Professional Writing Genre #3 **(due by class time on Mon, Feb. 2)**

Genre Name Design Docs

General Analysis: What are the characteristics of the genre? What are its purposes? Who is the audience? Who are the authors? What is the writing style?

Design docs are commonplace both in software and hardware engineering. They are typically informal pieces of documentation that give a high level overview of the implementation strategy and design decisions that place an emphasis on the trade offs considered in the design process. They are similar to technical documentation with key distinctions, for one they are typically made prior to the start of the project. As a result they use less deep technical terminology, simply identifying the plan, issues being tackled, and ensuring consensus around a design.They are often made within organizations as a pitch to get approved. The audience is both members of the project team, and those with stakes within the project.

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Find a Primary Source: Copy and paste an example of the genre (or include a link to it). Respond to the analytical questions above. What are the characteristics of the genre? What are its purposes? Who is the audience? Who are the authors? What is the writing style? Speak generally about the genre, but also explain a bit about the primary source itself (i.e. the author, their specific purpose, where they work, etc.)

https://sdmay25-19.sd.ece.iastate.edu/sdmay25-19-DD.pdf

4.1.3 Technical Complexity

Our design presents a variety of technical challenges:

1. Since we are using open source software, none of our team members are familiar with the tools we are using. This provides a barrier of entry to getting started with our actual design.
2. ReRAM is an emerging technology, and there are very few opportunities available for fabrication of ReRAM chips. Also, there is little information about ReRAM usage for compute-in-memory applications, so we are exploring a new frontier.
3. We are including four different ReRAM architectures in our design, which of course increases the complexity of our design. However, this will likely help us down the line: if we find that one of our architectures doesn't work as intended, there are still three others to test.
4. We are also integrating a number of components acting as the peripheral circuitry of the design. This includes S&H circuits, TIAs, DACs, and ADCs. While our team doesn't have direct experience with each of these components, they are very well studied in academia and in industry, so finding documentation about them shouldn't be a struggle.

4.2 Design Exploration

4.2.1 Design Decisions

1. **New ReRAM Architectures**

The first design decision we had to make was what kinds of crossbars we would use in our unique ReRAM architectures. For our first crossbar, we decided to do a similar 1T1R matrix as the two senior design teams that came before us, but ours would be different by parallelizing the bitlines and sourcelines in our layout. The previous two teams had their sourcelines parallel to their wordlines. We decided to change things up with our second crossbar design and explore a true ReRAM crossbar, which uses no transistors and only uses a matrix on ReRAM cells. We felt that this would offer a unique solution that maximizes density within our crossbar. The operations on this crossbar are more difficult and noise-prone, but the potential for high-density ReRAM computation could be worth the risk.

2. **ADC Resolution**

We had a few options for ADC resolution in our project. We could use the 1-bit ADC from team sddec23-08, the 4-bit ADC from team sddec24-13, or design our own new ADC at a different resolution. We were partly swayed in our decision due to verification difficulties with the 4-bit ADC (seemingly due to differences in our tool installations), but we ended up using the 1-bit ADC in our design. The advantage to this decision is that each bitline has its own ADC, so there is no need for additional circuitry for sharing a single ADC among each line. This simplistic nature should work well for a research chip that is more for proving the concept than getting precise results.

The following is a snippet of the ASIC Design of ReRam-based AI Accelerators Design Doc from the Iowa State University. It provides a high level overview of the project, including but not limited to requirements, the problem statement, goals, constraints, standards, project timeline, management, architectural design, and testing methodology. In no section does the document dive deeply into technical deeply because this is meant to be a preliminary before the project has not begun. In the section 4.1.3 outlines some of the technical complexities and challenges they have identified that could alter the project timeline or be a barrier to development. They purposely use plain english providing a simple here is the context and why it is an issue. It is intended this way since this design docs likely audience will be people who may be funding the project that are likely not technically literate in the field.

Section 4.2.1 starts explaining the design decisions which are more technical than most other sections. However, the focus in the writing is still high level and also places an emphasis on how they are different from other reference models. They explain why they made certain decisions and the implications it could have.

Due to the informal nature of design docs there isn't a specific style being used, and is up to what the designers see best fit. The document was written by engineering designers and is meant for engineers and supervisors.

Secondary Source (for example, a person or industry expert talking ABOUT what the genre is & how people in the industry use it): Who is the person? What does the person say? Respond to the analytical questions above based on what the person says. **Summarize** their perspective here and include a link to the source. Include a link to the source.

https://www.industrialempathy.com/posts/design-docs-at-google/

The following article was written by Malte Ubl who is the CTO of Vercel, and previously was the principle engineer responsible for Google Search Rendering and Engineering Director for Google Search. In this article he outlines the common structure of Design Docs at google. He makes note of their informal nature highlighting that “[d]esign docs are informal documents and thus don’t follow a strict guideline”. However, that is not to say there are certain criteria that good design docs should meet.

A design doc should provide a context and scope, what is the system being built and why. Goals and non goals should be a short list of bullet points. Importantly highlighting non goals, which are goals you aren't aiming for but your solution may end up implementing anyways such as meeting a compliance standard.

Then, the actual design overview where you start in general and go a little more into detail highlighting tradeoffs you made, why you made them and the benefits of those trade off. It's important to tie in relevant context like your goals and non goals, and why your current solution will satisfy them.

Diagrams are commonly used as they can be very useful for developers to visualize a plan or design that isn't just in words. Design Docs should also acknowledge the constraints being faced and how it influences the direction of the design. This may also mean you'd have to include alternative solutions to show that your project will know what to do if the constraints halt development.

Design Docs ultimately serve a purpose to make sure a team has a uniform consensus on the project. It also allows them to seek advice from senior engineers or developers for assistance and review.

Tertiary Source (for example, a reference guide that explains the genre, including an encyclopedia, Credo, a credible industry database, Claude, Chat GPT and/or Perplexity. You can also use these platforms to find primary and secondary sources that are credible, authentic, and authoritative.) What did you discover? What is the platform and are they credible? What were the prompt/s you used to find this information? And answer the analytical questions above: what did you learn about the characteristics of the genre? What are its purposes? Who is the audience? Who are the authors? What is the writing style? Include a link to what it generated & your prompt/s.

Design docs is a lesser known genre of writing and information on it is scarce. That stems from its informal nature. I decided to use ChatGPT as my tertiary source due to the lack of a wikipedia page on design docs. I prompted ChatGPT to use the internet to gather information on what a design doc is and give me a high level overview of it. I confirmed the cited sources it used and is how I discovered my primary source. ChatGPT draws from a range of primary and secondary sources and thus can produce relatively accurate information.

What I discovered was the common characteristics of the genre, structured sections such as problem statements, requirements, constraints, design decisions and trade offs. Explicit discussion of assumptions, risks, and limitations. The use of diagrams, tables, and high level often simple language

I also learned more about the purpose of the genre, to purpose and evaluate a possible technical solution. Ensure engineers and those with stakes in a project agree before implementation. Document engineering reasoning and trade offs. Reduce the likelihood of error and miscommunication when in development.

They are commonly used by engineers, technical leads and reviewers. A secondary audience being project managers or administration. They are typically written by the project team themselves consisting of engineers.

The writing style is informal, neutral, clear and concise.

NOW IT'S YOUR TURN

How would you use this genre? Who is your audience? What would you say? What is your purpose?

I had to create a design doc for a project I worked on in a lab. In that document I outlined my plan for implementation, some project goals I was aiming for, and the technical solution I came up with. I also outlined some of the key decisions I made and the trade off I had to make.

The audience was the professor I was working with so I was free to use technical terminology. The purpose was to get my project approved before diving into the implementation of the design. It is primarily on keeping the project organized with a clear focus on the goals rather than loosely developing.

Design Document

Project: Softened Barnes-Hut N-Body simulation

Author: Daniel Mejia
Status: proposed

1. Overview

This document proposes modifying the existing Direct Sum N-body simulation and incorporating Plummer softening in the gravitational force model and the Barnes-Hut approximation. The purpose of this upgrade is to improve numerical stability and allow for bodies to clump together to more accurately depict the behavior of colliding planets.

2. Assumptions

In writing this document we will assume the reader has an understanding of the current simulation physical model.

This paper is intended for research collaborators, physics students using the simulation, and faculty advisors reviewing architectural changes. With this in mind the document will make use of technical terminology.

3. Purpose

The purpose for this document is to seek approval for the proposed modifications before implementation. It aims to ensure agreement on:

- The necessity of the force model changes.
- The tradeoffs involved.
- The chosen stabilization strategy.

4. Problem Statement

In discrete N-Body simulations:

- Gravitational force scales as $1/r^2$.
- As $r \to 0$, forces approach ∞
- Numerical integrators cannot resolve extremely large acceleration within finite timesteps.
- Current direct sum algorithm scales as O(n^2).
- No current model for collision.

These issues can be mitigated through decreasing the time step but consequently also increase computational. This solution scales poorly, and does not resolve the explosive particle behavior.

The explosive behavior and no collision detection makes bodies clumping impossible. As N bodies increase the simulation begins to slow to a crawl as computation increases exponentially.

5. Goals

The current proposed goals for this project are to:

- Improve big O from n^2 to $n \, log \, n$ using the Barnes-Hut algorithm.
- Improve energy stability in long-duration simulation.
- Eliminate explosive acceleration at small separations.
- Maintain the accuracy of the current model.

6. Non-Goals

While not an intended goal our proposed solution also adds new functionality to the current simulator:

- Implementing adaptive timestep control.
- Eliminating I/O based data output.
- Adding multithreaded capabilities.
- Built in OpenGL Anim library

7. Proposed Design

7.1 Force Model Change

Replace classical force law:

$$F = \frac{Gm_1 m_2}{r^2} \hat{r}$$

With Plummer-softened force:

$$F = \frac{Gm_1 m_2}{(r^2 + \epsilon^2)^{3/2}} \bar{r}$$

Where:

- ϵ= softening parameter and $\epsilon << r$

7.2 Integration Impact

The project will use the same Leapfrog 2nd-order symplectic integrator as it is remarkably good at conserving the energy of the system.

7.3 Barnes-Hut Interaction

In order to overcome the O(n^2) barrier we use the Barnes-Hut algorithm which does increase the approximation.

- For each time step a tree is constructed representing the physical section of space an object resides in.
- Reduces computation by approximating clumps of objects as one.

7.4 Collision

Since objects will always experience gravity there is a need to implement collision to prevent objects from merging into each other. The proposed method is a Mass spring damper model which will result in non elastic collision.

7.5 Anim

A major bottleneck in the previous simulation model was I/O. For large n-body simulations with powerful enough hardware the limiting factor is I/O operations. The addition of a built-in Anim library allows for in-simulation openGL calls. This will mean the bottleneck will always be the computation.

8. Tradeoffs

8.1 Benefits

- The Barnes-Hut approximation significantly reduces computational costs which makes 1000+ N-Body simulations possible.
- Collision allows bodies to clump to represent planets.
- Bodies no longer explode at close distances.
- Reduced computation means the simulation could run at smaller time steps improving accuracy.
- Anim library eliminates I/O bottleneck.

8.2 Costs

- The Barnes-Hut improves performance by doing less work through approximation. This will mean it is less accurate than a direct-sum algorithm. For large expansive simulations this is often a negligible increase in error.
- Development of Anim library is expensive and introduces compatibility issues.
- The increased complexity makes verification of energy conservation costly.

9. Risks

- Oversoftening may suppress gravitational clumping and needs to be selected carefully.
- Undersoftening may fail to resolve instability
- Adding additional collision physics may result in energy conservation issues.

10. Validation Plan

- Stress tests high-density clusters over long runtimes ensuring stability.
- Comparing total energy drift of the original model compared to the new model.
- Validating the performance of the new model compared to the original model for similar scenarios.

PART 2 - due by classtime Wed, Feb. 4

<u>BIO & PHOTO & WEBSITE</u>

Write 35-50 words that positions you as a qualified industry professional.

Computer Engineering practitioner specializing in digital design, FPGA development, and embedded systems. Experienced in RTL implementation, verification, and hardware–software integration, with hands-on work building custom processors, communication protocols, and performance-oriented simulation tools for real-time and research-driven applications.

Copy and paste a photo of you in the space provided that displays your ethos as a qualified industry professional.