size.
- Should aim to add obfuscations for *all* of the variables.

Future Work

- Automation – need to consider:
  - where to place the obfuscations
  - what order to apply the obfuscations
  - composition of obfuscations
- Additional Concerns:
  - methods
  - pointers
  - arrays

Conclusion

- Proposed a new approach to designing obfuscations by attacking a program first then defending against further attacks.
- Create obfuscations that have false data dependencies.
- Aim is to include statements that are orphaned.