

Claude Shannon's - No Drop Juggling Diorama

Juggling

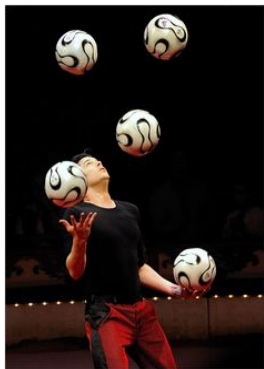


Figure 1: Types of Juggling

Basics of Juggling

- Juggling started many centuries ago and in many different and distant civilizations.
- It was also developed independently at very early times in India.
- Jugglers are among the most vulnerable of all entertainers(difficult to cover their slips)
- It appears to be a skill that very young people can master.
- It uses three basic tools – the ball, the ring and the club.
- University of Colorado, Pennsylvania State University, M.I.T., Wesleyan and many other universities have active juggling groups.

Scientific Aspects of Juggling

- At the instant a juggling object leaves contact with the hand of the juggler it enters the world of analytical dynamics subject to the laws and theorems of Newton, Euler, Poincaré and Poincaré.
- If juggling object is tossed to a height h_1 and caught after a drop of h_2 , the time of flight would be given by

$$\sqrt{2h_1/g} + \sqrt{2h_2/g}$$

g is the acceleration of gravity.

- Rotational motion of an object in free flight is much more complex than the motion of the center of gravity.
- The motion will depend on the distribution of mass of the body, which can be summarized in its ellipsoid of inertia.

Scientific Aspects of Juggling

- The ball has all three axes of inertia equal.
- The ring has two equal axes and the other axes very small.
- The club has two equal axes and the third axes very large.
- These three objects shows much more predictable behavior than that of an object with three unequal axes.
- The objects with three unequal axes will show stability in rotation about the largest and smallest axes but not about the intermediate one.
- The juggling repertoire has evolved a vast series of other patterns as shown in Fig.2.

Patterns of Juggling

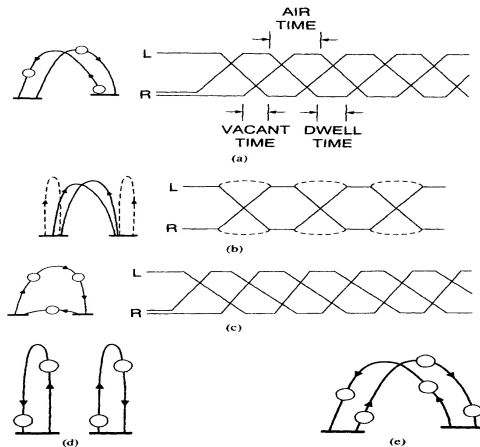


Figure 2: (a) Three-ball cascade (b) Two balls. (c) Three-ball shower. (d) Three-ball fountain. (e) Five-ball cascade.

Patterns of Juggling

- The right-hand parts of these diagrams show how the juggled objects progress from hand to hand with time.
- Fig. 2a shows the simplest three-ball cascade where jugglers can vary the height of the throw, the width of the hands and even reverse the direction of motion.
- Fig. 2b is the simplest case i.e. two balls and two hands, where a choice can be made at each toss whether to interchange the balls or keep them in the same hands.
- The three-ball shower in Fig. 2c is similar to the three-ball cascade but with different timing - the left to right throw going almost horizontally so that the whole pattern looks more like balls rotating in a circle.

Styles of Juggling

- Fig. 2d shows the fountain way of juggling four balls which are usually done in one of the two ways:
 - where the two hands are out of synchronism. Thus, the two balls in each of the two hands never interchange.
 - synchronous movement where the balls can be interchanged or not at each toss.
- Fig. 2e shows the pattern for a normal five-ball cascade, a natural generalization of the three-ball.

Uniform Juggle

- All dwell times(D), flight times(F) and vacant times (V) are the same for all the hands.
- Most common juggling patterns are the 3, 5 and 7-ball cascades, 2 or 3 in one hand, the 4-ball fountain and many passing routines among 2 or more jugglers.
- **Theorem 1:** Proportionality between the number of balls(B) and hands(H) is given as

$$\frac{B}{H} = \frac{F + D}{V + D} \quad (1)$$

- **Theorem 2:** If B and H are relatively prime then there is essentially a unique uniform juggle, such that each ball progresses through the hands in cyclical sequence and each hand catches the balls in cyclical sequence.

Uniform Juggle

- **Theorem 3:** If B and H are not relatively prime with $B = np$ and $H = nq$ (p and q relatively prime). Then there are as many types of juggles as ways of partitioning n into a sum of integers.
- **e.g.(Theorem 3)** : In the common case of two jugglers ($H = 4$), each with 3 clubs ($B = 6$), we have $n = 2$, which can be written as a sum of positive integers in two ways: 2 or $1 + 1$.
 - The case of 2 corresponds to the jugglers starting simultaneously. Thus, at each toss there is a choice of two possibilities: a self-throw or a throw to a partner.
 - The case of $1 + 1$, corresponds to two jugglers out of synchronism. There is no way to pass clubs from one pair of hands to the other without violating the uniform juggle condition.

Thank You!