Shri Ramdeobaba College of Engineering and Management
Compiler Design Lab (CSP327) Mini project Report
Session 2024-2025

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Problem Statement: Construct A Dag With Visualization And Find The Optimal Sequence Using Heuristic Algorithm.

PROBLEM DEFINATION :

This program takes a list of **three-address code (TAC) instructions** and constructs a **Directed Acyclic Graph (DAG)** to represent the sequence of operations and their dependencies. While it naturally helps eliminate repeated calculations, the main objective is to apply a **heuristic-based node ordering** strategy to determine an efficient sequence for evaluating the expressions.

The **heuristic ordering** ensures that each node (i.e., operation) in the DAG is computed only after all its required inputs (parent nodes) are ready. This results in an optimized, dependency-respecting evaluation order, which can later be used for efficient code generation or further compiler optimization steps. The final DAG is also visualized to better understand the flow and structure of the computation.

Solution Description:

This code takes a list of **three-address code (TAC)** instructions and builds a **Directed Acyclic Graph (DAG)** to represent how the expressions are computed. Instead of just focusing on removing common subexpressions, it mainly uses a **smart (heuristic) node ordering** to decide the most efficient sequence to evaluate expressions. It tracks the relationships between variables and operations, organizes them in a graph, and then visualizes that graph in a clear, hierarchical layout. Finally, it outputs an optimized order to compute the intermediate results by carefully analyzing dependencies between operations.

Core Data Structures:

nodes = [ ]

label_to_node_index = { }

- nodes is a list that will store all the nodes in our graph
- label_to_node_index keeps track of which node each variable name (label) belongs to

Node Creation Functions:

def create_node(op, left_index, right_index):

- Creates a new node in the graph with an operation and connections to other nodes
- Returns the index of the newly created node
- Each node has: operation, left child, right child, and variable names (labels)

def find_node(op, left_index, right_index):

- Looks through existing nodes to find one with matching operation and connections
- Returns the index if found, otherwise None
- Helps avoid creating duplicate nodes

def ensure_node_for_label(label):

- Makes sure a variable name has a corresponding node
- If not, creates a new leaf node (with no operation) for this variable
- Returns the node index for this variable

def attach_label_to_node(label, node_index):

- Associates a variable name with a specific node
- If the label was previously attached to another node, it moves it
- Important for handling variable reassignments

Instruction Parsing Functions:

def parse_instruction(instr):

- Takes a line of code like "x := y + z" and breaks it down into parts
- Returns a tuple: (result_variable, operation, first_operand, second_operand)
- Handles different formats including array access like "x := arr[i]"

def process_instruction(x, op, y, z):

- Takes the parsed instruction parts and updates the graph
- Creates nodes for variables if needed
- Finds or creates operation nodes
- Links the result variable to the appropriate node

def construct_dag_from_instructions(instructions):

- Main function that processes a list of instructions
- Calls parse_instruction and process_instruction for each line
- Returns the complete graph (list of nodes)

Heuristic Ordering Functions :

def node_listing():

- Determines a good order to compute nodes based on dependencies
- Creates a topological sort of the graph, optimized for efficient calculation
- Identifies interior nodes (ones with operations) and builds an evaluation order

Visualization Functions:

def hierarchical_layout(G):

- Arranges nodes in levels for clear visualization
- Places nodes with no inputs at the top, and their dependents below
- Creates coordinates for each node in the visualization

def visualize_dag(nodes):

- Converts our internal graph representation to a NetworkX graph
- Sets up node labels showing operations and variable names
- Creates a visual representation of the graph
- Displays the final graph visualization

CODE :

```
import networkx as nx
import matplotlib.pyplot as plt
nodes = []
label_to_node_index = {}
def create_node(op, left_index, right_index):
   node = {
      "op": op,
      "left": left_index,
      "right": right_index,
      "labels": []
   }
   nodes.append(node)
   return len(nodes) - 1
def find_node(op, left_index, right_index):
   for idx, n in enumerate(nodes):
      if n["op"] == op and n["left"] == left_index and n["right"] == right_index:
         return idx
```

```
    return None


def ensure_node_for_label(label):
    if label not in label_to_node_index:
        idx = create_node(op=None, left_index=None, right_index=None)
        nodes[idx]["labels"].append(label)
        label_to_node_index[label] = idx
    return label_to_node_index[label]
def attach_label_to_node(label, node_index):
    if label in label_to_node_index:
        old_idx = label_to_node_index[label]
        if old_idx != node_index and label in nodes[old_idx]["labels"]:
            nodes[old_idx]["labels"].remove(label)
    if label not in nodes[node_index]["labels"]:
        nodes[node_index]["labels"].append(label)
    label_to_node_index[label] = node_index
def parse_instruction(instr):
    left, right = instr.split(":=")
    x = left.strip()
    right = right.strip()
    if "[" in right and "]" in right:
        array_name, inside = right.split("[")
        array_name = array_name.strip()
        inside = inside.replace("]", "").strip()
        return (x, "[]", array_name, inside)
    parts = right.split()
    if len(parts) == 3:
        y, op, z = parts
        return (x, op, y, z)
    elif len(parts) == 2:
```

```
        op, y = parts
        return (x, op, y, None)
    else:
        return (x, None, right, None)
def process_instruction(x, op, y, z):
    y_index = ensure_node_for_label(y) if y is not None else None
    z_index = ensure_node_for_label(z) if z is not None else None
    if op is None:
        n_index = y_index
    elif op == "[]":
        existing = find_node(op, y_index, z_index)
        n_index = existing if existing is not None else create_node(op, y_index, z_index)
    else:
        if z is None:
            existing = find_node(op, y_index, None)
            n_index = existing if existing is not None else create_node(op, y_index, None)
        else:
            existing = find_node(op, y_index, z_index)
            n_index = existing if existing is not None else create_node(op, y_index, z_index)
    attach_label_to_node(x, n_index)
def construct_dag_from_instructions(instructions):
    for instr in instructions:
        x, op, y, z = parse_instruction(instr)
        process_instruction(x, op, y, z)
    return nodes
def node_listing():
    num_nodes = len(nodes)
    parents = {i: [] for i in range(num_nodes)}
    for i, node in enumerate(nodes):
        if node["left"] is not None:
```

```
            parents[node["left"]].append(i)
        if node["right"] is not None:
            parents[node["right"]].append(i)
    interior_nodes = {i for i, node in enumerate(nodes) if node["op"] is not None}
    listed = set()
    order = []
    def parents_listed(i):
        return all(p in listed for p in parents[i])
    while interior_nodes - listed:
        n = None
        for i in interior_nodes - listed:
            if parents_listed(i):
                n = i
                break
        if n is None:
            break
        order.append(n)
        listed.add(n)
        m = nodes[n]["left"]
        while m is not None and nodes[m]["op"] is not None and m not in listed and
parents_listed(m):
            order.append(m)
            listed.add(m)
            n = m
            m = nodes[n]["left"]
    return order
def hierarchical_layout(G):
    levels = {}
    for node in nx.topological_sort(G):
        if G.in_degree(node) == 0:
            levels[node] = 0
```

```
        else:
            levels[node] = max(levels[p] for p in G.predecessors(node)) + 1

    level_nodes = {}
    for node, level in levels.items():
        level_nodes.setdefault(level, []).append(node)
    pos = {}
    for level, nodes in level_nodes.items():
        num_nodes = len(nodes)
        x_spacing = 1.0 / (num_nodes + 1)
        for i, node in enumerate(sorted(nodes)):
            pos[node] = ((i + 1) * x_spacing, -level)
    return pos
def visualize_dag(nodes):
    G = nx.DiGraph()
    for idx, node in enumerate(nodes):
        label = (f"{node['op']}\n({', '.join(node['labels'])})"
                 if node["op"] is not None else ", ".join(node["labels"]))
        G.add_node(idx, label=label)
    for idx, node in enumerate(nodes):
        if node["left"] is not None:
            G.add_edge(idx, node["left"])
        if node["right"] is not None:
            G.add_edge(idx, node["right"])
    pos = hierarchical_layout(G)
    labels = nx.get_node_attributes(G, 'label')
    plt.figure(figsize=(8, 6))
    nx.draw(G, pos, labels=labels, node_color='lightblue', node_size=2000,
            font_size=10, arrows=True)
    plt.title("Hierarchical DAG Visualization")
```

```
    plt.show()


if __name__ == "__main__":
    instructions = [
        "t1 := a + b",
        "t2 := t1 - e",
        "t3 := a + b",
        "t4 := t2 * t3",
        "t5 := t4 + f",
        "t6 := t4 - g",
        "t7 := t5 * t6"
    ]
    dag = construct_dag_from_instructions(instructions)
    print("DAG Construction for Three-Address Code:")
    for idx, node in enumerate(dag):
        print(f"Node {idx}: op={node['op']}, left={node['left']}, right={node['right']}, 
labels={node['labels']}")
    visualize_dag(dag)


    ordering = node_listing()
    print("\nOptimal Sequence after Heuristic Ordering (Interior Nodes):")
    for i, node_idx in enumerate(ordering):
        node = nodes[node_idx]
        print(f"{i+1}. Node {node_idx} -> op: '{node['op']}', labels: {node['labels']}")


    print("\nFinal Sequence:")
    temp = list()
    for i, node_idx in enumerate(ordering):
        node = nodes[node_idx]
        temp.append(node['labels'])
    ans = temp[::-1]
```

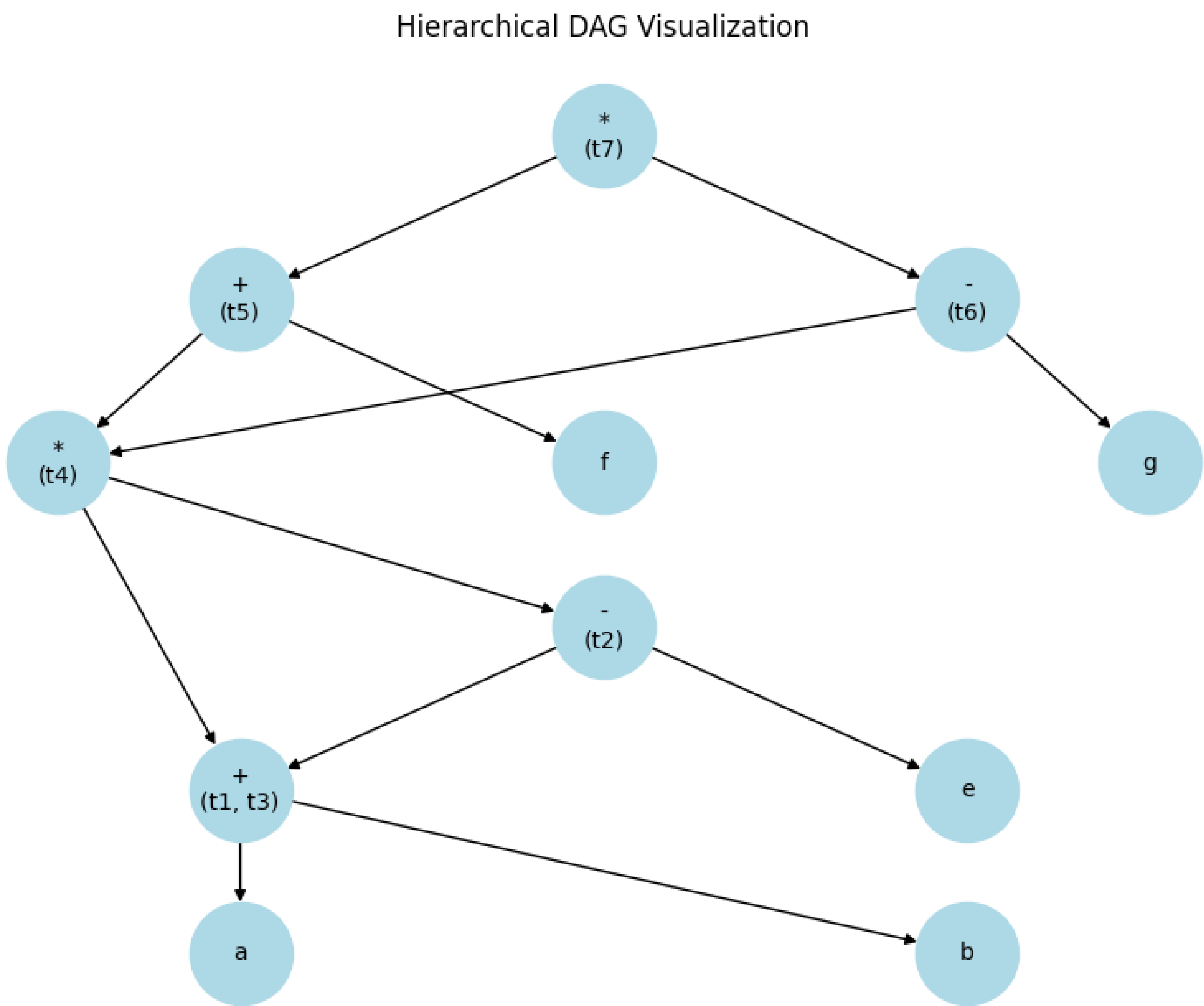
```
print(ans)
```

INPUT 1: THREE ADRESS CODE (TAC)

```
instructions = [
    "t1 := a + b",
    "t2 := t1 - e",
    "t3 := a + b",
    "t4 := t2 * t3",
    "t5 := t4 + f",
    "t6 := t4 - g",
    "t7 := t5 * t6"]
```

OUTPUT :

```
DAG Construction for Three-Address Code:
Node 0: op=None, left=None, right=None, labels=['a']
Node 1: op=None, left=None, right=None, labels=['b']
Node 2: op=+, left=0, right=1, labels=['t1', 't3']
Node 3: op=None, left=None, right=None, labels=['e']
Node 4: op=-, left=2, right=3, labels=['t2']
Node 5: op=*, left=4, right=2, labels=['t4']
Node 6: op=None, left=None, right=None, labels=['f']
Node 7: op=+, left=5, right=6, labels=['t5']
Node 8: op=None, left=None, right=None, labels=['g']
Node 9: op=-, left=5, right=8, labels=['t6']
Node 10: op=*, left=7, right=9, labels=['t7']
```



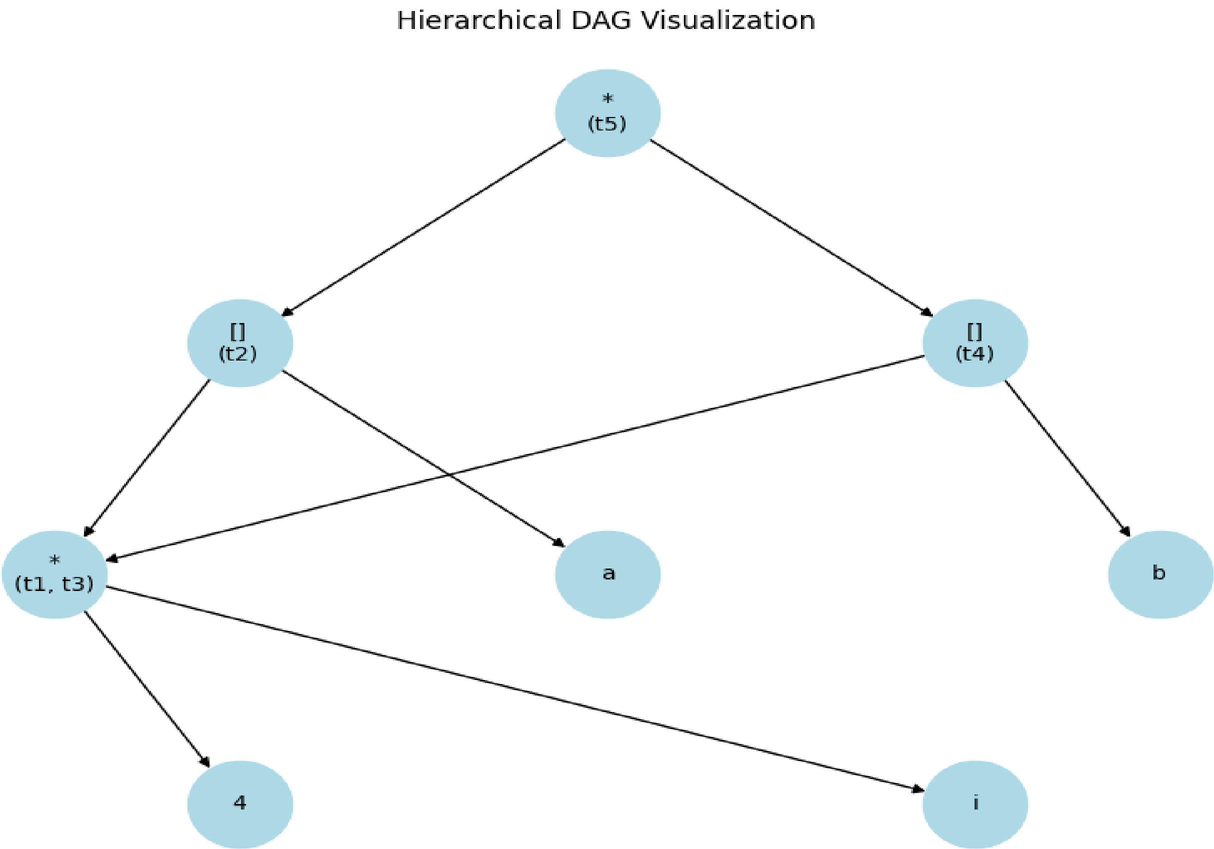
Optimal Sequence :

```
Optimal Sequence after Heuristic Ordering (Interior Nodes):
1. Node 10 -> op: '*', labels: ['t7']
2. Node 7 -> op: '+', labels: ['t5']
3. Node 9 -> op: '-', labels: ['t6']
4. Node 5 -> op: '*', labels: ['t4']
5. Node 4 -> op: '-', labels: ['t2']
6. Node 2 -> op: '+', labels: ['t1', 't3']

Final Sequence:
[['t1', 't3'], ['t2'], ['t4'], ['t6'], ['t5'], ['t7']]
```

INPUT 2: THREE ADRESS CODE (TAC)

```
instructions = [
    "t1 := 4 * i",
    "t2 := a[t1]",
    "t3 := 4 * i",
    "t4 := b[t3]",
    "t5 := t2 * t4"
 ]
```




```
Optimal Sequence after Heuristic Ordering (Interior Nodes):
1. Node 7 -> op: '*', labels: ['t5']
2. Node 4 -> op: '[]', labels: ['t2']
3. Node 6 -> op: '[]', labels: ['t4']
4. Node 2 -> op: '*', labels: ['t1', 't3']

Final Sequence:
[['t1', 't3'], ['t4'], ['t2'], ['t5']]
```

GITHUB REPOSITORY LINK :
https://github.com/Hassanahmd210/Compiler_design_miniproject.git