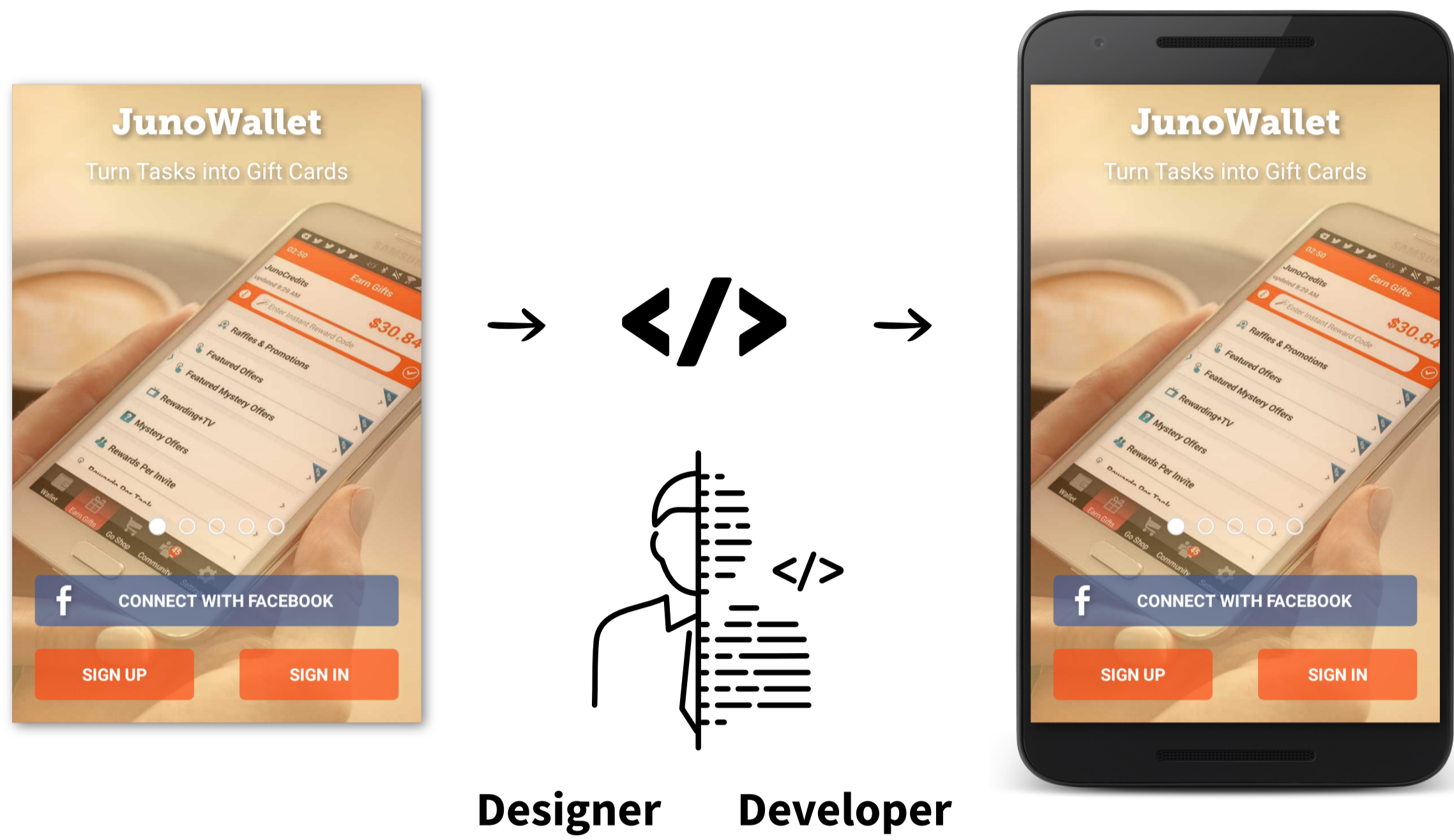


Robust Relational Layout Synthesis from Examples

Pavol Bielik, Marc Fischer, Martin Vechev



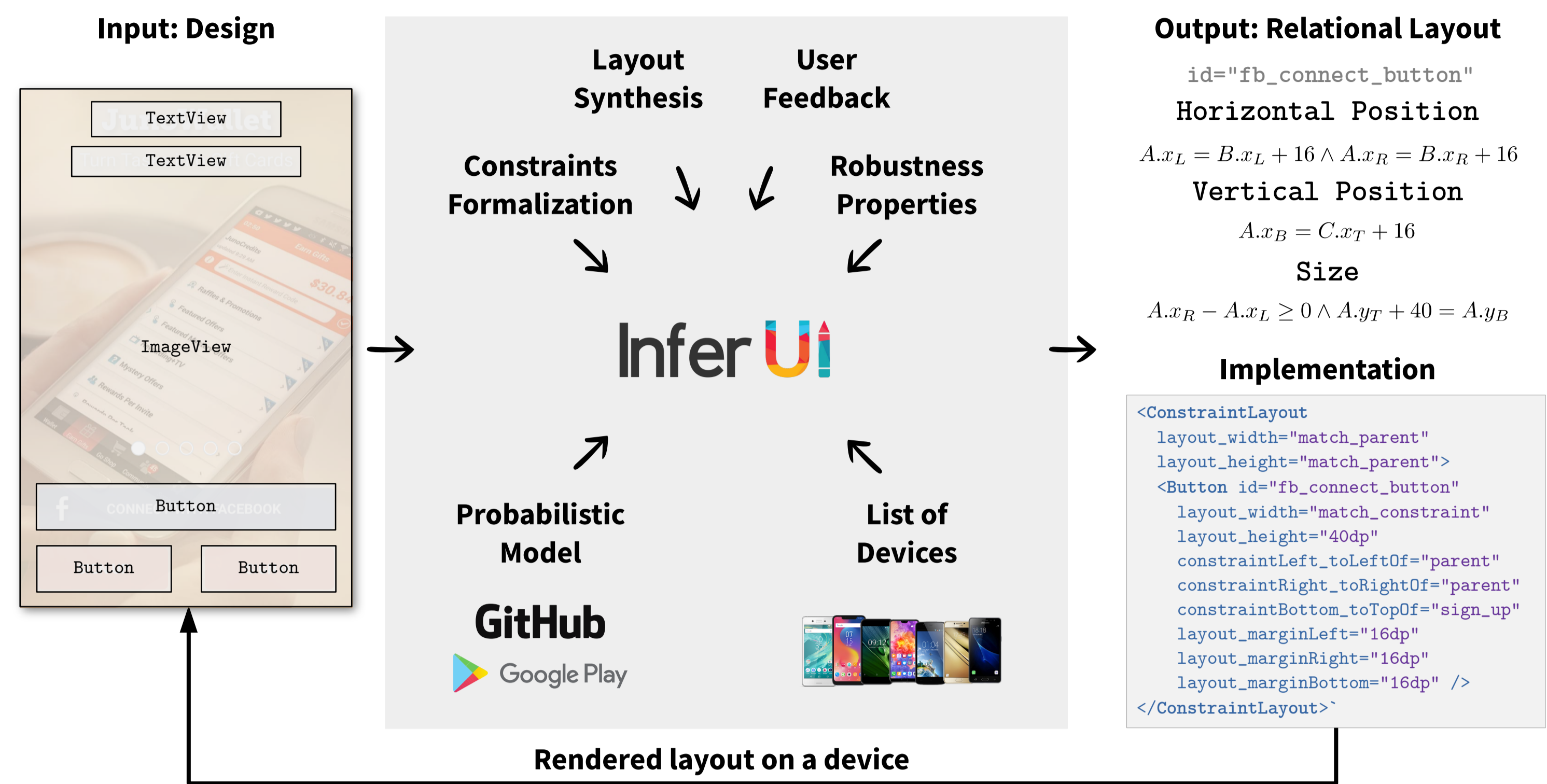
User Interface Design Today



Designer Developer

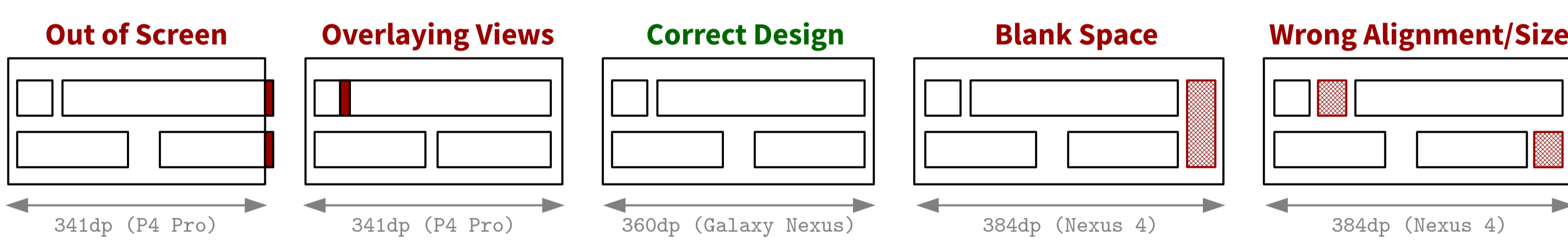
- ✗ Maintenance
- ✗ Time Consuming
- ✗ Layout Errors
- ✗ Performance
- ✗ Layout Porting

Our Work: InferUI



Layout Generalization Errors

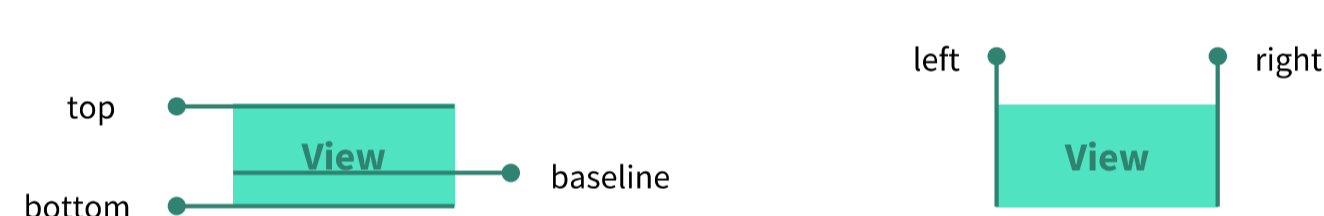
Discovered more than 100 layout errors in GitHub + PlayStore applications



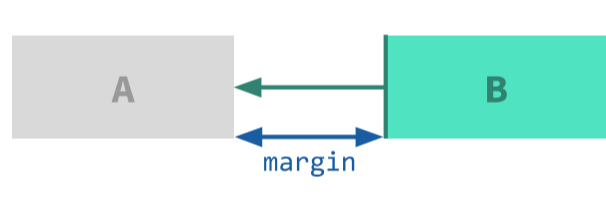
Constraint Formalization

Relate views to each other via set of constraints that specify their position and size

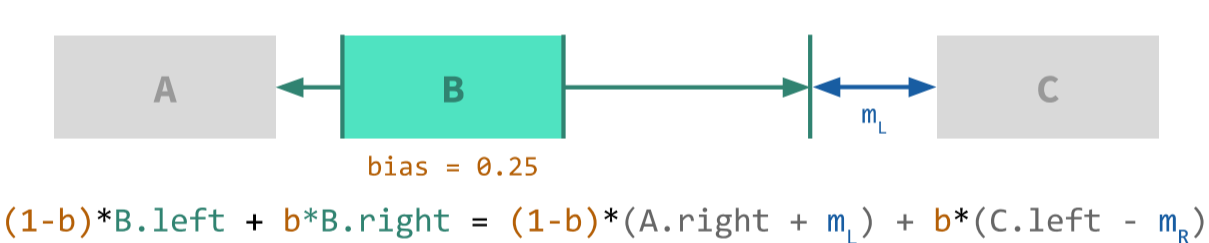
Handle points used to related views



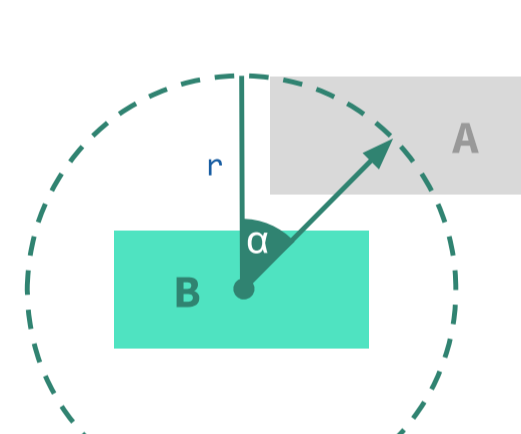
Relative Constraints



Fixed View Size Centering Constraints



Circular Constraints



Dynamic View Size Centering Constraints



Overall we formalize 26 types of constraints

Probabilistic Model of Constraints

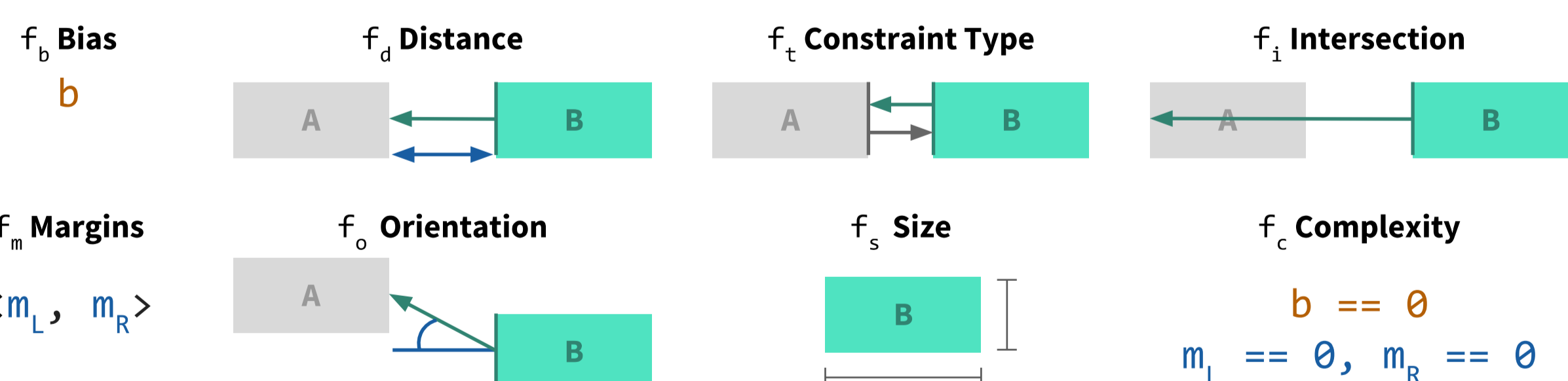
Learn a model that assigns probability that a given constraint is used based on its context

✓ Faster Synthesis

✓ Better Generalization

$$P(c \mid \text{screen}, v) = \frac{1}{Z(\text{screen}, v)} \prod P_f(c \mid f_k(c, \text{screen}, v))^{w_k}$$

weighted combination of models trained using maximum likelihood estimation over a set of feature functions



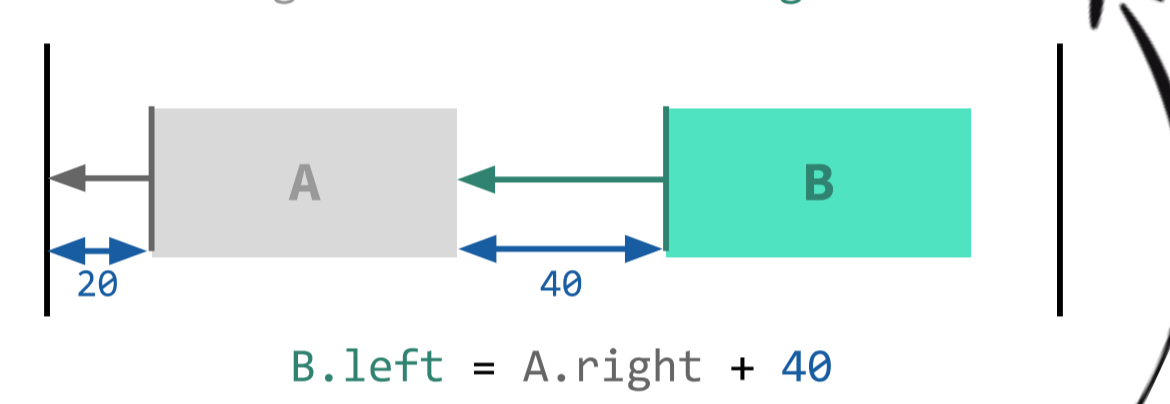
Feature functions used to learn a probabilistic model from existing GitHub and Google Play Store applications

Layout Synthesis

Layout Solving

Goal: Compute absolute position of all the views

$$A.\text{left} = ? \quad B.\text{left} = ? \\ A.\text{right} = ? \quad B.\text{right} = ?$$

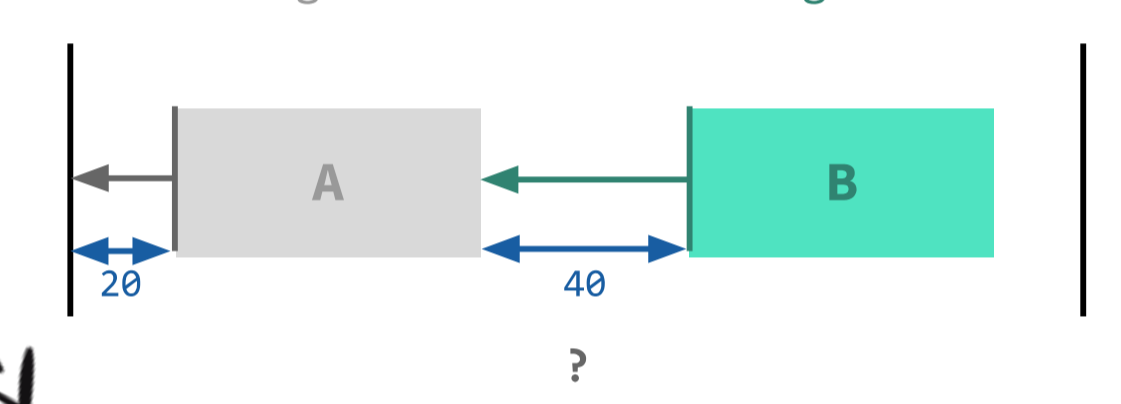


$$v \models \psi_{\text{layout}}(\text{screen}, c, s)$$

Layout Synthesis

Goal: Synthesize position and size constraints

$$A.\text{left} = 0 \quad B.\text{left} = 120 \\ A.\text{right} = 80 \quad B.\text{right} = 200$$



$$c \wedge s \models \psi_{\text{syn}}(\text{screen}, v)$$

Our Approach

1. Synthesize Layout Using Input Specification for a Single Device
2. Render on Multiple Devices
3. Check that Synthesized Layout Generalizes

All encoded as a single formula that can be solved by an off-the-shelf SMT solver

Layout Synthesis

Set of views and their desired absolute position on the screen \rightarrow SMT Encoding + Optimization \rightarrow Constraints specifying view size and its horizontal and vertical position

$$\text{syn}(\rho \in \text{View}, d \subset \text{View}, v \subset \text{View}) = \max_{\sum_{i=1}^{|v|} \text{score}^i} \left((c \wedge s) \models \psi_{\text{single-syn}}(\rho, v) \wedge \bigwedge_{k=1}^{|d|} \psi_{\text{gen}}(d_k, v, c, s) \right)$$

Synthesize most likely layout, Synthesize layout satisfying input specification, For each target device ensure that views generalize well

$$\psi_{\text{gen}}(d, v, c, s) \stackrel{\text{def}}{=} v_d \models \psi_{\text{layout}}(d, v, c, s) \wedge \left\{ \begin{array}{l} \text{Layout views on a device with different screen size} \\ \phi_{\text{inside_screen}}(d, v_d) \wedge \phi_{\text{pixel_perfect}}(v_d) \wedge \phi_{\text{preserve_aspect_ratio}}(v, v_d) \wedge \\ \phi_{\text{preserve_order}}(v, v_d) \wedge \phi_{\text{preserve_centering}}(v, v_d) \wedge \phi_{\text{preserve_margins}}(v, v_d) \end{array} \right.$$

$$\text{Single device synthesis from the input specification } \left\{ \begin{array}{l} \psi_{\text{single-syn}}(\rho \in \text{View}, v \subset \text{View}) = \phi_{\text{position}} \wedge \phi_{\text{valid}} \wedge \phi_{\text{constraints}} \wedge \phi_{\text{acyclic}} \\ \phi_{\text{position}} \stackrel{\text{def}}{=} (x_L^0 = \rho.x_L) \wedge (x_R^0 = \rho.x_R) \wedge \left(\bigwedge_{i=1}^{|v|} x_L^i = v^i.x_L \wedge x_R^i = v^i.x_R \right) \end{array} \right.$$

$$\phi_{\text{constraints}} \stackrel{\text{def}}{=} \bigwedge_{i=1}^{|v|} \left(\bigwedge_{k=0}^{|c^i|} g_k^i \Rightarrow \left(\bigwedge_{k=0}^{|c^i|} \text{score}^k = P(c_k^i, v) \right) \right) \wedge g_0^i + \dots + g_{|c^i|}^i = 1$$

Boolean flag denoting whether constraint was selected, Constraint probability, Select exactly one horizontal and one vertical constraint

Evaluation

Synthesis Success Rate / Runtime with Increasing Number of Views

| Algorithm | [2,4] | [4,8] | [8,12] | [12,16] |
|-------------------------|----------------------|----------------------|-----------------------|-----------------------|
| Single Device | | | | |
| Standard Synthesis | 99% 29 ms | 83% 94 ms | 38% 490 ms | 27% 1.8 s |
| Guided Synthesis | 100% 37 ms | 100% 59 ms | 100% 129 ms | 100% 519 ms |
| Multi Device | | | | |
| Standard Synthesis | 61% 49 ms | 24% 580 ms | 4% 19 s | 0% - |
| Guided Synthesis | 99% 44 ms | 93% 95 ms | 73% 314 ms | 56% 3 s |

Percentage of views that generalize to multiple devices

Constraint Naturalness

62%

of synthesized constraints are the same as written by a developer

View Generalization

87%

92%

GitHub Top 500 Google Play Top 500

+ Robustness Properties

↑

+ Probabilistic Model

↑

Synthesis Considers only Single Device

13%

User Feedback

63%

of layouts generalize with zero user feedback

25%

1 user feedback

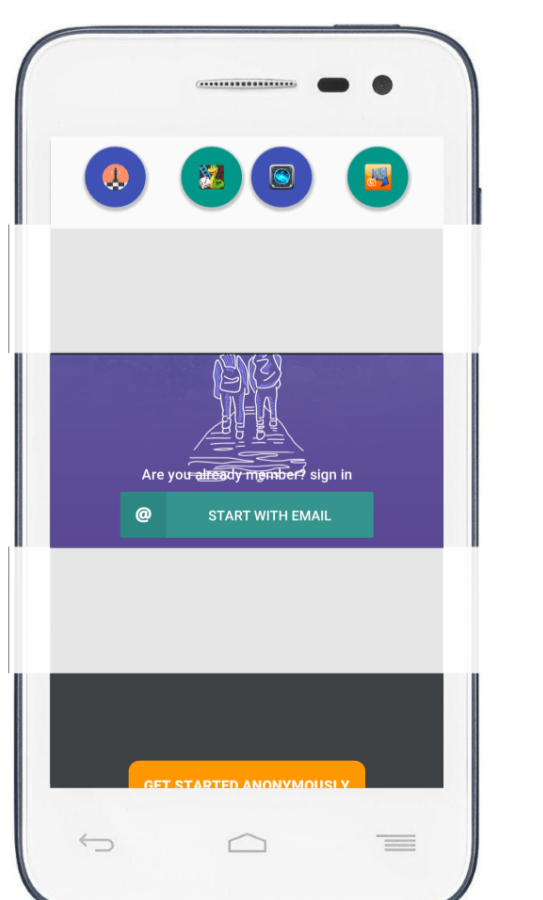
8%

2 user feedbacks

4%

3+ user feedbacks

Layout Errors



SPLASH OOPSLA
4th - 9th November 2018

BOSTON 2018