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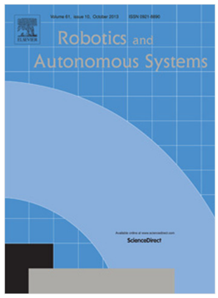

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Experiments in Robust Path Following Control of a Rolling and Spinning Robot on Outdoor Surfaces ⋆

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Abstract: This paper presents path following control experiments of a miniature spherical rolling and spinning robot mechanism on three different types of outdoor surfaces. The research is inspired from the efficient locomotory rolling patterns of various insects in unstructured environment. A nonlinear adaptive sliding mode (*ASMC*) feedback method maintains the robot stability and robustness in the presence of parameter uncertainties and external disturbances. The proposed path following control policy is developed, implemented and tested for the miniature spherical robot on three different types of irregular surfaces in outdoors. Path following accuracy, roll angle stability and wheel velocity response are three parameters measured to evaluate robot performance. *ASMC* controller capability is compared with an integral sliding mode (*ISMC*) controller. Experimental results show that proposed nonlinear robust control policy precisely tracks the different paths on these irregular surfaces in practical outdoor conditions.

Keywords: Spherical Robot, Rolling gait, Central Pattern Generator (*CPG*), Path following control, Adaptive sliding mode (*ASMC*) control.

1. INTRODUCTION

Active rolling behavioral locomotion [1] found in insects is a fascinating mechanism. This mechanism allows the organism to attain rolling and regulate the roll direction simultaneously by using its self-sufficient energy. Some examples commonly found are Pleurotya (Mother-of-pearl moth) caterpillar [2,3], Stomatopod shrimp, Huntsman spider etc. According to literature [3,4] and also shown in Fig.1, in response to certain stimuli, these invertebrate insects can roll swiftly and efficiently over a considerable distance by recoiling themselves into a wheel shape by with heads pushed inside while back to outside. Insects adopt the transformative recoil-roll mechanism to indicate the direct benefits of softness, speed and efficiency [4,5] in locomotion.

The rolling mechanism is produced by central pattern generator (*CPG*) based rhythmic rolling gaits [6,7]. In present research, the one-sided complete roll is denoted by angular parameter φ_1 shown in Fig.2. It is the resultant of a series of smaller rolling gaits φ_{11} , φ_{12} and vice versa for other side. Section *2* discusses parameter φ. *CPG* based rhythmic mechanisms are found in both amphibian vertebrates and insect invertebrate locomotion [7,8]. Using

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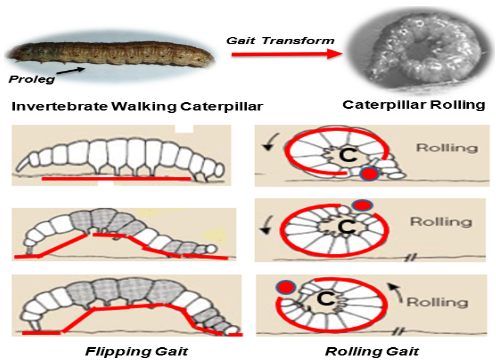

Fig. 1. Caterpillar locomotory recoil (flip) and rolling gaits. A half wave (redline) helps to retreat the body from tail to head. Cited from [2]

*CPG*s coordinated patterns of high-dimensional rhythmic output gait signals are produced with low-dimensional input feed signals. Based on this principle, bioinspired mobile robots have widely exploited the *CPG* based dynamics and control [9,10,11,12,13] policies. Desirable control properties like distributed structure, global convergence and inherent stability of a limit cycle are supported by a *CPG* network [10]. These properties have been used by researchers to add sensory feedback capability and tune locomotion (control) parameters [9,11].