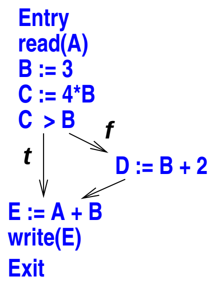
Constant Propagation

Discover values that are constant on all possible executions, and propagate values

Undecidable → Conservative methods

Can create new constants in process by constant folding

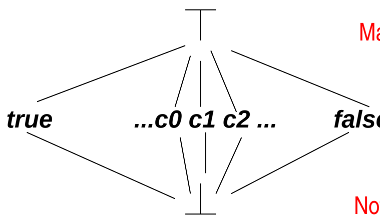
Ex.



→ read(A)
write(A+3)

Benefit?

Lattice for Constant Propagation



May be constant

constant

Not constant

$$\textit{any} \sqcap \top = \textit{any}$$

$$\textit{any} \sqcap \bot = \bot$$

$$c_i \sqcap c_j = \begin{cases} c_i & \text{if } i=j \\ \bot & \text{if } i \neq j \end{cases}$$

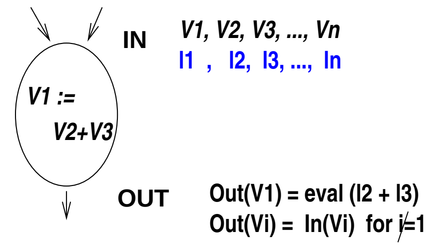
Initial value: $\top$

Simple Constant Propagation (Kildall)

Propagate constants through CFG, each branch equally likely

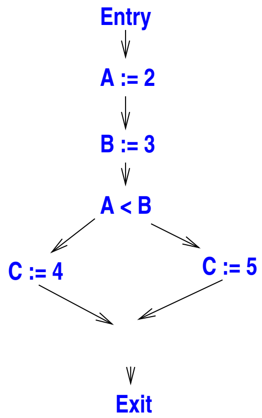
Worklist algorithm

$O(E * N^2)$



$$\text{eval(I2+I3)} = \begin{cases} \text{I2 + I3 if both are constants} \\ \perp \quad \text{ow if I2 or I3 is } \perp \\ \top \quad \text{ow if I2 or I3 is } \top \end{cases}$$

Simple CP Example



Sparse Simple CP (Reif & Lewis)

Propagate constants through SSA graph (def-use chains from SSA)

for expected efficiency (size of SSA graph)

Worklist algorithm

Assign lattice values to expressions e

- ***e not evaluated at compile time:*** $\perp$
- ***no variables in e*** ***eval(e)***
- ***o.w.*** $\top$

Initialize WL to set of SSA edges where def is not $\top$

Algorithm terminates when WL is empty

Sparse Simple CP (continued)

Take SSA edge off WL

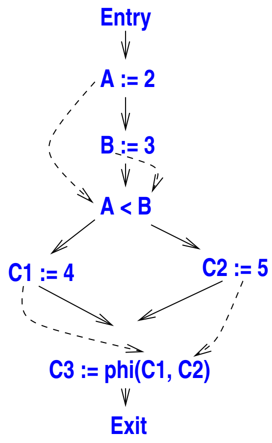
	V1 :=	*V1, V2, V3, ..., Vn*
		i1 , i2, i3, ..., in
	↓	
e:...	*Use(V1)*	*V1, V2, V3, ..., Vn*
		j1 , j2, j3, ..., jn

Compute **n1 = i1 $\sqcap$ j1**

If n1 $\neq$ j1, set j1 = n1

Evaluate e; if its value has changed, add to WL all SSA edges from e's node

Sparse Simple CP Example



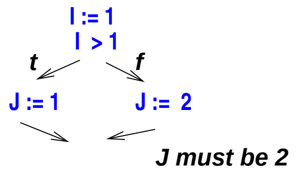
Conditional Constant Prop. (Wegbreit)

Propagate constants through CFG, taking branches into account

Performs CP + Unreachable code elimination

More powerful than SCP or SSCP

Ex.



Executable Edges:

Determined by symbolic execution, starting from Entry

If node with single successor executed, that successor edge is marked executable

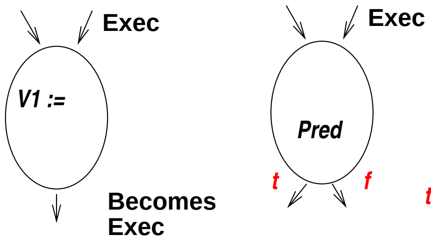
If predicate is executed, evaluate predicate and determine branch taken, if possible

Conditional CP (continued)

Worklist algorithm:

Each edge is initialized to be non-executable
The edge from Entry is marked executable, and put on WL

Proceed by symbolic execution:

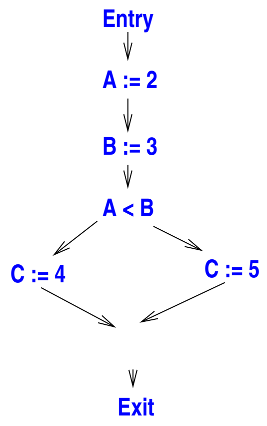


Eval(Pred)

$\perp$	then all branches exec.
true	then true branch exec.
false	then false branch exec.

$O(E * N^2)$

Conditional CP Example



Sparse Conditional CP (Wegman,Zadeck)

Like Conditional CP but uses SSA graph for efficiency

Like Sparse Simple CP but meet applied only to arguments which correspond to executable incoming edges to Phi function

O(# Flow edges + # SSA edges)

Assumes only 1 statement or predicate per node

Worklist Algorithm

- **FlowWL** *flow graph edge work list, initialized to edges out of Entry*
- **SSAWL** *SSA edge work list, initialized to empty set*
- **ExecFlag(e)** *records whether flow graph edge e is executable*
- **LatCell(V,B)** *lattice value for variable V at node B*

Sparse Conditional CP Algorithm

Do while (FlowWL nonempty or SSA WL nonempty)

Take edge e from WL.

If e is a flow edge, then if it is executable, do nothing

else Set ExecFlag to true

Call VisitPhi for all Phi functions at e's target

If this is the first time the target node is visited, Call VisitExp

if the target node has 1 out flow edge, add to WL

If e is a SSA edge, and its target has a Phi function, call VisitPhi

if its target is an expression, and an incoming flow edge to it is executable, then Call VisitExp

ow do nothing

Sparse Conditional CP Algorithm, cont.

VisitPhi: *Called when value of Lattice Cell of operand is lowered, or when edge becomes executable*

ex ↘ **nex** ↓ **ex** ↙

V4 := Phi(V1, V2, V3)

l1, $\perp$, l3

Compute l4 by taking meet of these values

VisitExp: ***Evaluate expression, taking values from lattice cells where defined***

If value of e changes,

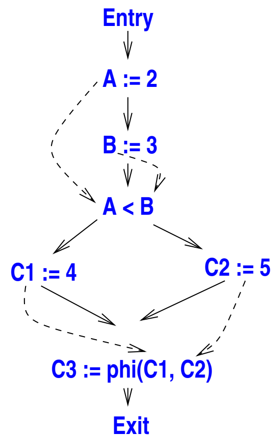
if its an asst., add all SSA edges starting at asst. to SSAWL

if its a pred., and value is $\perp$, then add all exit edges to FlowWL

value is a constant, add appropriate edge to Flow WL

Sparse Simple CP Example

SSAWL



FlowWL