The locomotion capabilities of the EPFL jumpglider: A hybrid jumping and gliding robot

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Abstract— **Recent work suggests that wings can be used to prolong the jumps of miniature jumping robots. However, no functional miniature jumping robot has been presented so far that can successfully apply this hybrid locomotion principle. In this video publication, we present the locomotion capabilities of the 'EPFL jumpglider', a miniature robot that can prolong its jumps using steered hybrid jumping and gliding locomotion over varied terrain. For example, it can safely descend from elevated positions such as stairs and buildings and propagate on ground with small jumps [1].**

Locomotion in rough and varied terrain is one of the grand challenges in miniature mobile robotics. One promising way of moving at a low energetic cost is to adopt jumping locomotion, as used by many small insects such as fleas, locusts, frogs and many others. In robotics, several jumping systems have been presented which use the same bioinspired locomotion principles [1]–[13], .

Recently, it has been suggested [5,7,14] that wings could be used to prolong the flight phase of a jumping system. The idea is that the robot would jump with closed wings, open the wings on top of the jumping trajectory and perform a subsequent gliding phase. Due to the lack of an existing term for this hybrid jumping and gliding locomotion, we introduce the term 'jumpgliding' for this concept of winged jumping. Armour et al. [7] have pioneered this field by presenting a 0.7kg jumping robot called 'Glumper' that jumps and deploys membraneous wings with the intention of increasing jumping distance. However, the final prototype has been shown to perform only one single jump without the ability to recharge and jump again. Scafogliero et al. [5] mention in their future work section the potential extensions of the 'Grillo' robot with wings to increase its jumping distance, but no realization has been presented so far. Previous versions of our 'Self Deploying Microglider' [14] include exploratory prototypes of gliding robots which can deploy themselves into the air by means of a jumping mechanism. Although these preliminary prototypes were promising, no systematic evaluation of different wing folding designs has been presented so far as well as no funtional jumpgliding robot has been developed that can perform repetitive jumpgliding locomotion in varied terrain.

[1]This work has been carried out at EPFL. Video footage of the EPFL jumpglider with rigid wings moving in varied terrain can be found at http://www.youtube.com/watch?v=DxugW3XfWao

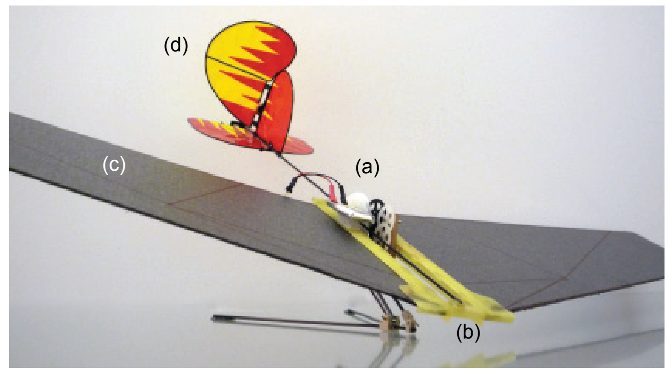

Fig. 1. EPFL jumpglider (version with rigid wings). 16.5g jumpgliding robot that can jump, perform steered gliding flight and move on ground with small jumps. (a) jumping mechanism, (b) CNC cut Polyimide frame, (c) wings, (d) tail with rudder for in-air steering

In this video, we present the locomotion capabilities of the EPFL jumpglider. It illustrates that it can perform steered and safe descend from elevated positions of several meters height and subsequently move on ground. The average gliding velocity is 2m/s and the gliding ratio is 2.2. It can perform repetitive jumps on level terrain without human intervention. The jumping height is 12cm and the jumping distance is 30.2cm.

The implemented version of the EPFL jumpglider weights 16.5g, has a wingspan of 49cm and a surface area of $0.039m^2$. As wing material we use Durobatics^{TM}, a Polysterene foam which is widely used in the hobbyist community to build lightweight wings for remote controlled airplanes. For steering, we adapted the tail and rudder system from a previously developed microflyer [15]. Due to the wings, the robot keeps an upright position after landing for the next take-off. This enables the robot to perform repetitive jumps without needing a cage or an uprighting mechanism. The weight budget of the EPFL jumpglider is summarized in table I. As possibilities of different mechanical wing designs, we considered three biologically inspired wing folding mechanisms which are described in more detail in [16]. Adding a wing folding mechanism offers the advantage to be more compact on ground but it increases the complexity and weight of the jumpglider which has negative effects on its flight performance as compared to rigid wings.

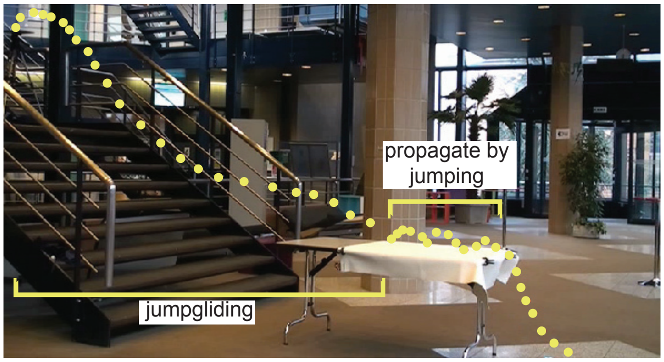

Fig. 2. Illustration of the locomotion capabilities of the EPFL jumpglider. It jumps from an elevated position of 2.53m height from the ground, lands safely on a table and performs three sequential jumps to progress on level terrain. Finally, it jump off the table to glide down to the floor

TABLE I
WEIGHT BUDGET OF THE EPFLJUMPGLIDER

Part EPFL jumpglider	**(rigid wings)**
Jumping [g] mechanism	6.03
20mAh battery [g]	0.94
Remote control [g] receiver	0.81
Wings [g]	4.5
Polyimide frame [g]	2.59
Tail [g]	1.63
Total mass [g]	**16.5**
Wing loading [kg/m^2]	0.42

Although it has been suggested that jumping robots can benefit from having wings, no theoretical considerations for this claim has been presented so far. In order to evaluate under which conditions wings provide jumping robots with added benefits, we developed a closed form mathematical model on the design parameters of the wings and the jumping mechanism in [17]. We conclude that for locomotion on level terrain and the jumping performance of the robots presented to date, jumping without wings leads to larger distance covered per jump. For example, the 16.3g EPFL jumper v3 [10] jumps a distance of 46cm and a height of 62cm which is much higher than the EPFL jumper with wings and similar weight. Both robots use the same jumping mechanism and are protected on landing and steerable. However, having wings is beneficial when jumping from elevated position because they can increase the jumping distance due to the gliding phase and can decrease the impact energy which has to be absorbed by the robot structure on landing.

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