BagSim: A Realistic Physics Simulator for Deformable Bags

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Figure 1: Seattle Mariners at Spring Training, 2010.

ABSTRACT

The manipulation of deformable objects such as bags is a challenging task in computer graphics. Simulating the behavior of such objects is crucial for several applications, including animation, virtual reality, and gaming. Unfortunately, simulating deformable objects like bags is difficult due to the variety of behaviors depending on the material used. Existing simulators fail to accurately simulate critical properties of bags such as handles and different bag shapes. In this paper, we present BagSim, a physics-based simulation system for simulating the manipulation of deformable bags. Our proposed approach is to model a bag as several attached cloths with adjustable stiffness parameters. We also incorporate air resistance into our simulations to more accurately model real-world interactions with bags. Our experimental results show that BagSim can effectively simulate the behavior of different types of bags.

CCS CONCEPTS

• **Computing methodologies → Physical simulation**; *Motion processing*; *Collision detection*; *Mesh geometry models*; Ray tracing.

KEYWORDS

Deformable object simulation, Plastic bag, Physical simulation

1 INTRODUCTION

Accurate simulation of deformable objects such as cables, cloth, fluid, and biological tissues is a crucial component in many applications such as animation, computer-aided design, films, and games. The demand for realistic motions becomes even more apparent for virtual reality applications and robotic simulators as the quality of simulation makes a huge difference in the user experience and for training machine learning models. However, it is also well-known that modeling and simulation of such deformable objects are challenging, and they have been an active research area in mechanical engineering and computer graphics for several decades.

There are many different ways to model the deformation of objects [5]. On the one extreme of the spectrum are non-physical approaches, where a designer manually adjusts control points or shape parameters to edit or design the shape. However, this is not scalable. On the other end of the spectrum are approaches that are based on continuum mechanics, which considers the material properties, external forces, and environmental constraints that affect the deformation of objects. However, tuning the parameters, also known as system identification, is also very time-consuming and challenging. Even with identified parameters, there are still aleatoric uncertainties in the real world that cannot be fully modeled. Additionally, simulating and rendering realistic visuals can be slow and inaccurate.

In recent years, there has been huge progress in the physics-based simulation of cables and fabrics, which has been found useful by the robotics community to learn control policies for deformable objects [6, 8, 14]. For example, OpenAI Gym [2] and Mujoco [11] both support rope and cloth simulations, as well as sponge-like soft 3D objects. Lin et al. [9] build a higher-fidelity simulator for ropes, cloth, and water. Huang et al. [7] simulate soft 3D objects such as fruits, internal organs, and flexible containers.

In this project, we focus on deformable bag simulation. There has been a growing interest in simulating the behavior of bags,

Table 1: Frequency of Special Characters

Non-English or Math	Frequency	Comments
Ø	1 in 1,000	For Swedish names
π	1 in 5	Common in math
$	4 in 5	Used in business
Ψ_1^2	1 in 40,000	Unexplained usage

which are ubiquitous in daily life, including in home, commercial, and industrial settings. Building a high-fidelity simulator can be useful in robotics as it can significantly reduce the real-world data required for training models. For example, [3, 4] study the task of opening a plastic bag and inserting objects, and they train their model entirely in real, which requires collecting a large amount of real-world data. This can potentially be accelerated with the help of a bag simulator. Similarly, [13] leveraged simulation to learn a robot policy for hanging a bat onto a rack. In contrast to cloth, however, there exist very few high-fidelity simulators for bags. DeformableRavens [10] is one of the first few works that present physics-based bag simulation. However, their bag model is hugely simplified. [12] presents a graph-based model of a handbag and its simulation. Antonova et al. [1] build up on that and allow more complex movements. Still, the bag model is limited and the parameters are not systematically tuned to match with the real world. We aim to address these shortcomings.

Simulating deformable objects like bags is challenging due to the variety of behaviors depending on the material used. Existing simulators fail to accurately simulate critical properties of bags such as handles and different bag shapes, which limits their usefulness for several computer graphics applications. In this work, we present BagSim, a physics-based simulator environment built on top of NVIDIA Omniverse for simulating deformable bags.

Our proposed approach is to model a bag as several attached cloths with adjustable stiffness parameters. We also incorporate air resistance into our simulations to more accurately model real-world interactions with bags. Our system can generate realistic animations of bags that can be used in several computer graphics applications such as animation, virtual reality, and gaming.

The project goal is to contribute BagSim, a realistic physics simulator environment for simulating the movement of deformable bags, a systematic way of tuning the parameters, and an experimental evaluation of BagSim compared to existing simulators as well as bags in the real world.

In particular, we plan to model the shapes of various types of bags (with and without handles or bottoms, stiff or soft fabric material), and simulate the bag movement (elasticity, dynamics, deformation) when dragged around by a cursor. We will simulate the interaction between the deformable bag and rigid objects when placed into the bag, and tune the simulation parameters to approximately match real bags manually. We will provide both visual and quantitative evaluation of the simulator across each of the different bag types (comparing BagSim to SoftGym, DeformableRavens, DEDO, and a similar real bag), and benchmark the computation time for generating the state of the bag after some perturbation.

Figure 2: 1907 Franklin Model D roadster. Photograph by Harris & Ewing, Inc. [Public domain], via Wikimedia Commons. (https://goo.gl/VLCRBB).

2 RELATED WORK

2.1 Simulation of Cables, Fabrics, and Fluids

Prior work related to the simulation of deformable objects such as fabrics, cables, and fluids also focused on creating an artificial environment in which robots could be trained to manipulate such objects. This reduces the need to run physical simulations to collect data and saves a significant amount of time during training. One such example

2.2 Simulation of Deformable Bags

3 SIMULATOR COMPARISON

3.1 Unity

In terms of scripting capability, out of the box Unity does not have much flexibility for customizable cloth physics through their UI or scripting API. Although, basic parameters for the entire cloth can be tweaked through both mediums. there ultimately is not a particle level api which we can work with to manpulation contrainst on a particle level for

4 BAG MODELS

To gain familiarity with the capabilities of Unity and Omniverse, we imported basic bag meshes into both simulators and setup a simple simulation of the meshes with cloth properties. The bag meshes that we imported into Unity and Omniverse can be found in the DEDO Github repository linked in Dynamic Environments with Deformable Objects [6].

After loading a bag mesh into Unity, we ran into a problem where the outer surface of the bag mesh renders fine, however the inside is completely transparent. After a bit of debugging, we discovered that Unity performs a rendering optimization called "backface culling" where only one side of triangle meshes are rendered. The mesh faces that are rendered by Unity are the front faces. In other words, sides of the faces with normals pointing out of them. Thus, if we decide to continue working with Unity, we will likely need to create our own bag meshes in Blender that have double sided faces. On the other hand, when importing the bag mesh into Omiverse, both the front and back faces are rendered in.

Currently, our goal is to leverage Blender to create a bag mesh with a more realistic appearance, similar to the plastic bags commonly found in grocery stores.

5 PROGRESS SUMMARY

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