Survey of Micro Air Vehicles in an International Even & Utilization in Thailand

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Abstract

Micro Air Vehicle (MAV) is a very small autonomous aerial vehicle which can be carried and operated by one person. It had been originally interested for military as surveillance, pointing target, dropping sensor, and etc. The flight competition of MAV has been first organized in 1997 by USA. Numerous researches on MAVs have been done around the world. This paper talks about the MAVs which have been developed and presented in the international MAV flight competition, in particular IMAV in Germany, July 2010. Different MAV configurations and some technologies are presented. Finally, the application of MAVs / UAVs in Thailand will be discussed.

Keywords: MAVs, UAVs application, Low Reynolds number.

1. Introduction

Unmanned air vehicles (UAVs) have been thriving among both military and civil environments. Their applications are multiple, concerning traffic surveillance, video-recording of public demonstrations or even delicate rescue missions. UAVs are now highly observed for the military services. UAVs are also used for some civil missions. One of the well known long-endurance UAV for civil application is such as the Aerosonde developed by the Australia Company [1].

After an increasing of UAVs applications, DARPA, the USA research agency, announced the requirement of new class of very small air vehicle. Micro Air Vehicles (MAVs) are defined as a 15-cm-size autonomous air vehicles which can be carried and operated by only one person. Now MAV is widely developed in USA and in Europe. Many MAV platforms are studied and designed including Fixed-Wing, Rotating-Wing and Flapping-Wing platforms. Due to its very small size and its low flight speed that result in very low Reynolds number regime, one of the main exciting problems is its poor aerodynamic performance. New control systems and new sensors are widely focused as well. Therefore, an International Conference and Flight Competition have been organized every year in Europe and in USA since 1997.

Developing and researching on MAVs or small UAVs spend very low budget and there might be some applications can be useful for Thailand. However, Thailand has very low activity and research on UAVs for general applications. For this reason, this paper aims to introduce and to show some of MAVs which had been developed by international stadium. Then, application of MAV in Thailand will be discussed.

2. MAVs Flight Competitions

The flight competition of MAVs has been organized since 1997 just after the requirement of DARPA. In the beginning, only outdoor mission was organized in the competition. According to an increasing of military mission requirement and a possibility of civil use, an indoor mission has been included in the international flight competition since 2007. Both, the outdoor and the indoor event, consist of two different competitions. The first one is focused on flight dynamics and maneuverability, while the second one emphasizes more the autonomous flight as illustrated in Fig 1 and 2, respectively [2].

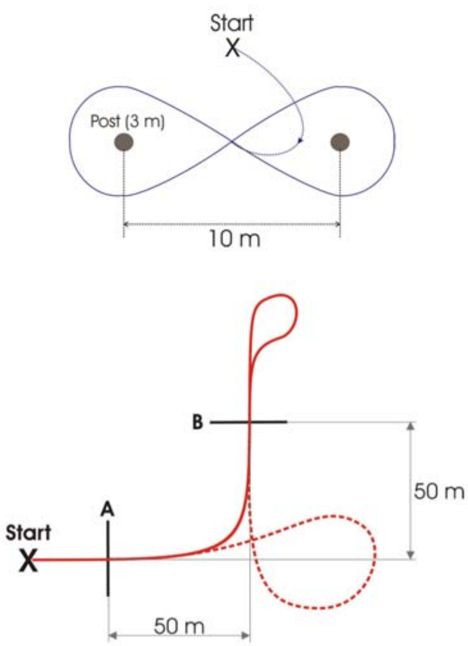


Fig. 1 Flight Dynamics Contest

Top: indoor, bottom: outdoor

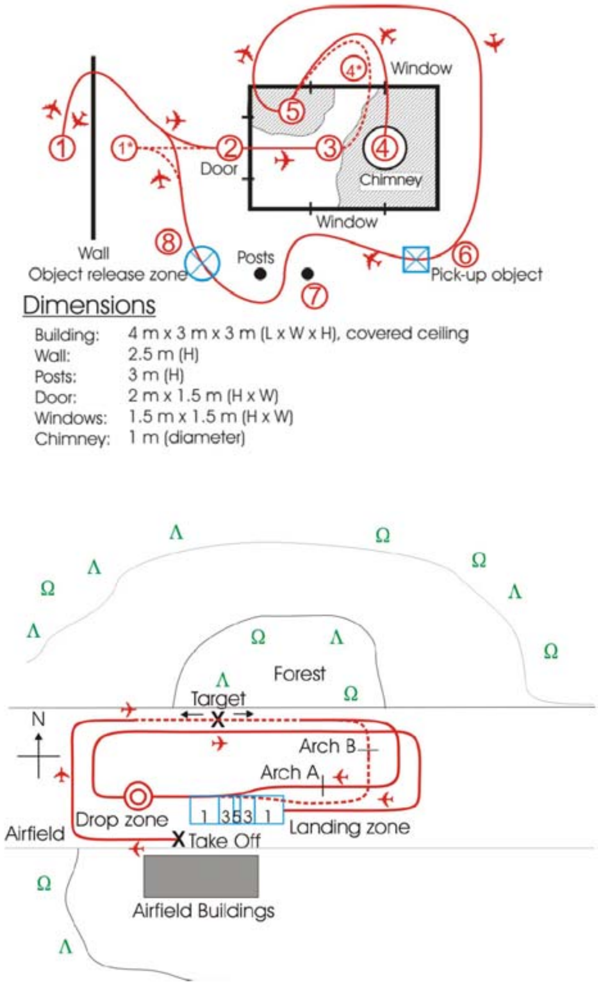


Fig. 2 Flight Autonomy Contest

Top: indoor, bottom: outdoor

Many teams can design small MAVs as dimension of about 15-25cm-span. Nevertheless, they could not achieve the mission automatically. The size of "autonomous" air vehicles could not reach the demanding of 15cm due to the present technology of system hardware. For this reason, the present flight competition still accepts the maximum size of about 60 – 70 cm or sometime up to 1m span which is more now realizable and applicable. The accepted weight is around 1 kg maximum. However, there is a penalty factor "S" in Eq. (1) applied to the final score relate to its size as shown in Eq. (2).

$$S = (2\text{-}D/D_{max})^2 \quad (1)$$
$$T = (S)(A)(M) \quad (2)$$

D_{max} is the maximum dimension that arrowed in the competition. More information can be found from www.imav2010.org or www.imav2011.org website. The regular in detail may change for each competition.

Level of autonomy (factor "A" in Eq" (2)) is another parameter that considered in the competition. The scoring factor of "A" is presented in Table 1.

Table. 1 Level of Autonomy Factor and Descriptions

Name	Description	Factor A
Level 1	Manual Control (RC Control, Visual Contact)	1
Level 2	Video Based Control (RC Control, no Direct Visual Contact)	2
Level 3	Automated Control (no Intervention by Pilot/Operator after Take-off)	6

3. The Survey of MAVs

Consider a small size of UAV, MAV can be mainly divided in to three categories according to the lift generating method; fixed-wing, rotating-wing or rotorcraft, and flapping wing. They are detailed in this section.

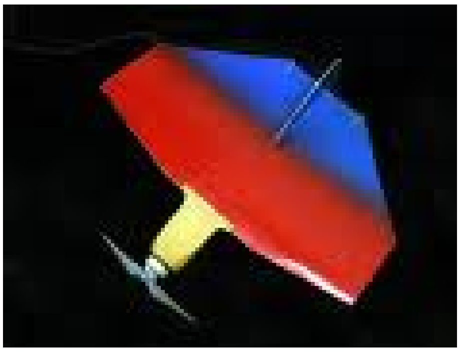
3.1 Fixed Wing MAVs

As large dimension is still arrowed for the competition, the UAVs with the conventional fixed-wing configuration and the high aspect ratio wing configuration of dimension more than 40cm-span are usually found as shown in Fig. 3.

Lerche 500, span 50cm,

Vision based MAV of LIS-EPFL, span 80cm

Fig. 3 Conventional Type Fixed-Wing MAVs



MAV, The University of Arizona

Nanos MAV, Aerotonomy

Fig. 4 Very Low Aspect Ratio Fixed-Wing MAVs

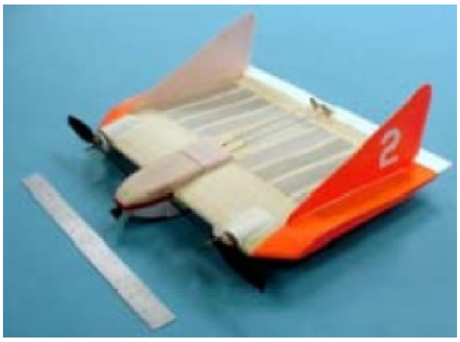
However, new concept of air vehicle has been designed. An unconventional and / or a very low aspect ratio wing configuration are developed in order to minimize a dimension of wing span [3-4]. Aerodynamics of very low Reynolds number and very low aspect ratio wing was first studied by the Notre Dame University. [5] found that aerodynamics performance of this type of wing is very poor, presenting of laminar separation bubble results in a decreasing of lift and an enhancing of lift. This separation bubble can be control by the Micro-Jet [6]. Nevertheless, there is an advantage of very low aspect ratio (LAR) wing. Strong wing tip vortex can delay a stall angle so that high lift coefficient can be obtained (of course with high induced drag) [7]. Some of very low aspect ratio MAVs is in Fig. 4.

Gators MAV, The University of Florida

Fig. 5 Flexible Wing Based MAV, FL

Since MAV is very small, it is very sensitive to the external perturbations; ex. strongly variation of wind speed [8]. Thus, the University of Florida highly worked on a flexible membrane wing concept (Fig. 5). Carbon structure and flexible latex sheet are used. Many theoretical and analytical studies were performed and show the advantage of flexible wing concept [9-10]. The wind tunnel test carried out by [11] confirmed the reduction of reduction of lift coefficient variation results as well.

Because of the problem of high induced drag, some study was performed and new configurations MAVs were realized. Naval Research Laboratory [12] performed the MITE MAV (Fig. 6-top) based on LAV wing. Two motors are installed close to the leading edge wing tip in order to gain the propulsive-induced swirl flow countering the wing tip vortex. Therefore, an artificial wing span can be generated.



MITE, span 20cm,

TYTO MAV, span 30cm

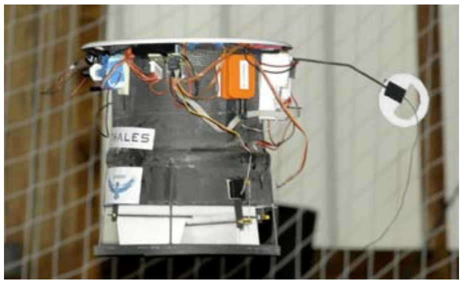
Fig. 6 Unconventional MAV

Another concept was analyzed for induce drag reduction as well. Going back to the early of flight when aircraft structure technology was underdeveloped while high lift was still need to carry the airframe, a biplane concept was selected. [13] applied the same concept into their MAV. Many studies including wing planform, aspect ratio, wing arrangement combination, and propulsive interaction were performed. Finally, the study came out with TYTO [14] configuration as shown in Fig. 6-bottom. Propulsive-pusher configuration profits in term of local angle of attack when compared with propulsive-tractor configuration that loses wing aerodynamics performance by high drag. TYTO MAV participated in IMAV07 at Toulouse, France and got the 4th rank from 17 competitors for outdoor competition. TYTO received also the "*Best Aerodynamics and Design Award*" from the committees.

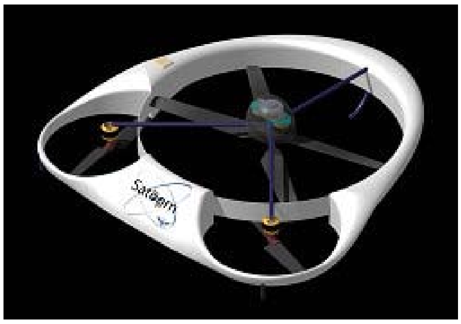
3.2 Rotor Wing MAVs

To reduce the size of vehicle, the coaxial concept is usually used for MAV. The tail rotor, that normally installed for torque elimination, is then can be neglected. However, it is still difficult to control and hard to realize in small size. Ducted fan configuration can be found also since it gives better performance and the duct can protect the rotor. The system can be controlled by the control surface under the flow induced by rotor as shown in Fig 7-middle. However, ducted-fan is very sensitive by the external wind perturbation, it can success only for indoor mission. Therefore, study of new concept by applying shorter ducted, called shrouded rotor in Fig. 7-bottom, was conducted. [15-16] experimentally studied this concept. The result was also compared with the CFD computation [17]. The aim is to profit an interaction between rotor - shroud and to reduce lateral surface. Finally, fast forward speed can be achieved.

PixHawk, CoAxial Rotor MAV of ETZ, Switzerland
Won the 1st place for indoor competition, EMAV09



Br2C, Ducted fan MAV of ISAE, Toulouse, France



SaToorn, Shrouded Rotor, ISAE, Toulouse, France

Fig. 7 Rotor Wing MAVs

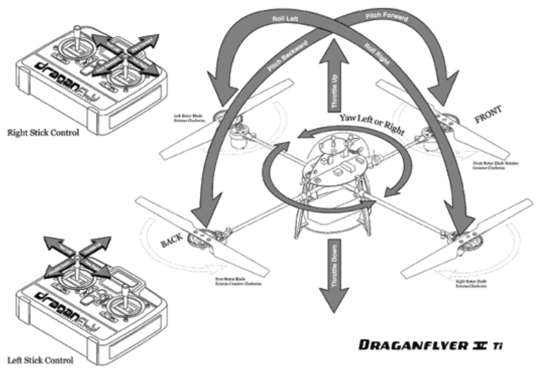


Fig. 8 The control methodology of Quadrotor

After the successful of the competition in 2008 at Braunschweig in Germany by multi-rotor concept, rotor wing configuration is another platform which becomes more attractive for MAV. Multi rotors are now interested because it is much easier for control. Instead of use the swash plate, the control can be done directly by the power of rotor as simply present by RC-toy Draganfly Innovation INC in Fig. 8. Many studies had been done in particularly for control law [18-19]. The trirotor, quadrotor, 6, or 8-rotor platform can be found such for example illustrated in Fig. 9.

Shrediquette, Tricopter won 1st place at IMAV 2010 (indoor)

Quadrotor MAV concept, ENAC team

HezaKopter, Germany

Fig. 9 Multi-Rotor MAV

3.3 Flapping Wing MAVs

Flapping wing generates thrust and lift by the optimized movement of wings. This subject seems to be the most attractive and the most challenge. Aerodynamics phenomenon and wing movement are complex. Some of rigid flapping wing is used but not very success. Flexible wing structure is usually playing with so an aeroelasticity problem often takes in account for design. New idea of Auto-Resonant is considered in order to reduce an input energy to move the wing [20]. Presently US-Army supports a lot of budget on this subject. Therefore, many universities in USA and around the world such U. of Arizona, U. of Florida, Wright State U., Bringham Young U., U. of Toronto, Valentin Kiselev, TU-Delft and etc, focus on flapping activities. Many researches had been done and presented, for ex. [21-23]. However, they are not often presenting in the competition.

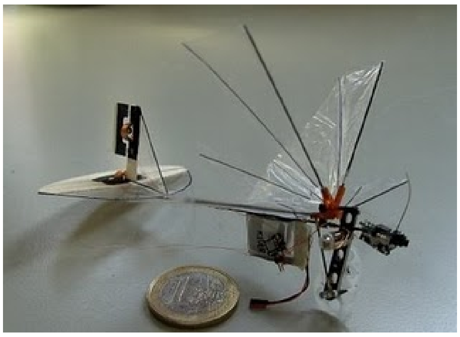


Fig. 10 Flapping Wing Concept, Delft team

The most success flapping team in IMAV event is taken by TU-Delft, the Netherlands. There flapping mechanism is simple but high thrust can be produced by clamping effect of bi-wing. Aerodynamics study was performed by force measurement and PIV method. TU-Delft still developed the flapping

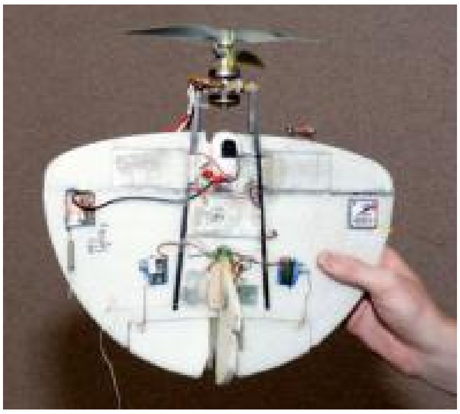
MAV, [24] found that the efficiency of DelFly can be improved by modify mechanism and wing structure. The smallest DelFly has the weight just about 10 grams. This already includes on-board camera.

Very tiny flapping system is now another field of research. High technology, such MEMS (Micro-Electro-Mechanical-System), is applied. The size of air vehicle can be very small as an insect-scale [25-26].

3.4 Hybrid Configurations

As mentioned before, fixed-wing type providing good high speed forward flight are usually used for outdoor applications while on the other hand rotorcraft and flapping configurations are interesting for flying in indoor mission due to their low speed and better hovering performance. In addition, the mission requirement has become more complex and more attractive in particularly these last few years. Therefore, new concept of multi-mission MAV configuration has been considered.

[27] done the feasibility and comparative study of using tilt-rotor, tilt-wing, and tilt-body concept for vertical take-off and landing MAV. Tilt-body was finally selected because the mechanism and the fabrication process are much easier than other tilt concept while the aerodynamics performances are quite similar. [28] then focused the study on tilt-body "MiniVertiGo" MAV. Coaxial rotor was applied both to give high thrust and to eliminate of motor's torque during hovering. The MiniVertiGo (Fig. 11-top) well demonstrated in MAV07 event. In 2009, ISAE presented another tilt-body concept called "MAVion" (Fig.11-bottom). Tandem motors were used instead of coaxial motor. Ground effect test was also carried out by very high accuracy sting balance [29]. The MAVion very well performed its flight characteristics by won the 1st place in IMAV09 at Pensacola, Florida.



MiniVertiGo, span 30cm,

MAVion MAV, span 30cm

Fig. 11 Unconventional MAV

MMALV, Land and Air micro vehicle

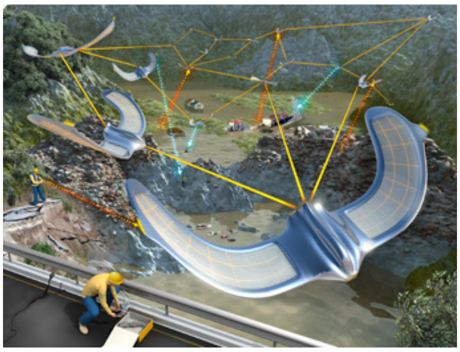
Fig. 12 Unconventional MAV

The idea of hybrid MAV is now interesting both for USA and Europe side. Morphing micro air and land vehicles (MMALV) [30] had been developed by the University of Florida (UF) and the Case Western Reserve

University (Case). Leg system of the Case had been applied to the morphing wing concept of the UF. The MMALV (Fig.12) demonstrates ground movement capability while remain the high speed flight performance of morphing MAV concept. On Europe side, Kuo [31] designed the hybrid MAV and present in IMAV2010 as well. However, MMALV and MAV of Kuo cannot conduct the low speed, hovering flight nor VTOL capacity.

4 Operating as a Network

According to the MAVs presented in previous session, the last MAV concept presented in this paper is the multi-MAVs network [32]. Each MAV can communicate and transfer the information to each other. Therefore the mission can be done faster. Different platforms can be used in the network so that optimized platform can be applied for different demanding. An example of this research is the SMAVNET project of LIS (Laboratory of System Intelligent), EPFL in Switzerland.



SMAVNET project, LIS

Fig. 13 Unconventional MAV

Saarland University in Germany is presently focuses the work on the operation network between MAV and ground robot as well as the hybrid concept MAV. Their project was presented at IMAV2010 [31].

5. System Navigation and Control

Control and navigation system is another main topic for UAVs / MAVs research and development. This subject is very challenge since MAVs has very small size. Thus, the size and weight must be very small. In addition, since the size is very tiny, there is also an interference of each electronics component problem to be considered. Material of airframe should be carefully selected. Carbon composite material can be the problem of data link transfer. The size and weight of controller board are now can be small as 3x4cm^2 and 15 grams or even smaller and lighter.

Sensor is an important part of navigation system as well. For the outdoor mission, Gyro, accelometer, magnetometer, and GPS are normally used to obtain MAV's position. Sometime, low cost infrared sensor is applied to determine roll and pitch angle of air vehicle instead of IMU. However, it has a limitation since an infrared can work only if there is enough different temperature between sky and ground as the problem found at EMAV 2008 competition in Delft. The altitude can be obtained by the GPS but very low accuracy. A good pressure sensor can used solve this low accurate problem but mass is added into the total weight. Since most MAVs equipped with video camera, the concept of using image for altitude determination was present by [33]. However, MAV of TU-Delft could not well demonstrate their technology at IMAV 2010.

The most exciting for developing navigation sensor is for an indoor flight. Since MAVs (GPS) cannot receive the signal from the satellites. Many sensors are studied such ultrasonic, optical mouse sensor, video based [34], Wii sensor, acoustic sensor [35], and etc.

6. Applications in Thailand

UAVs and MAVs are usually used for military mission. In the past, only low funding support invests for the civil UAVs application. However, it is grad that some developers interest to focus on civil applications. The research group in Europe had purposed the proposal to the European committee in 2009 although it was rejected. The proposal got the score of 9.5 from 15 which they need only 0.5 to be accepted. Anyhow, the proposal is been revising and will be submitted again soon. In February 2010, CyPhy Works [36] won $2.4 million award from USA government to develop small aerial vehicle for inspection and monitoring of civil infrastructure – highways, bridges and dam. In Malaysia, the UAV research group of the University Putra provides UAVs for civil service as well.

One reason that UAVs are not accepted for civil application is due to the security when operating in a publish area. However, since MAVs is smaller, the danger from the vehicle may acceptable in the future if it can prove their reliability.

According above paragraph, aerial vehicles are presently becoming more interesting for civil application. The application in Thailand may such environmental-, traffic-, monitoring, observation of forest, infra–structure, dam, and building. As Thailand is an agriculture country, there is very interesting and innovative use of UAVs to meet the niche requirements of widespread for agriculture as well done in Japan.

AeroEyes Company imports MikroKopter from Germany and starts some service of small UAVs. The job already done is such sky-monitoring [37]. Students of Aerospace Department, Kasetsart University are currently doing a project on the marketing of UAV application in Thailand. Because of low developing budget, MAVs may one of service market in Thailand. However, finally, the development of UAVs at Kasetsart University will be not limited only on MAV class, other size of UAVs will be also interested depend on the requirements.

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