Sample Masters Thesis Editing

Materials Engineering – National Taiwan University

~~Chapter 1~~Introduction

1.1 Background

In recent years the widespread ~~The~~ use of the ~~Discrete~~ discrete ~~Element~~ element ~~Method~~ method (DEM) (Cundall, 1971; Williams, *et al.*, 1985) in engineering has generated increasing research interest across a variety of fields. ~~increasingly been the object of study in recent years, f~~From geotechnical engineering (Ting, *et al.*, 1989; Ting and Corkum, 1992; Oda, *et al.*, 1982; Iwashita and Oda, 1998) to the foodstuff industry (Cleary, *et al.*, 2008; Van Zeebroeck, *et al.*, 2008), ~~from~~ to material simulation (Chan and Liu, 2003; Kim, *et al.*, 2008; Liu, 2002; Noor, 2000; You, *et al.*, 2008) ~~to~~ and disaster reduction (Bourrier, *et al.*, 2007; Kiyono, *et al.*, 2001a; Kiyono, *et al.*, 2001b; Kiyono and Nagai, 2003; Kiyono and Furukawa, 2006; Komodromos, *et al.*, 2008; Ku, *et al.*, 2003; Pena, *et al.*, 2007; Shamy and Zeghal, 2007; Shiu, *et al.*, 2006). ~~Today, depending on~~As a result of ~~the~~ rapid and continuing developments ~~of~~ in computer science, DEM ~~has~~ is now ~~been~~ being applied ~~on~~ to modeling ~~more complex~~ physical phenomena and ~~solving more difficult~~ engineering problems of ever increasing complexity. ~~which beyond our own imagination.~~

Comment [CB1]: CHECK – It's not immediately clear that you are referring to studies in these fields, and this is true of all references in this paragraph.

Comment [CB2]: IDEA – Here, it might be helpful to briefly point out that Cundall first applied the technique to rock mechanics in 1971, while Williams, et al., developed the theoretical framework in 1985. This would just help to frame your introduction.

Comment [CB3]: CHECK – You may wish to clarify the nature of the works done under each of these publications, as this would provide context. For example:
"In geotechnical engineering, a 1989 study was undertaken by Ting, et al., into a discrete numerical model for soil mechanics. Subsequently, a collaboration between Ting and Corkum …"

DEM treats materials as ~~an~~ finite assemblies~~y~~ of ~~a finite number of~~ distinct elements. The expected macroscopic~~-scale~~ behavior of the assembly is exhibited by the model only when the parameters governing microscopic~~-scaled~~ interactions between elements are appropriately defined. Traditionally, ~~it is often~~the method has been used for modeling ~~a pure solid~~ dynamic systems composed purely of solids; this application stems from~~ because of~~ its original purpose – solving the blocky rock system problem (Cundall, –1971). ~~However, different~~ As distinct from continuum-based theories~~y~~, DEM does~~n't~~ not require~~ need~~ continuous conditions between elements.~~ That is,~~ This affords the method far greater flexibility, as the relationship between elements can be set as continuous or discontinuous ~~which depends on~~in accordance with the characteristics of a given problem ~~s and provides more flexibility.~~thus enabling~~ This advantage makes~~ DEM ~~can~~ to model not only solid but also multi-phase materials, such as solid-liquid mixtures.

Solid-liquid mixtures ~~appears both~~are ubiquitous in nature and industry. However, ~~its~~ dynamic behavior in such systems is difficult to ~~be~~ predict~~ed~~ ~~because of~~due to complex interactions ~~in~~ at the solid-liquid interface. Although ~~some~~ continuum-based numerical ~~methods~~approaches~~,~~ such as those of ~~Finite Element Method (FEM) or~~ ~~C~~computational ~~Fluid~~ fluid ~~Dynamics~~ dynamics (CFD) and the ~~F~~finite ~~E~~element ~~M~~method (FEM)~~,~~ have provided some solutions, ~~but following~~ vast computational requirements impose practical limits ~~its~~ on the feasibility ~~on~~ of solving real-world engineering problems with this

Comment [CB4]: CHECK – Do you mean to say that microscopic DEM parameters are varied until the macroscopic behaviour of the model mimics experimental observations?

Comment [CB5]: CHECK – You might consider varying the use of the term "solid-liquid" (which appears quite often) with the more general word "heterogeneous" occasionally, to remove any hint of repetitiveness.

Comment [CB6]: CHECK – The original order is reversed here as CFD is a **branch** of numerical methods, while FEM is an individual **technique**. Moving from more general to less general sounds a little more natural to a reader.

range of techniques. ~~Although While~~Although ~~D~~direct ~~E~~element ~~S~~simulation (DES) is less processor-~~-~~intensive~~more economical~~ than continuum-based numerical methods~~ on computation, however~~, complex interactions ~~in~~ at solid-liquid interfaces still ~~brings~~ invoke considerable computational overhead. ~~Besides,~~ DEM is classified as an explicit numerical method~~s,~~; its numerical time step is much smaller than implicit ~~numerical methods~~equivalents ~~because of the consideration of~~due to stability considerations, and~~. That is,~~ the method is thus constrained by processing power~~computing requirement is an innegligible issue of DEM~~. Thus, an efficient ~~Discrete~~ discrete ~~Element~~ element ~~Simulation~~ simulation (DES) system is needed for solving large-scale~~d~~ solid-liquid interaction problems.

In this dissertation, a ~~parallel~~ computing technique is introduced to implement a parallel discrete element simulation system ~~and its application on simulating the~~for modeling solid-liquid flow behavior~~ is discussed~~.

1.2 Objective~~s~~

The objective of this research is to develop an efficient parallel DES system for the simulation of sold-liquid flow behavior. ~~The works include~~ This involves improving the efficiency of an existing parallel DES system, KNIGHT&ANNE/IRIS 1.0, and proposing specific numerical strategies for the simulation of solid-liquid flow behavior. This dissertation concerns itself with the simulation of ~~Two types of solid-liquid flow simulation,~~ both ~~Self~~self-~~Compacting~~ compacting

Comment [CB7]: IDEA – You may wish to point out that the exhaustive computational overhead limits either the length of the simulation or the size of the system under considerations. I know this is implied, but making this explicit would likely benefit your audience.

Comment [CB8]: IDEA – It might be good to discuss some of the stability considerations that arise as the time step increases, i.e. the Gibbs phenomenon.

Comment [CB9]: CHECK – In this context, a "parallel DES" implies that the computing technique used was itself parallel.

Comment [CB10]: CHECK – You may wish to reword this sentence to avoid repeating the phrase "for the simulation of solid-liquid flow behavior". Perhaps consider using "for the simulation of heterogeneous flow", or something similar.

~~Concrete ~~concrete (SCC) and wet granular flow~~, are discussed in this dissertation~~. In the first topic, SCC flow behavior, the liquid ~~part~~ component (mortar) is modeled by tiny discrete elements. In the second topic, wet granular flow, the liquid ~~part ~~component is not modeled directly but its effects ~~is ~~are ~~represented by~~incorporated into the interactions between discrete elements of the solid component.

1.3 Scope

The scope~~s~~ of this research ~~can be summarized as~~comprises three main tasks: (a) development of an efficient parallel DES system; (b) simulation of SCC flow behavior; (c) simulation of wet granular flow behavior. ~~More discussion of these tasks is made in the following sub-sections.~~

1.3.1 Parallel Discrete Element Simulation System

Although DEM is a flexible numerical method~~ which allow~~ allowing the user to define a~~ any type of element and~~ set of system parameters governing interactions~~–~~ between virtually any type of element, ~~them, however, it also~~increasing system complexity brings a commensurate increase in the degree of difficulty for DES system developers during implementation. An element in the model can be used ~~for modeling~~to represent a single object~~ in real world~~ or a uniform material unit (~~in other words, ~~a single object may be modeled by cluster of elements). Interactions between elements can include both contact ~~force ~~and non-contact ~~force ~~(~~or ~~action-at-a-distance~~ force~~) forces, and ~~.~~ ~~Different~~various geometric shapes~~ of element~~, contact types~~,~~ and contact

Comment [CB11]: IDEA/CHECK – "tiny" is not very specific and generates some ambiguity here. You may wish to be just a little more specific in characterizing the discrete elements for SCC modeling, e.g. "modeled by discrete elements of order X …"

Comment [CB12]: CHECK – Do you mean that the liquid component is considered by modifying the model for a purely solid discrete system? The edit is made under this assumption, but if this is not your intended meaning you may need to reword the sentence.

mechanisms often appear in the same system. Thus, a flexible framework is needed for~~ a~~ DES software to be effective.

To satisfy this requirement, in 2003 the Computer-Aided Engineering (CAE) laboratory of the ~~department~~ Department of ~~civil~~ Civil ~~engineering~~ Engineering in National Taiwan University (NTU) started a project to design a flexible object-oriented DES framework ~~from 2003~~. ~~One years ago~~Last year, the VErsatile Discrete Objects (VEDO) framework ~~is~~ was proposed (Yang and Hsieh, 2002; Yang, 2004; Yang and Hsieh, 2005). Any DES system which ~~follows~~ conforms to the VEDO framework is much easier to ~~be~~ extend~~ed~~ than a traditional system~~.~~; a DES system developer can easily add~~ a~~ discrete elements with dissimilar ~~different~~ geometric shapes, different contact detection algorithms~~,~~ and different impact solving strategies to satisfy the requirement of a simulation. ~~In addition, a~~An object-oriented DES system~~,~~ KNIGHT&ANNE 1.0, based on the VEDO framework, ~~has been~~was developed by Yang in 2004~~ (Yang, 2004)~~. ~~Following~~Subsequently, ~~for the~~to accommodate high-performance computing ~~requirement~~overheads~~,~~ a parallel VEDO framework ~~is~~ was proposed and the~~a~~ corresponding parallel DES system, KNIGHT&IRIS 1.0, was ~~is developed~~built in 2005 (Lin, 2005). The KNIGHT&IRIS 1.0 prototype system does indeed provide accelerated ~~speed the~~ simulation speeds ~~of~~ compared with predecessor KNIGHT&ANNE 1.0~~,~~; ~~however, it is a prototype system and~~unfortunately, current implementations~~ only~~

Comment [CB13]: CHECK – Do you mean "proposed", or developed? If the VEDO framework was *completed* last year, the sentence should express this fact.

Comment [CB14]: CHECK/IDEA – It is a little unclear as to whether these references cite research groups, or papers published under these collaborations.

Comment [CB15]: IDEA – You may wish to expand your description of VEDO (and solve the referencing ambiguity) by stating something like "the Versatile Discrete Objects (VEDO) framework was proposed by Yang and Hsieh in 2005 to provide a robust environment for simulation using design patterns".

can only be executed on shared-memory platforms ~~which~~ and this limits the practical feasibility of parallel DES.

In this ~~work~~paper, KNIGHT&IRIS 1.0 is extended for solid-liquid flow behavior simulation. The design of this prototype system is reassessed~~analyzed~~, and ~~its next generation,~~ KNIGHT&ANNE/IRIS 2.0~~,~~ is developed as the next generation of DES systems. ~~The p~~Performance is evaluated ~~with~~ over several SCC flow behavior examples ~~with~~ representing different problem sizes. Furthermore, a load balance index is proposed to standardize the evaluation of ~~for evaluating the degree of~~ load balance status.

1.3.2 Simulation of SCC Flow Behavior

In 1986, ~~a new concrete material which is named the Self-Compacting Concrete is proposed by~~ Prof. Okamura ~~in~~ of the Kochi University of Technology proposed a novel self-compacting concrete material. The ~~word~~ term ~~“~~*~~S~~self-~~C~~compacting*~~”~~ ~~indicates~~ refers to the fact that during the building and construction process, SCC can pass through ~~the~~ gaps ~~of~~ in reinforcing bars ~~and~~ to fill ~~the~~ formwork ~~only depends on its~~under its own gravity and ~~(that is, it~~ does~~n't~~ not ~~need~~ require additional vibration~~)~~ to obtain the necessary compaction. ~~However, a good~~Well-designed SCC also needs to have high workability, ~~and depends on appropriate mix design.~~ the achievement of which is highly sensitive to mix proportions. Typically SCC is composed of coarse aggregates, sand, cement, water, powder-sized

Comment [CB16]: IDEA – You might like to mention that under Okamura the first SCC prototype was completed in 1988.

particles, and ~~several kinds~~a variety of chemical materials ~~.~~— ~~I~~its flow behavior is therefore complex and difficult to ~~be~~ simulate~~d~~.

~~From~~ In 2003, Professor~~.~~ Yin-Wen Chan of the ~~d~~Department of ~~c~~Civil ~~e~~Engineering at NTU ~~started~~ undertook to simulate the flow behavior of SCC with a commercial DES software package,