Data Structures and Circuit Representation

This document details the data structures and circuit representation methods used in the project, serving as a common reference for team members.

1. Circuit Vector Representation

Circuits are represented using integer vectors in the following format:

```
[feed_unit, unit0_high, unit0_inter, unit0_tail, unit1_high, unit1_inter, unit1_tail, ...]
```

Where:

- `feed_unit`: Index of the unit receiving the circuit feed (0 to num_units-1)
- `unitX_high`: Destination of the high-grade concentrate stream from unit X
- `unitX_inter`: Destination of the intermediate stream from unit X
- `unitX_tail`: Destination of the tailings stream from unit X

Destinations can be:

- `0` to `num_units-1`: Index of the unit receiving the stream
- `-1` (PALUSZNIUM_PRODUCT): Final Palusznium concentrate product
- `-2` (GORMANIUM_PRODUCT): Final Gormanium concentrate product
- `-3` (TAILINGS_OUTPUT): Final tailings output

Example

For a circuit with 3 units, a vector might be:

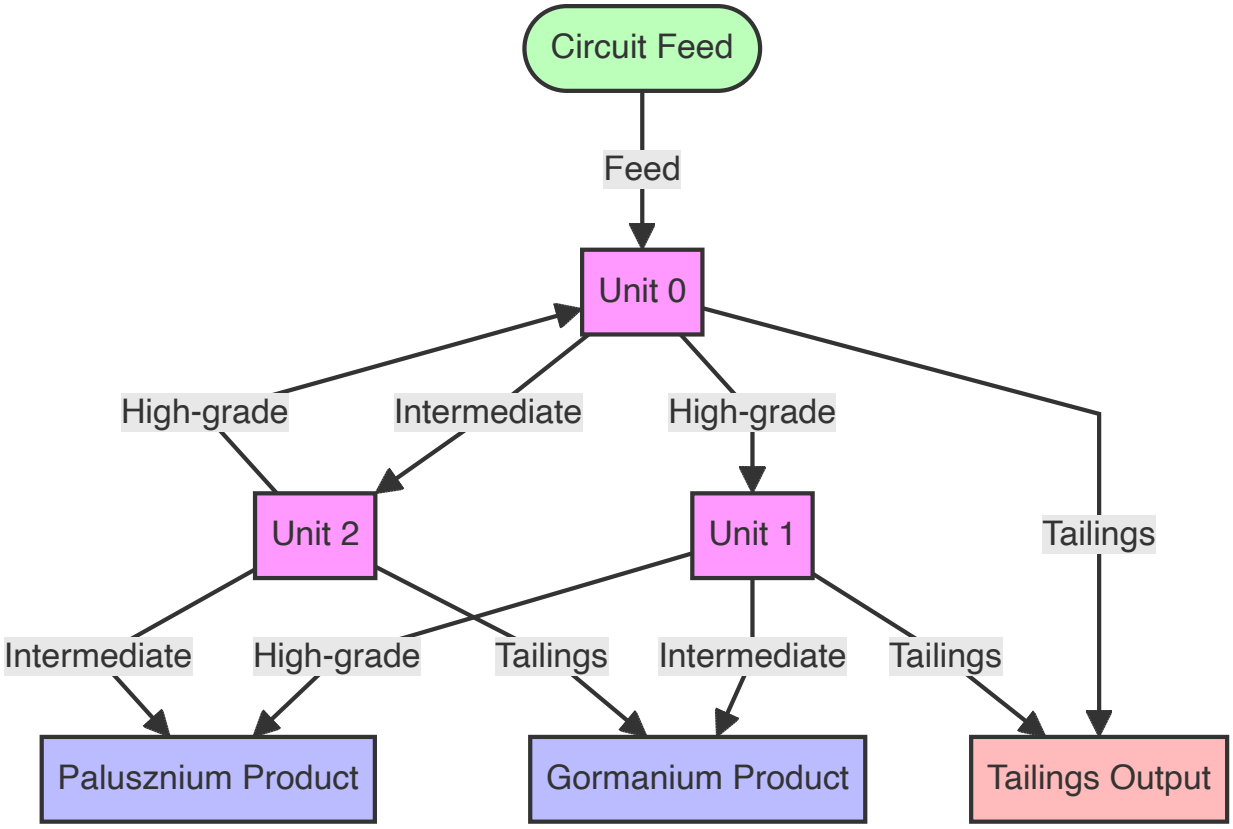
```
[0, 1, 2, -3, -1, -2, -3, 0, -1, -2]
```

This represents:

- Feed enters unit 0
- High-grade stream from unit 0 goes to unit 1
- Intermediate stream from unit 0 goes to unit 2
- Tailings stream from unit 0 goes to tailings output
- High-grade stream from unit 1 goes to Palusznium product
- Intermediate stream from unit 1 goes to Gormanium product
- Tailings stream from unit 1 goes to tailings output
- High-grade stream from unit 2 goes back to unit 0
- Intermediate stream from unit 2 goes to Palusznium product

- Tailings stream from unit 2 goes to Germanium product

Visual Representation



2. Key Data Structures

2.1 Separation Unit (CUnit)

The `CUnit` class represents a single separation unit, containing the following key properties:

- Connection properties:
  - `conc_num`: Unit connected to high-grade concentrate stream
  - `inter_num`: Unit connected to intermediate stream
  - `tails_num`: Unit connected to tailings stream
  - `mark`: Boolean flag used during graph traversal
- Physical properties:
  - `volume`: Unit volume (m^3)
  - Feed flow rates: `feed_palusznium`, `feed_gormanium`, `feed_waste`
  - Separation constants: `k_palusznium_high`, `k_palusznium_inter`, `k_gormanium_high`, `k_gormanium_inter`, `k_waste_high`, `k_waste_inter`

2.2 Circuit (Circuit)

The `Circuit` class represents the entire separation circuit, with key functions:

- Initialize circuit configuration from circuit vector
- Check circuit validity
- Run mass balance calculations
- Calculate economic value of the circuit
- Calculate recovery and grade metrics
- Generate visualization output

2.3 Simulator Parameters (Simulator_Parameters)

The `Simulator_Parameters` structure contains all parameters needed for simulation:

- Convergence parameters: `tolerance`, `max_iterations`
- Material properties: `material_density`, `solids_content`
- Separation constants
- Feed flow rates
- Economic parameters
- Unit volume parameters
- Visualization options

2.4 Genetic Algorithm Parameters (Algorithm_Parameters)

The `Algorithm_Parameters` structure contains all genetic algorithm parameters:

- General parameters: `max_iterations`, `population_size`, `elite_count`
- Selection parameters: `selection_pressure`
- Crossover parameters: `crossover_probability`, `crossover_points`
- Mutation parameters: `mutation_probability`, `mutation_step_size`
- Termination criteria: `convergence_threshold`, `stall_generations`
- Debug options: `verbose`, `log_results`

2.5 Circuit Vector (CircuitVector)

The `CircuitVector` class provides a convenient interface for working with circuit vectors:

- Constructors for empty or specified-size vectors
- Get/set unit connections
- Random generation of valid circuits
- Import/export circuit configurations

3. Interfaces and Function Signatures

3.1 Circuit Validity Check

```cpp
bool Circuit::check_validity(int vector_size, const int* circuit_vector);
```

3.2 Circuit Performance Evaluation

```cpp
double circuit_performance(int vector_size, int* circuit_vector,
                           int unit_parameters_size, double* unit_parameters,
                           Simulator_Parameters simulator_parameters);
```

3.3 Optimization Function

```cpp
int optimize(int int_vector_size, int* int_vector,
             std::function<double(int, int*)> func,
             std::function<bool(int, int*)> validity,
             Algorithm_Parameters algorithm_parameters);
```

4. Global Constants

All global constants are defined in `constants.h`, including:

- Physical constants: material density, solids content, separation constants
- Economic parameters: product values, waste penalties, operating costs
- Default feed flow rates
- Circuit parameters: unit volumes, circuit volume limits
- Simulation parameters
- Genetic algorithm parameters

5. Circuit Validity Rules

Valid circuits must satisfy the following conditions:

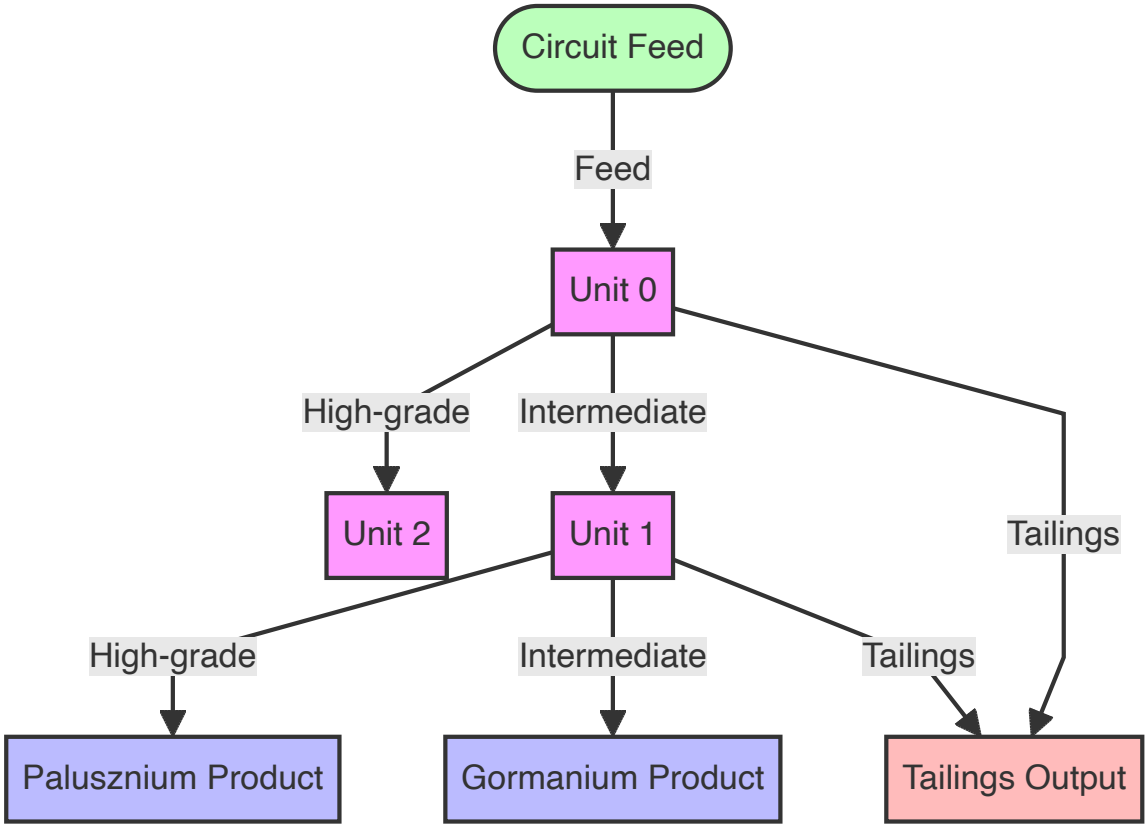
1. Every unit must be accessible from the feed
2. Every unit must have a path to at least two outlet product streams
3. No self-recycling (a unit's output cannot connect directly back to itself)
4. All products from a unit should not point to the same destination

Circuits that violate these conditions may fail to converge or be physically unreasonable.

Appendix A: Common Circuit Configurations

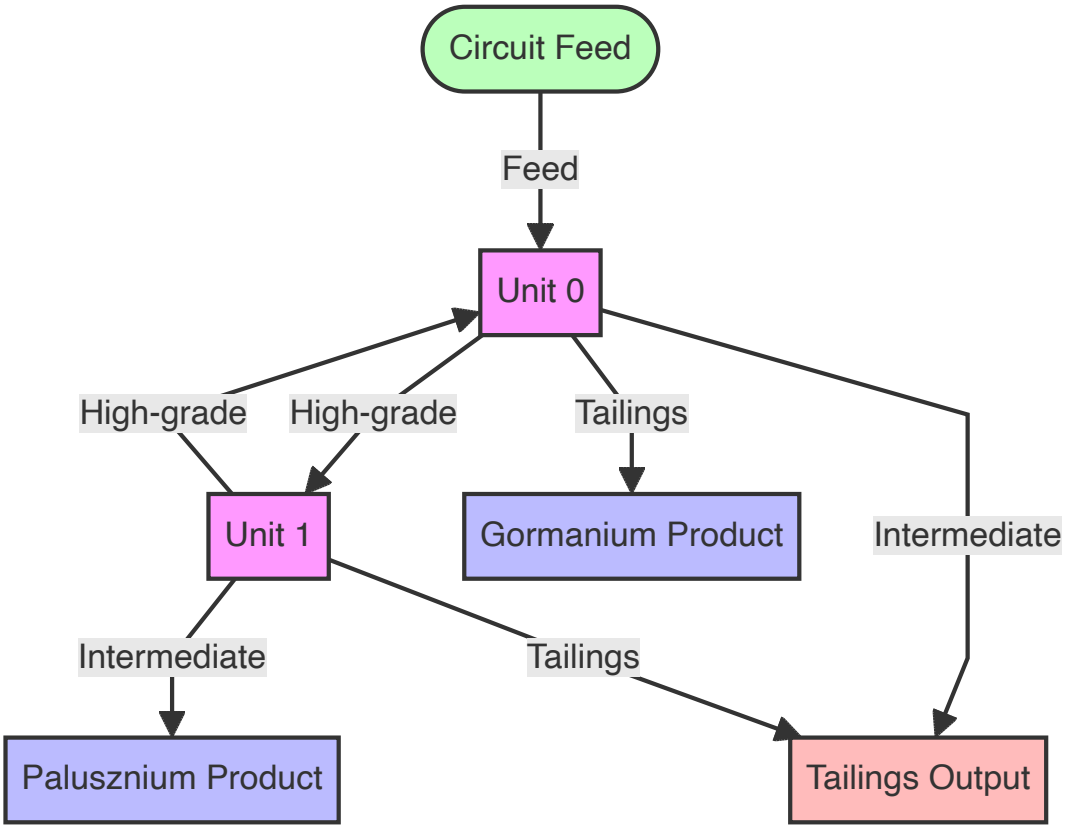
A.1 Two-Stage Simple Circuit

Vector: `[0, 2, 1, -3, -1, -2, -3]`



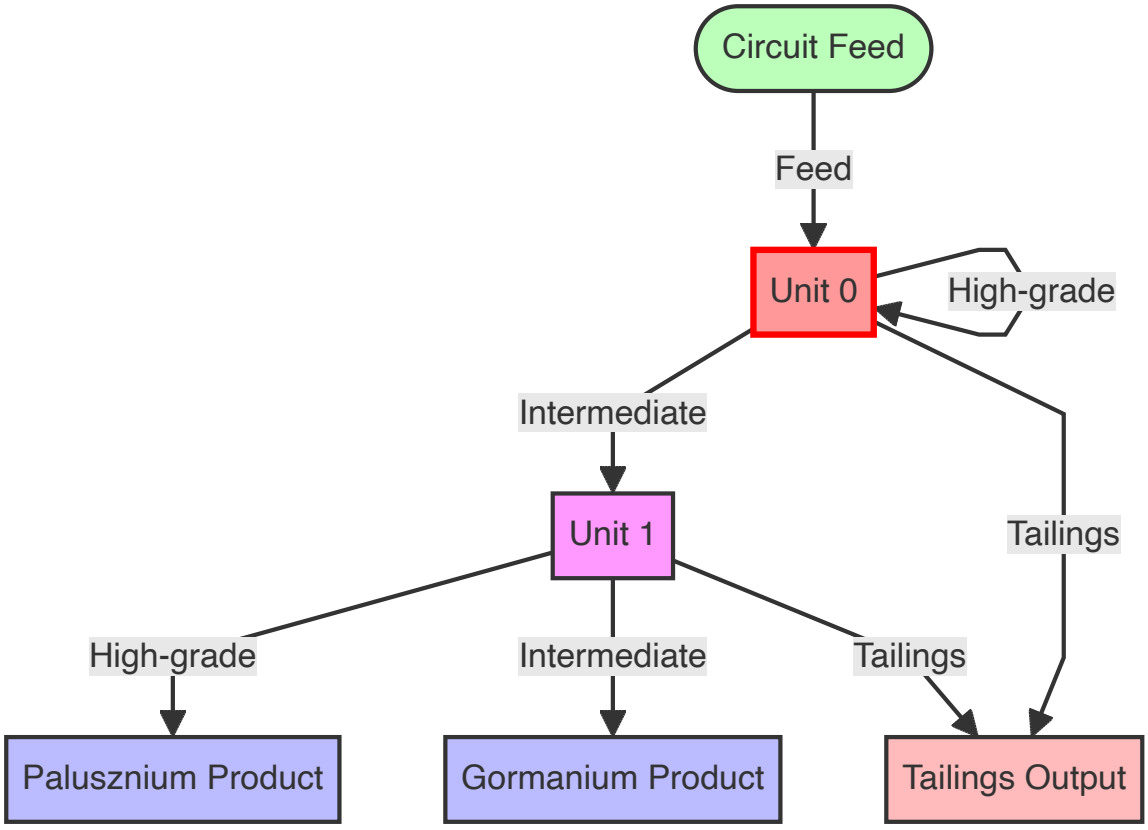
A.2 Circuit with Recycle

Vector: `[0, 1, -3, -2, 0, -1, -3]`



A.3 Invalid Circuit (Self-Recycle)

Vector: `[0, 0, 1, -3, -1, -2, -3]`



Note: This circuit is invalid because Unit 0 has a self-recycle connection (high-grade stream feeds back to itself).