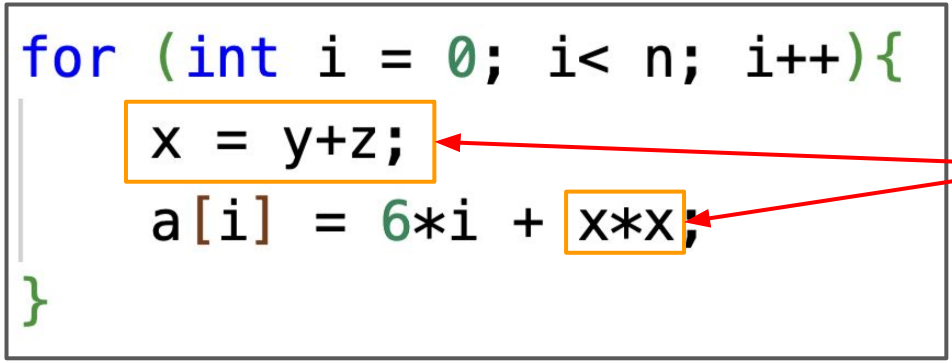
CSE 583 HW2

Frequent Path LICM

Due On: Oct 08, 2025

Loop Invariant Code Motion (LICM)



```
for (int i = 0; i< n; i++){
    x = y+z;
    a[i] = 6*i + x*x;
}
```

These values do not change within the body of the loop.

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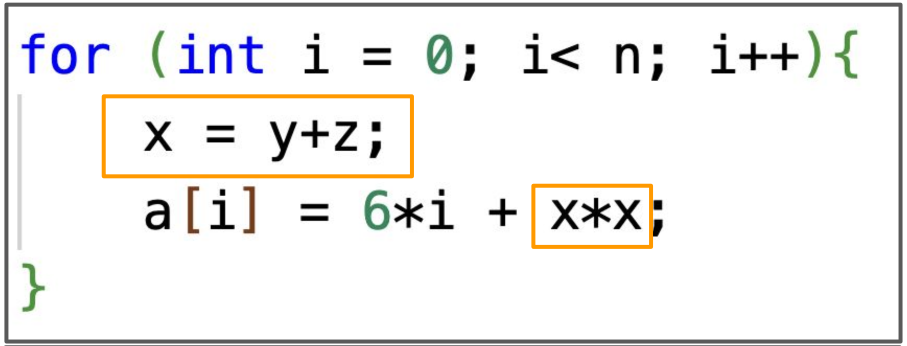

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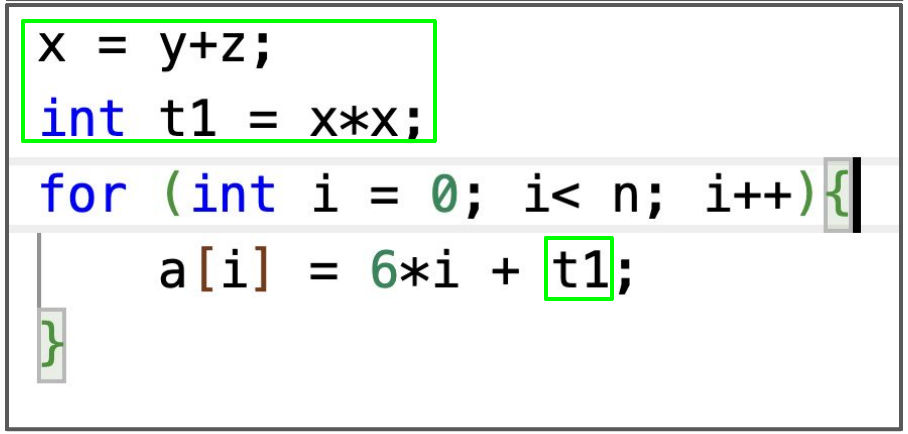


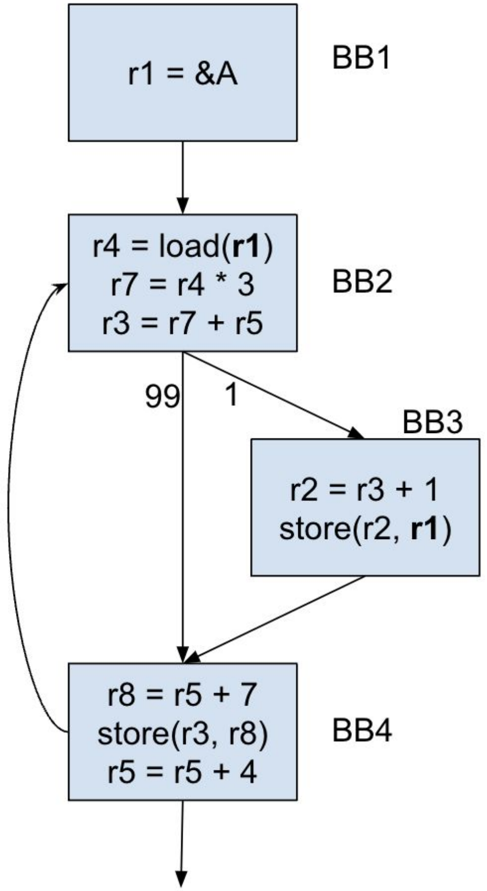
```
x = y+z;
int t1 = x*x;
for (int i = 0; i< n; i++){
    a[i] = 6*i + t1;
}
```

- Move operations whose source operands do not change within the loop to the loop preheader.
  - Execute them only 1x per invocation of the loop.
- LICM is already implemented in LLVM
  - /lib/Transforms/Scalar/LICM.cpp

Frequent Path LICM

- There is a store-load dependency.
- The load cannot be hoisted up because it is not invariant in the loop.

- But according to the profile data, it nearly never changes.

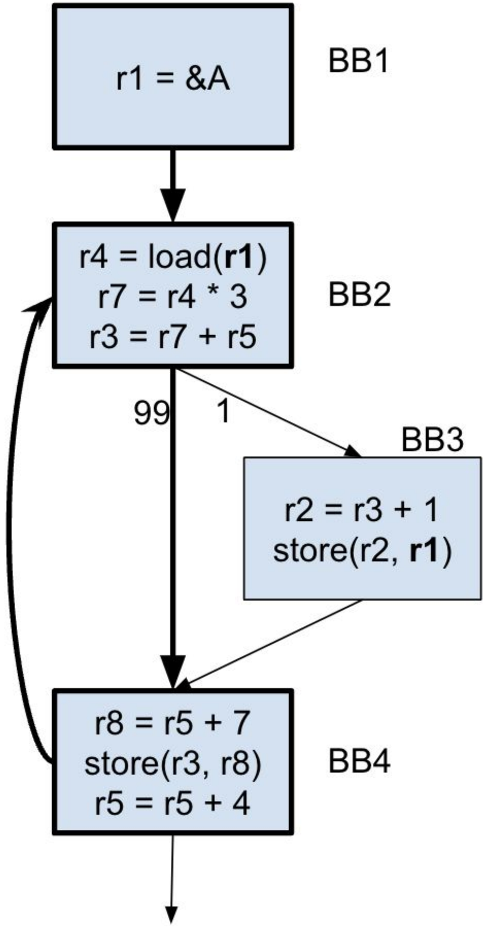


Implementation Steps

- Identify the loops. Then for each loop:
    - Identify the frequent path ($\geq$ 80%).
    - Identify loads that are invariant on the frequent path.
    - Perform LICM on those loads.
    - [Bonus] Perform LICM on other instructions.
    - Add fix-up code to ensure that the execution is correct.

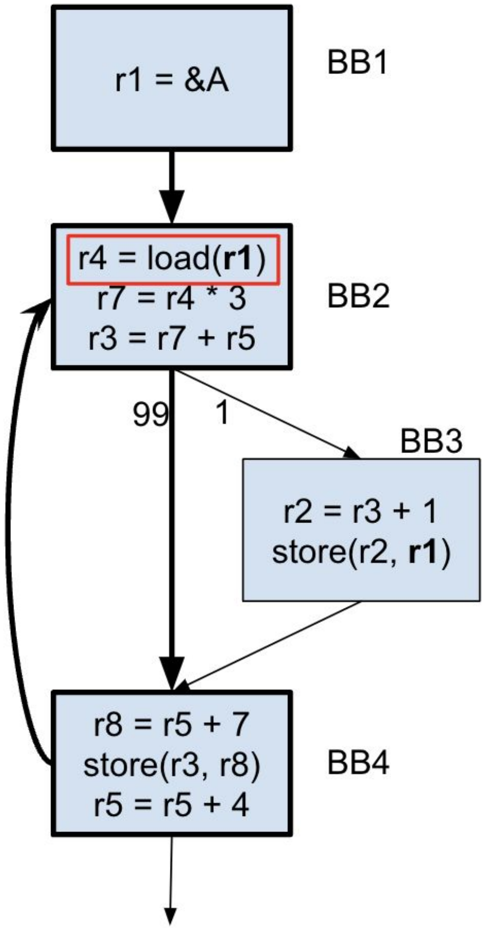
Identify the Frequent Path

- Start at the loop header, keep choosing the branch that is taken at least 80% of the time, or until the loop is closed.
- We do not consider the cumulative probabilities (they may drop lower).
- Everything not on the frequent path is considered to be on the infrequent path.



Identify the (Almost) Invariant Loads

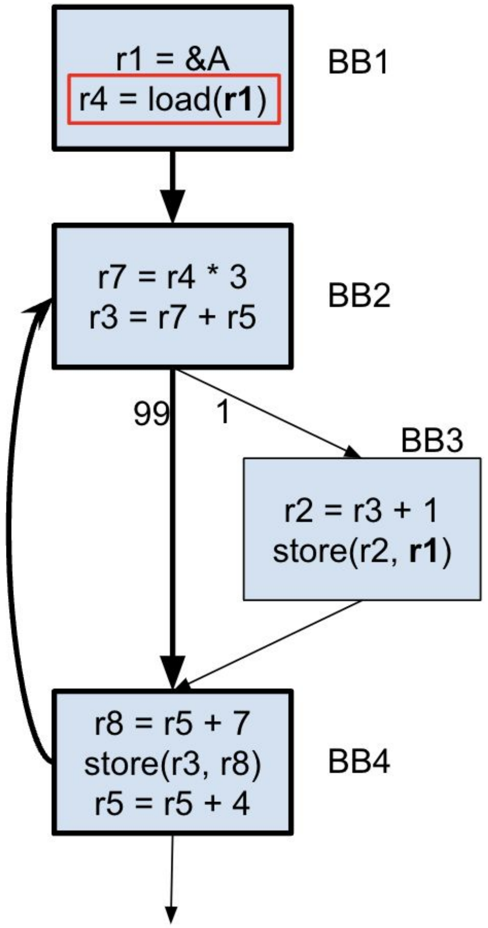
- Now that we consider only the frequent path, the load has become invariant.
- For the correctness pass, you only need to consider the loads.



Move the Load

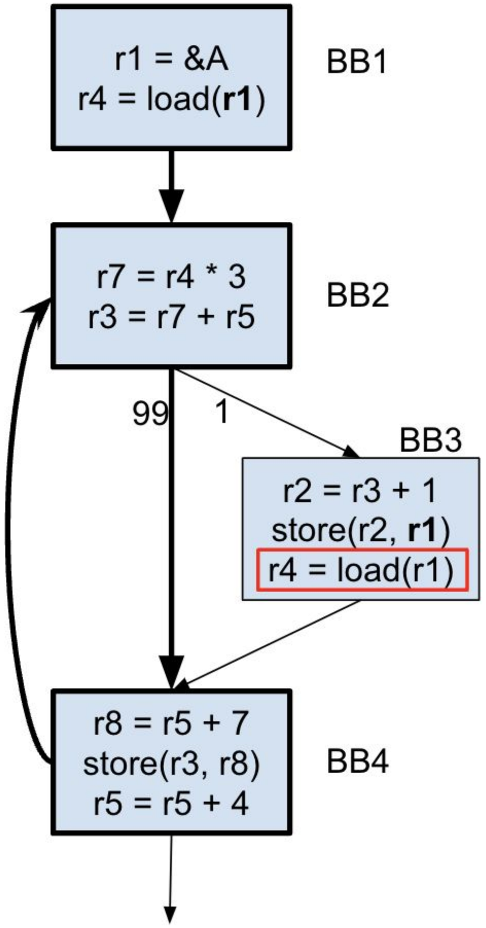
- We can now move the load up to the pre-header.
- This is the key optimization step as the load is now executed only once.

- However it is important to note that the program in its current state will not be correct.



Fixing Up

- Now that we have moved the load, we need to add code so that the program execution is correct.
- Just copying the load instruction to the infrequent path will ensure that it works correctly.

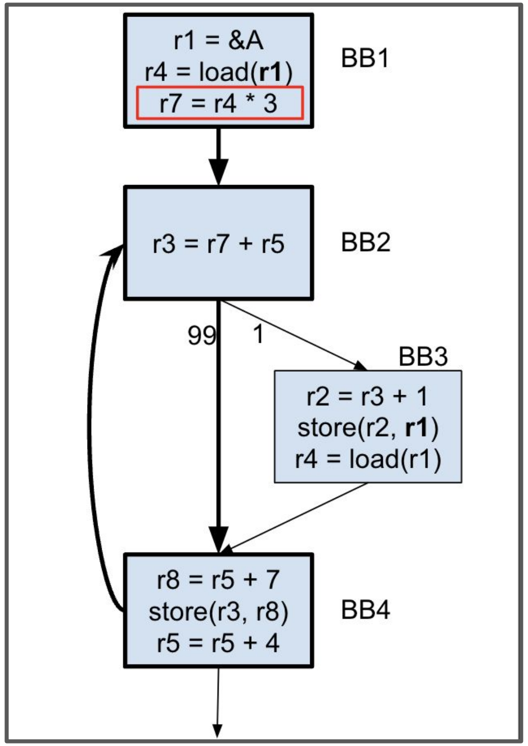


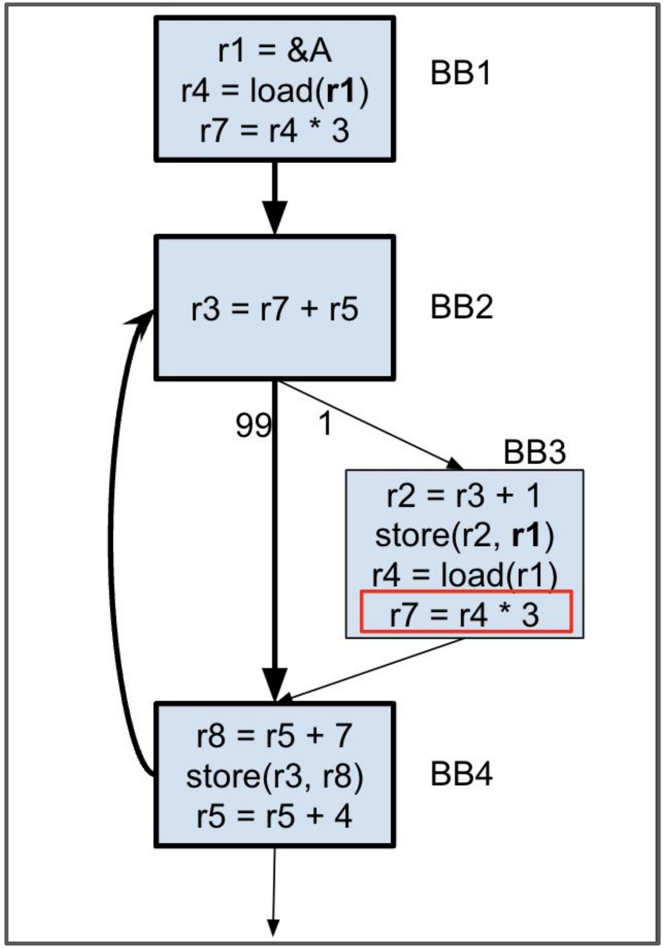
[BONUS] Move more instructions

Since we moved the load, the following instruction has also become invariant in the loop.

So we can move it up to the pre-header as well, adding to our gains.

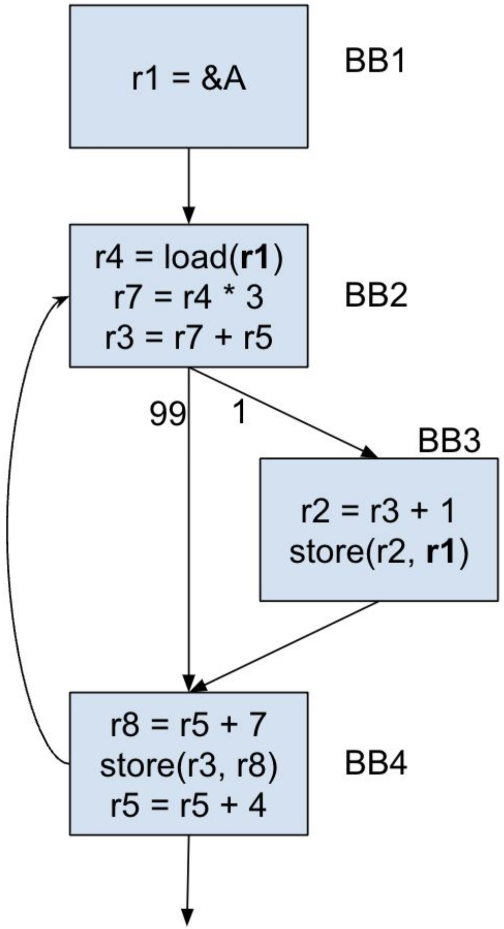
And we need to add the fix up code too.

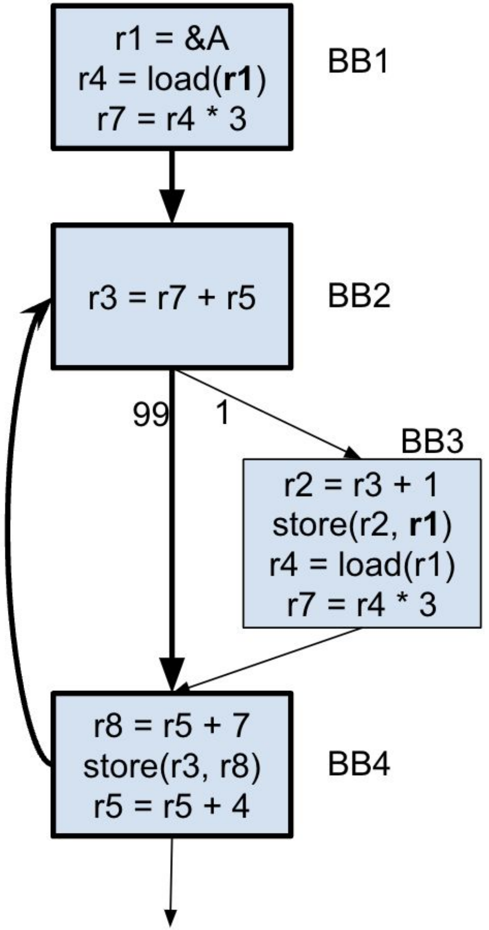




FPLICM

Before





After

HW2 Overview

- Implement FPLICM.
- Two passes:
  - Correctness (Mandatory):
    - Perform FPLICM on almost-invariant loads.
  - Performance (Bonus):
    - Perform FPLICM on any instruction.
    - Adjust heuristics (threshold for hot-path detection).
    - Any other optimization you want to do.

What you have been given

1. A run script
    a. Includes option to visualize the CFG
2. Benchmarks
    a. 6 correctness (Mandatory)
        i. Simple cases exploring different scenarios that your code should be able to handle.
    b. 4 performance (Optional)
        i. Cases with high trip counts and more opportunities for hoisting.
3. Basic template to write code in.

Some LLVM Resources

- Disclaimer: These are only recommendations, you do not have to use these.

Always a useful resource: https://llvm.org/docs/ProgrammersManual.html

Manipulating Basic Blocks

SplitBlock()

- Splits the BB at the specified instruction.

SplitEdge()

- Insert a BB on the edge connecting two specified BBs

Instructions and Variables

- Most Instructions have a constructor (look at the documentation)
    - It allows you to specify operands
    - It also allows you to specify where you want to insert this instruction.
- Many instructions also have a clone() function
- Functions that are useful across all Instructions are in llvm/IR/Instructions.h
    - These include functions that can be used to insert/move instructions
- Use AllocaInst to allocate memory space on the stack.

An important note on SSA

- LLVM is in SSA form.
- This means that when you clone an instruction, the **LHS** will be different.
- You need to ensure that the correct values are used in the correct places.
    - One solution is to store the value onto the stack (in the pre-header) and retrieve it before any use.
    - A better solution is to use PHI nodes to merge the values of the copy and the moved instruction.

Final Notes

- Read the spec and the **Piazza post** carefully and thoroughly.
- Start early.
- Make sure you do not break the program.
- Use the **-v** option on the run script to visualize the CFG and debug.
- Start with the given script and template.
- If you finish early, attempt the bonus part.
- Check Piazza frequently, someone may have encountered the same issues as you.
- For performance, your code needs to be correct, not just fast.