Pink Dolphins: A Serious Simulation Game

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Abstract Creating a 3D virtual dolphin requires more than just virtual reality (VR) technological know-how. It also involves a good understanding of the behavior and habits of a particular species of dolphin, and in this case, the chosen species of Delphinidoe is the Indo-Pacific humpback dolphin (known by its scientific name as *Sousa Chinensis*), also known by other names, such as Chinese white dolphin and Pacific humpback dolphin. In Singapore, they are commonly known as pink dolphins because of their color as they mature into adulthood. This chapter describes how to model a virtual pink dolphin resembling closely to the real one basing on a good understanding of the pink dolphin in terms of its size, behavior and habits, and its acrobatic acts. The virtual pink dolphins model are used for a serious game developed to assist the special needs education.

Keywords Dolphin · Virtual reality · Simulation and modeling · Game

1 Introduction

Dolphins are generally popular with humans because they appear friendly, intelligent, are graceful, and their performance while jumping in the ocean fascinates humans. The family Delphinidae (dolphins) evolved about 10 million years ago

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during the Miocene Period. Their early ancestors became fully aquatic around 38 million years ago. The *Basilosaurus* and *Dorudon* were two such aquatic ancestors of dolphins. In fact, they resembled like modern-day dolphins and whales. These ancient whales or dolphins were known as Archaeoceti and they probably evolved in the early Paleocene Period, around 65 million years ago. They were completely land-based and it was only in the following Eocene Period that they began living in water more than on land. One such terrestrial ancestor of dolphins is known as the Pakicetus that resembled the modern-day wolf (Fordyce 1980; Fordyce and Barnes 1994).

Today, there are as many as 17 genera with about 40 different species of dolphins in them. Dolphins are close cousins of whales and porpoises. They are warm-blooded mammals. These toothed whales belong to the order of *Cetacea* and the family of *Delphinidae*. They like to live in warm, shallow waters along the coast. They can also be found in open seas and oceans as well as in guls, lagoons, bays, and even harbors. Sometimes they come into large rivers, and sometimes they go further out to sea. In fact, they are found in almost every part of the world, with the bottlenose dolphin being the most widely distributed. Dolphins live in family groups called pods. There are often about 12 dolphins in a pod, but sometimes several hundred dolphins get together. They do not usually migrate, but they may follow schools of fish that are moving. These fish provide them the source of food.

As there are so many different species of dolphins, the authors have chosen to focus on a particular species of dolphins known as the Indo-Pacific humpback dolphins (*Sousa Chinensis*) which they have been researching on for the last 5 years since 2007 in partnership with the Underwater World Singapore based in Sentosa—a holiday resort island south of Singapore mainland.

This chapter is organized as follows: Section 2 examines the species of Indo-Pacific humpback dolphins covering on the anatomy of a dolphin, functions of some selected parts, its behavioral pattern. Section 3 discusses the technical aspects that were taken into consideration in the design of a virtual pink dolphin game to assist the special needs education. Section 4 concludes this research.

2 Dolphin Anatomy, and Behavioral Patterns

Humpback dolphins belong to the genus of *Sousa* (Fig. 1) and they are characterized by the conspicuous humps ahead of the dorsal fin, which is to some degree falcate, as well as a careen on a ventral side Their pectoral flippers are considerably small and the tail flukes have a well-defined median notch. On each side of the jaw there are 30–34 small coned-shaped teeth. Their pectoral flippers are considerably small and the tail flukes have a well-defined median notch. On each side of the jaw there are 30–34 small coned-shaped teeth (Ross 2002; Rice 1998).

Fig. 1 An Indo-Pacific humpback dolphin

Different dolphin species vary in size, lying anywhere between 1.2 and 9.5 m in length and between 40 kg and 10 tons in weight. An adult humpback dolphin can reach from 1.8 to 2.4 m and weigh in the range of 100–139 kg.

Newborn calves are a cream or pearl shade of white, whereas the adults have a more dull off-white coloring from the tail to the snout. Their flanks are somewhat of a dark gray, and their belly is a lighter shade of gray. These humpback dolphins can be found swimming close to shore along the West African coast as well as along the coast of the Indian Ocean from South Africa to Australia. The main diet of the humpback dolphins consists of mullet and other fish, though the feeding habits are widely unknown, as this animal is not widely known itself.

The taxonomy of the *Sousa* genus is complex and continues to be the topic of debate among the experts. As many as 5 species have been proposed and they are *S. chinensis* (Chinese white dolphin, Pacific humpback dolphin, or Indo-Pacific humpback dolphin), *S. plumbea* (Indian humpback dolphin or Plumbeous humpback dolphin), *S. teuszi* (Atlantic humpback dolphin), *S. Lentiginosa, and S. Borneensis* (Ross 2002). However, Rice (1998) argued that there are only three sub-species of *Sousa*, viewing the Indo-Pacific as an intermixing between two other sub-species named simply the Indian and the Pacific.

2.1 Anatomy of a Dolphin

In designing a virtual dolphin, it is important to have the correct size so that once it is created, it should not be under or over exaggerated, but be true or close to its real proportions. From Fig. 2, beginning with the mouth known as beak or rostrum in

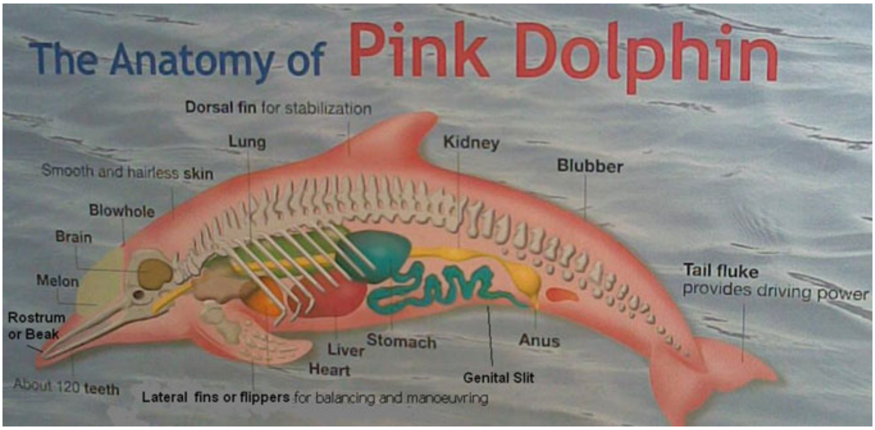

Fig. 2 Parts of a dolphin (Photo Courtesy of Underwater World Singapore)

which the lower jaw is longer than its upper. The teeth of a dolphin are conical, arranged around its beak-shaped mouth. It has a wide forehead known as melon. Further up the melon is a blowhole, which the dolphin uses to get air. Dolphins are mammals, not fish, and so they do not have gills but lungs. On the back of its body is the dorsal fin. Further down its body is the tail with two lobes known as flukes. On both sides of the body are the pectoral fins of flippers. It navel (the dolphin's belly button is found close to its genital slit which conceals the reproductive organs and anus.

2.2 Dorsal Bursa and Dolphin Whistles

Dolphins can be very noisy animals and they make three main types of nasal vocalizations—whistles, burst-pulse sounds, and clicks—from the air-sacs below their blowholes.

Unlike human, a dolphin does not have vocal cords in its larynx to make sounds. Anatomical and bioacoustic research suggests that a dolphin has two tissue complexes in the nasal region called dorsal bursa, which includes what are known as phonic lips (structures that project into the nasal passages) is probably the most likely site. The phonic lips can work independently or simultaneously of each other. As air pushes through the nasal passage passing by the phonic lips, the surrounding tissue vibrates to produce one or more types of sounds.

The sounds that dolphins produce resemble grunts, moans, squeaks, and trills that can be made any time and at considerable depths varying in volume, wavelength, frequency and pattern. The frequency of dolphin sounds ranges from 0.2 to 150 kHz. The lower frequency vocalizations (about 0.2–50 kHz) are likely used in social communication between and among dolphins. Social signals have their most energy at frequencies less than 40 kHz. Higher frequency clicks (40–150 kHz) are primarily used for echolocation.

Chia and Kee (2012) investigated sounds made by bottlenose dolphins to see the response of children with autism. Their study suggested that these children preferred buzzing clicking, which they felt more ambient, than the other three sounds: clicking, creaking, and squeaking. It would be interesting to create a dolphin avatar or virtual dolphin that could make buzzing clicks to give a calming effect to those interacting with it. Of course, to create a virtual dolphin that resembles a real one, it must be able to make all the four sounds.

Dolphins rely heavily on echolocation for two reasons. First, they live in an underwater habitat that has favorable acoustic characteristics. Second, in such an increasing depth underwater, vision is extremely limited in range due to absorption, i.e., sunlight is absorbed and the amount of visible light diminishes. Because absorption is greater for the long wavelengths than for the short ones, the color spectrum (as in the rainbow) is rapidly altered with increasing depth. For instance, objects that are white at the surface appear bluish underwater. Similarly, red objects will appear dark or even black. Although light penetration will be less if water is turbid, in the open ocean with very clear water, <25 % of the surface light will reach a depth of 10 m. At a depth of 100 m, the light present from the sun is normally about 0.5 % of that at the surface. Such details must be taken into consideration when designing the virtual aquatic habitat for the virtual dolphins.

Dolphins emit a focused beam of high-frequency clicks in the direction that their head is pointing. These sounds are generated by passing air from the bony nares through the phonic lips (Cranford 2000), and are reflected by the dense concave bone of the dolphin's cranium and an air sac at its base. On the dolphin's head is a large fatty organ called melon that helps to modulate the focused beam (Ketten 1992, 2000). It is composed of lipids of differing densities and serves as an acoustic (Ketten 1992).

Most dolphins use clicks in a series, or click train, for echolocation to find their location, identify objects as well as their sizes and see how far they are from them as well as the location of other animals. Different click train production rates give rise to the familiar barks, squeals, and growls of the dolphins. A click train with a repetition rate more than 600 clicks per second is called a burst pulse (Ketten 1992). In the species of bottlenose dolphins, their auditory brain response resolves individual clicks up to 600 clicks per second, but yields a graded response for higher repetition rates (Ketten 1992, 2000).

2.3 The Behavioral Patterns of Dolphins

Dolphins are well adapted to living underwater. A dolphin possesses sensitive skin on its lower jaw which allows it to identify small objects, and it has a blowhole on top of its head that enables it to breathe air from the surface.

The streamlined body of a dolphin has few appendages (like ears, arms, and legs) sticking out to slow it down as it swims through the water. Its sleek body with smooth rubbery skin which secretes an oily substance that enables it to swim through water smoothly and speedily (Zagzebski 2009; Fish 2006).

However, the dolphin takes more than just a sleek body to maneuver in the water. When dolphins are going after their food, they not only swim at the surface, they also dive to great depths. They need rudders and propellers and these are their dorsal fin (i.e., the fin that sticks up from its back) which acts as a stabilizer or a rudder. The dorsal fin has no bones in it, unlike the fins on fish. Instead, it is made up of dense tissue, somewhat like a ridge of thick, folded skin (Zagzebski 2009). The pectoral flippers on the sides of the dolphin are used for steering, balancing, slowing down, and stopping. They are not used for moving forward through the water (Zagzebski 2009). Forward motion is created by the dolphin's tail known as fluke, which is not perpendicular (up and down) like a fish or a shark. Instead, its fluke spreads out side to side. When a dolphin swims, it pushes its fluke up and down to help it dive or leap out of the water. When swimming at high speed, the dolphin leaps out of water. Leaping helps the dolphin to conserve its energy as it can move a longer distance with one long jump compared to swimming in denser media of water relative to air (Fig. 3) (Au and Weihs 1980).

In other words, the flukes serve as the propeller. Powerful muscles running along the backbone and sides of the dolphin's body move the tail up and down in the water, providing the power that pushes the animal through the water, or deep into the ocean (Zagzebski 2009). In fact, one way to remember that dolphins, like whales, are not fish which move their bodies sideways when they swim; dolphins move their bodies up and down.

In creating a virtual dolphin to swim like one, its motions in the water must be observed carefully, especially how it actually executes its various strokes and maneuvers using its dorsal fin, its pair of pectoral flippers and its tail fluke.

Fig. 3 Leaping out of water

3 From Physical Pink Dolphins to Virtual Pink Dolphins

In this research, virtual pink dolphins are modeled following the real dolphins with the Underwater World Singapore. They have different sizes, different characters, and different behavioral patterns. In the followings, we detail the modeling, visualization, interaction, user interface and simulation with the virtual pink dolphins serious game (Fig. 4).

3.1 Dolphin Shape Modeling

We model pink dolphins based on their anatomy. Efforts are made to model the shapes, skeleton, and skins of pink dolphins. Geometric representation is used to create smooth surface of virtual pink dolphins which is then tessellated into triangular meshes for digital representation. Digital geometry processing techniques are further applied to produce compact and optimal representation of the virtual pink dolphins (Fig. 5). Based on the dolphin shapes created, we insert the skeleton in the dolphin surface model for animation and simulation. The virtual pink dolphins such modeled have typical dynamic behaviors such as swimming, jumping, whistling, etc., which serve a basic role in communication among dolphins. Figure 6 shows three virtual pink dolphins modeled following their real counterparts from a dolphin family in UWS (Left: the daughter, Middle: the son, and Right: the mother).

3.2 Dolphins Visualization

The 3D modeling of the virtual pink dolphins can be easily used for realistic visualization in either stereographic or normal modes. For stereographic visualization, active shutter glasses or anaglyph glasses can be used for viewers to have 3D perception with the virtual pink dolphins.

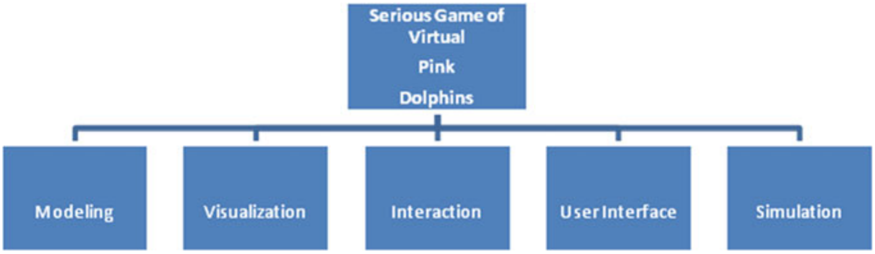

Fig. 4 Overall structure of the virtual pink dolphin system

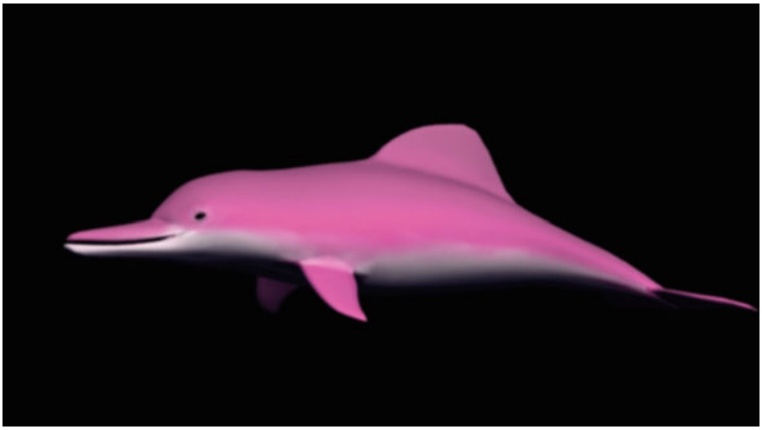

Fig. 5 A virtual dolphin modeled with a multilayer structure

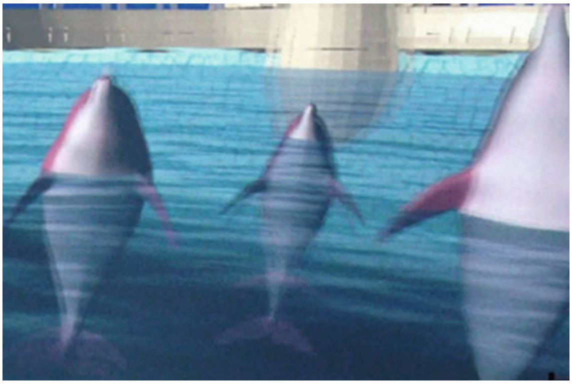

Fig. 6 Three virtual dolphins modeled following their real counterparts from a dolphin family in UWS

3.3 Real-Time Interaction

The virtual pink dolphins also have certain interactive functions. For instance, they can be interactively controlled to swim, leap, and whistle. For this, both geometrically and physically based modeling techniques are implemented with the virtual pink dolphins. One of the most important physical modeling tasks is to deal with collision detection. We use Graphic Processing Unit (GPU) technology to speed up the physical modeling process. The interactive control, however, will be carried out through the user interface specially designed.

3.4 Natural User-Interface

Instead of using mouse and keyboard to control the virtual dolphin interaction, we implement an easy-to-use natural interface to control the virtual pink dolphins with hand gesture. The Microsoft Kinect device is integrated with the virtual pink dolphin system through its natural interface programming.

3.5 Serious and Simulated Game of Virtual Pink Dolphins

We have developed an interactive simulation game with virtual pink dolphins for children with autism or other special needs. A 3D immersive environment is designed and developed allowing those kids to interact with the virtual pink dolphins. They can use their hand gestures to control the dolphins' behaviors (swimming, leaping, whistling, etc.). We hope this interactive game can help those children improving their nonverbal communication skill. Figure 7 shows two children from a special needs school in Singapore playing the interactive game.

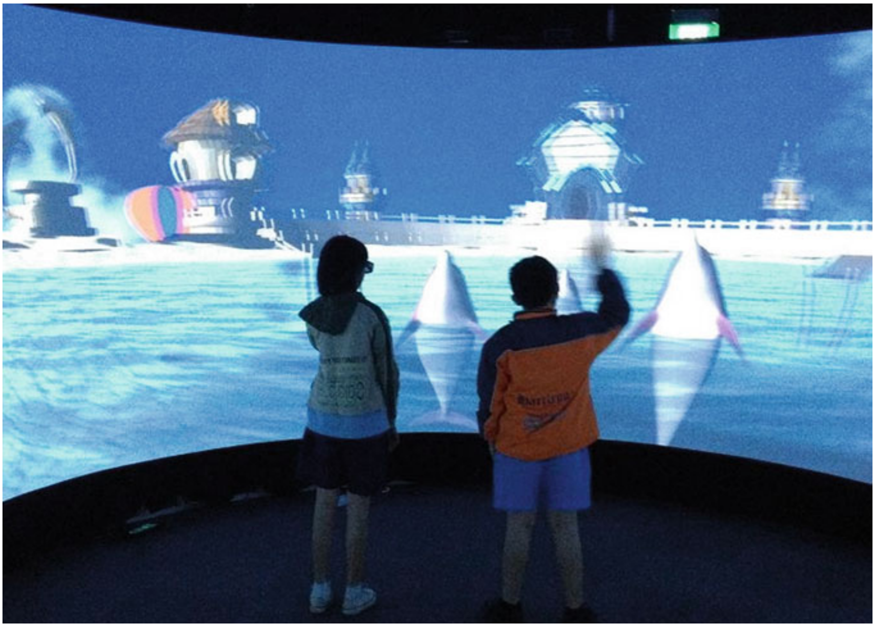

Fig. 7 Two special needs children are interacting with the virtual pink dolphins

Fig. 8 A reflection by a special need child after her interactive play with the virtual pink dolphins

4 Conclusion

The Virtual Pink Dolphins Project is a new initiative to study the VR technology for applications of special needs education. A serious game is developed with a focus on improving the nonverbal communication skills of special needs children. For this aim, significant research has been carried out to understand the anatomy of the pink dolphins, and their behavioral patterns. From there, techniques of 3D modeling, visualization, interaction, natural interface, and simulation are investigated for the development of the virtual pink dolphin game.

Five sessions have been conducted for a dozen of children from a local special needs school. Special teaching plan and teaching activities are designed based on the dolphin context. These children learn anatomy, vocabulary, and shapes of the pink dolphins. They also learn hand gesture-based nonverbal communication through interactive playing with the virtual pink dolphins. Figure 8 is one of the reflections by a child after her game play with the virtual pink dolphins.

There are lots of work can be done with the virtual pink dolphins. A pilot study on the use of virtual pink dolphins to assist children with autism was recently reported (Cai et al. 2013). We believe edutainment concept and edutainment technology (Cai et al. 2006) have big room to develop for the special needs education.

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References

Au D, Weihs D (1980) At high speeds, dolphins save energy by leaping. Nature 284(5756):548–550

Cai YY, Lu BF, Fan ZW, Indhumathi C, Lim KT, Chan CW, Jiang Y, Li L (2006) Bio edutainment: learning life science through X gaming. Comput Graph 30(2006):3–9

Cai Y, Chia N, Thalmann D, Kee N, Zheng J, Thalmann N (2013) Design and development of a virtual dolphinarium for children with autism. IEEE Trans Neural Syst Rehabil 21(2):208–217

Chia NKH, Kee NKN (2012) A study on the responsivity of children with autism to dolphin sounds during manipulative activities. Paper presented at the meeting of the association of educational therapists-Singapore, Chapter Study Group, Singapore, 8 June 2012

Cranford TW (2000) In search of impulse sound sources in odontocetes. In: Au WWL, Popper AN, Fay RR (eds) Hearing by whales and dolphins. Springer-Verlag, New York, pp 109–156

Fish FE (2006) The myth and reality of Gray's paradox: implication of dolphin drag reduction for technology. Bioinspiration Biomimetics 1:17–25

Fordyce RE (1980) Whale evolution and oligocene southern-ocean environments. Palaeogeogr Palaeoclimatol Palaeoecol 31:319–336

Fordyce RE, Barnes LG (1994) The evolutionary history of whales and dolphins. Annu Rev Earth Planet Sci 22(1):419–455

Ketten DR (1992) The marine mammal ear: specializations for aquatic audition and echolocation. In: Webster D, Fay R, Popper A (eds) The evolutionary biology of hearing. Springer-Verlag, New York, pp 717–750

Ketten DR (2000) Cetacean ears. In: Au W, Fay R, Popper A (eds) Hearing by whales and dolphins. Springer-Verlag, New York, pp 43–108

Rice DW (1998) Marine mammals of the world: systematics and distribution. The Society for Marine Mammalogy, San Francisco Special Publication 4

Ross GJB (2002) Humpback dolphins: *Sousa chinensis*, *S. plumbea* and *S. teuszi*. In: Perrin WF, Wursig B, Thewissen JGM (eds) Encyclopedia of marine mammals. Academic Press, San Diego, pp 585–589

Zagzebski K (2009) How do whales and dolphins swim? National Marine Life Center, Buzzards Bay