同行专家业内评价意见书编号: 20240855045

附件1

浙江工程师学院（浙江大学工程师学院）
同行专家业内评价意见书

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申报工程师职称专业类别（领域）：　　机械

浙江工程师学院（浙江大学工程师学院）制

2024年03月19日

一、个人申报

（一）基本情况【围绕《浙江工程师学院（浙江大学工程师学院）工程类专业学位研究生工程师职称评审参考指标》，结合该专业类别(领域)工程师职称评审相关标准，举例说明】

1.对本专业基础理论知识和专业技术知识掌握情况：
本人通过硕士期间的学习，掌握了工程伦理意识，在实际工程中践行工程伦理规范。通过专业的学习以及工作实践经历，本人系统掌握了机械相关的专业理论知识、技术知识和研究方法，具备良好的数理基础，获得了良好的学业成绩；熟练掌握机械设计软件如Solidworks、CATIA以及有限元分析软件ANSYS。此外，本人积极使用多专业跨学科领域交叉知识解决工程问题，将机器学习技术融入机械领域。
2.工程实践的经历：
工程实践中，我的主要工作为基于各类新型深度学习模型，建立不同类型无人飞行器的气动代理模型，实现对气动参数的快速预测且预测误差不超过5%。已高质量完成所负责部分，分别针对扑翼飞行器、折叠翼飞行器等气动参数具有高度非定常特征的无人飞行器建立了高精度快速预测模型。通过此次实践经历，我深入了解了多种无人飞行器的气动特性和参数预测代理模型的理论知识，掌握了常见深度学习算法的原理和应用，同时掌握了相关的气动数据处理和特征工程技术。工程能力方面，我学习到了如何构建、训练和评估深度学习模型来实现对飞行器气动参数的预测，以加快飞行器前期的气动外形设计工作。
3.在实际工作中综合运用所学知识解决复杂工程问题的案例：
在学习与专业实践工作中，本人将深度学习技术，与航空变体飞行器前期的设计与空气动力学优化相结合，针对不同类型的变体飞行器，提出多种气动参数预测模型，大大加快了变体飞行器的初期设计与气动优化流程。变体飞行器一般指基于智能材料和智能控制等技术，根据不同的工作环境主动改变飞行器的气动外形，在不同飞行状态下达到最优的气动性能。机翼变体是一类典型的变体飞行器，包括折叠机翼飞行器与扑翼飞行器，已成为未来飞行器发展的重要方向之一。
仿生扑翼飞行器在扑动过程中产生的气动力具有强非定常、非线性特性，了解气动特性是进行扑翼优化设计与控制的基础，如何快速获得准确的气动特性，是扑翼飞行器的设计难点。在本人的专业学习与实践工作中，针对这种强非定常、非线性的气动力，提出一种基于门控循环单元与多层感知机的扑翼非定常气动参数快速预测模型，实现对扑翼扑动时高度非定常、非线性气动参数的实时预测。首先使用计算流体力学方法获得扑翼二维翼型扑动时的气动参数，以该参数为样本训练预测模型。在预测模型中，将扑翼的扑动振幅、频率、摆动角度与运动时间输入预测模型，快速得到扑翼在对应扑动状态下的升力、阻力与力矩。实验结果表明，所建立的预测模型精度高、计算速度快，对三种气动力的预测误差均小于3%，实现了对扑翼非定常气动参数变化的实时高精度预测。相关研究成果通过同行评议，发表在EI期刊浙江大学学报（工学版）。
折叠机翼变体飞行器的气动特性，在机翼的变形过程中经常表现出高度非线性的特征，使得基于传统计算流体动力学方法难以快速获得准确的气动参数。在本人的专业实践中，基于交叉网络和多任务学习的深度学习方法，提出了一种数据驱动的多任务交叉网络模型，用于预测折叠翼飞行器在不同迎角下的非定常气动参数，包括升力系数、阻力系数以及力矩系数。所提出的多任务交叉模型有效的对外部流场和飞机特性之间交互进行模拟，同时充分利用了非常稀疏的输入特征，如迎角，和十分有限的训练数据。将迎角、机翼展开时间和机翼展开角度作为模型的输入，通过多层非线性映射输出非定常力系数和力矩系数。实践结果表明，利用所提出的预测模型，可以在几秒钟内获得任何攻角和任何变形状态下的非定常气动参数。实验结果表明，本人所提出的多任务交叉模型能够快速、准确地预测折叠翼变体飞行器的气动参数，与其他传统以及智能预测方法相比，所提出的新型模型实现了更高的预测精度，将预测结果的平均误差降到5%以下，相关研究结果成功通过国内外专家评议，发表在中科院

一区期刊Aerospace Science and Technology，并获得多次同行引用。
基于航空航天领域机械设计中遇到的困难问题，结合智能方法如深度学习算法，本人成功运用所学知识与技能解决了空气动力学参数难以预测的问题，大大加快了变体飞行器的初期设计与气动优化流程，相关研究成果获得了同行的一致肯定。

（二）取得的业绩（代表作）【限填3项，须提交证明原件（包括发表的论文、出版的著作、专利证书、获奖证书、科技项目立项文件或合同、企业证明等）供核实，并提供复印件一份】					
1. 公开成果代表作【论文发表、专利成果、软件著作权、标准规范与行业工法制定、著作编写、科技成果获奖、学位论文等】					
成果名称	成果类别 [含论文、授权专利（含发明专利申请）、软件著作权、标准、工法、著作、获奖、学位论文等]	发表时间/授权或申请时间等	刊物名称/专利授权或申请号等	本人排名/总人数	备注
A novel prediction method for unsteady aerodynamic force on three-dimensional folding wing aircraft	国际期刊	2023年03月29日	Aerospace Science and Technology	1/3	SCI期刊收录
基于GRU的扑翼非定常气动特性快速预测	核心期刊	2023年06月01日	浙江大学学报（工学版）	1/4	EI期刊收录
Energy-Harvesting Strategy Investigation for Glider Autonomous Soaring Using Reinforcement Learning	国际期刊	2023年10月19日	aerospace	1/3	

2.其他代表作【主持或参与的课题研究项目、科技成果应用转化推广、企业技术难题解决方案、自主研发设计的产品或样机、技术报告、设计图纸、软课题研究报告、可行性研究报告、规划设计方案、施工或调试报告、工程实验、技术培训教材、推动行业发展中发挥的作用及取得的经济社会效益等】

（三）在校期间课程、专业实践训练及学位论文相关情况	
课程成绩情况	按课程学分核算的平均成绩： 82 分
专业实践训练时间及考核情况(具有三年及以上工作经历的不作要求)	累计时间： 1.5 年（要求1年及以上） 考核成绩： 94 分（要求80分及以上）
本人承诺	
个人声明：本人上述所填资料均为真实有效，如有虚假，愿承担一切责任，特此声明！ **申报人签名：**赵嘉犀	

22160090

二、日常表现考核评价及申报材料审核公示结果

日常表现 考核评价	非定向生由德育导师考核评价、定向生由所在工作单位考核评价： ☑优秀　　☐良好　　☐合格　　☐不合格 德育导师/定向生所在工作单位分管领导签字（公章）：　2026 年 01月25日 （中共浙江大学工程师学院委员会）
申报材料 审核公示	根据评审条件，工程师学院已对申报人员进行材料审核（学位课程成绩、专业实践训练时间及考核、学位论文、代表作等情况），并将符合要求的申报材料在学院网站公示不少于5个工作日，具体公示结果如下： ☐通过　☐不通过（具体原因：　　　　　　　　　　） 工程师学院教学管理办公室审核签字（公章）：　　　　年　月　日

浙 江 大 学 研 究 生 院

攻读硕士学位研究生成绩表

学号：22160090	姓名：赵嘉墀	性别：男	学院：工程师学院	专业：机械	学制：2.5年
毕业时最低应获：24.0学分		已获得：24.5学分		入学年月：2021-09	毕业年月：2024-03
学位证书号：1033532024602160			毕业证书号：103351202402600386		授予学位：机械硕士

学习时间	课程名称	备注	学分	成绩	课程性质	学习时间	课程名称	备注	学分	成绩	课程性质
2021-2022学年秋季学期	高性能复合材料制造技术及装备		2.0	80	专业学位课	2021-2022学年春季学期	智能无人机系统设计		2.0	76	专业选修课
2021-2022学年秋季学期	数值计算方法		2.0	93	专业选修课	2021-2022学年春季学期	飞机数字化装配技术与系统		2.0	60	专业学位课
2021-2022学年秋季学期	实验力学（I）		2.0	80	专业选修课	2021-2022学年夏季学期	自然辩证法概论		1.0	83	公共学位课
2021-2022学年秋冬季学期	中国特色社会主义理论与实践研究		2.0	83	公共学位课	2021-2022学年夏季学期	世界经典剧作赏析		1.0	92	公共选修课
2021-2022学年冬季学期	工程伦理		2.0	91	公共学位课	2021-2022学年春夏季学期	工程技术发展前沿		2.0	93	专业学位课
2021-2022学年秋冬季学期	研究生论文写作指导		1.0	77	专业学位课	2023-2024学年秋季学期	工程技术创新前沿		1.5	94	公共学位课
2021-2022学年冬季学期	智能工业机器人		2.0	86	专业选修课	2023-2024学年秋季学期	研究生英语应用能力提升		2.0	84	公共学位课

说明：1. 研究生课程按三种方法计分：百分制，两级制（通过、不通过），五级制（优、良、中、及格、不及格）。

2. 备注中“*”表示重修课程。

学院成绩校核章：

成绩校核人：张梦依

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A novel prediction method for unsteady aerodynamic force on three-dimensional folding wing aircraft

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ABSTRACT

The aerodynamic characteristics of morphing aircraft frequently exhibit extremely unsteady and nonlinear features during morphing process, making it challenging to obtain accurate aerodynamic parameters fast based on traditional computational fluid dynamics methods. In this paper, a data driven model Multi-Task Cross network, which is based on deep learning methods of cross network and Multi-Task Learning, is proposed to predict the unsteady aerodynamic parameters of a three-dimensional folding wing aircraft at any angle of attack. The Multi-Task Cross model seeks to effectively fuse external flow field and aircraft properties while making full use of sparse input features and limited training data. More accurate results can be obtained by using the Multi-Task Cross model to predict different aerodynamic parameters of folding wing aircraft. The model takes three inputs: angle of attack, time and unfolding angle of wing. It outputs the unsteady forces and moments coefficients through multi-layer nonlinear mapping. The training and testing data used for the Multi-Task Cross model are calculated by computational fluid dynamics method. With the proposed prediction model, the unsteady aerodynamic parameters at any angle of attack and any morphing state can be obtained in seconds. The testing results indicate that the Multi-Task Cross model predicts aerodynamic parameters quickly and accurately. The proposed Multi-Task Cross model achieves higher prediction accuracy when compared to prediction models based solely on Multilayer Perceptron, Multi-Task Learning method, and Cross method.

1. Introduction

For morphing aircraft, how to quickly obtain accurate unsteady aerodynamic parameters plays an important role in shortening the design cycle and supporting the flight control [1]. To support real-time control during morphing flight and optimization of flight strategy throughout the flight envelope, a fast and accurate aerodynamic parameters prediction model is urgently needed, for morphing aircraft, because traditional computational fluid dynamics (CFD) method has difficulty in quickly calculating highly unsteady aerodynamic parameters of three-dimensional morphing aircraft. Furthermore, because of the high computational cost of CFD, the amount of training data is relatively limited, and the input characteristics are quite sparse, making it difficult for the general prediction model to be effective. To address the aforementioned issue, a fast real-time data-driven aerodynamic parameter prediction model that can successfully exploit limited training data and sparse input features has become an interesting concern.

Researchers have used a variety of methods to study the aerodynamic characteristics of morphing aircraft. Liu *et al.* [2] proposed a novel morphing mechanism to solve the challenge of a wide Mach-number range aircraft design. Kriging surrogate model, a parallel infill-sampling method and a multi-round strategy were employed to address aerodynamic shape optimization challenge and got a good aerodynamic performance improvement of the optimized morphing wing features. Hui *et al.* [3] investigated the aerodynamic performances of the bio-inspired discrete wing configurations with different morphing states in detail based on the aerodynamic force measurements and wing-tip vortex measurements. Ajaj *et al.* [4] experimentally assess the impact of span morphing on the flight performance and on its ability to enhance roll control authority by wind-tunnel and flight testing performed. Han *et al.* [5] made the numerical simulation of variable-sweep morphing by CFD method, to explored its unsteady aerodynamic characteristics.

Traditional approaches to solving the fluid mechanics problems rely on physics modeling or wind-tunnel test, usually in the form of differential equations [6]. Researchers usually use CFD method to solve the aerodynamic parameters of the morphing aircraft [5,7]. CFD method requires complex and tedious preprocess such as geo-

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2. 以上检索结果来自 CALIS 查收查引系统。
3. 以上检索结果均得到委托人及被检索作者的确认。

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2023 年 12 月 27 日

aerospace

MDPI

Article

Energy-Harvesting Strategy Investigation for Glider Autonomous Soaring Using Reinforcement Learning

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Abstract: Birds and experienced glider pilots frequently use atmospheric updrafts for long-distance flight and energy conservation, with harvested energy from updrafts serving as the foundation. Inspired by their common characteristics in autonomous soaring, a reinforcement learning algorithm, the Twin Delayed Deep Deterministic policy gradient, is used to investigate the optimal strategy for an unpowered glider to harvest energy from thermal updrafts. A round updraft model is utilized to characterize updrafts with varied strengths. A high-fidelity six-degree-of-glider model is used in the dynamic modeling of a glider. The results for various flight initial positions and updraft strengths demonstrate the effectiveness of the strategy learned via reinforcement learning. To enhance the updraft perception ability and expand the applicability of the trained glider agent, an extra wind velocity differential correction module is introduced to the algorithm, and a strategy symmetry method is applied. Comparison experiments regarding round updraft, the Gedeon thermal model, and Dryden continuous turbulence indicate the crucial role of the further optimized methods in improving the updraft-sensing ability of the reinforcement learning glider agent. With optimized methods, a glider trained in a simplified thermal updraft with a simple training method can have more effective flight strategies.

Keywords: autonomous soaring; reinforcement learning; TD3; energy harvesting; algorithm optimization

check for updates

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1. Introduction

The phenomenon of exploiting atmospheric updrafts for energy harvesting and long-distance flight is widely present in migrating birds and experienced glider pilots [1,2]. This method of using atmospheric updrafts is referred to as soaring, which has received a lot of research and made significant progress. With increasing attention paid to soaring, many researchers have attempted to implement soaring using unmanned aircraft. The behavior of unmanned aircraft exploiting wind updrafts to increase endurance is called autonomous soaring [3].

Traditional research on the autonomous soaring of UAVs has relied heavily on locating the center of updrafts or using simplified wind field environments and UAV models. Allen [4] proposed a flight method for tracking the updraft center. For known updraft centers, he applied a circular strategy to obtain energy from the center by measuring its movement. The simulation results show that UAVs can greatly improve their endurance by utilizing convective lift in the atmosphere. Depenbusch et al. [5,6] proposed a complete set of algorithm systems that can be used for the autonomous soaring of aircraft. They conducted research on wind estimation, updraft identification, the measurement and dynamics of heat flow, and exploration methods. The components of autonomous algorithms include the mapping of thermals, exploration/utilization decisions for wind fields, navigation, the calculation of optimal airspeed, and energy state estimation. The feasibility of this algorithm is proven by actual flight experiments. Edwards et al. [7] developed a new way to locate and keep the glider in the rising thermal and applied this method to a glider

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基于 GRU 的扑翼非定常气动特性快速预测

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摘 要：为了克服传统计算流体力学代理模型不能有效模拟流体力学高度非线性系统的困难，解决现有基于深度学习的代理模型难以有效处理时间顺序信息的问题，以扑翼飞行器的二维翼型为研究对象，基于门控循环单元（GRU）与多层感知机，建立扑翼非定常气动参数的快速预测模型，实现对扑翼扑动时高度非定常、非线性气动参数的实时预测. 使用计算流体力学方法获得扑翼二维翼型扑动时的气动参数，以该参数为样本训练预测模型. 将扑翼的扑动振幅、频率、摆动角度与运动时间输入预测模型，快速得到扑翼在对应扑动状态下的升力、阻力与力矩. 实验结果表明，所建立的预测模型精度高、计算速度快，能够实现对扑翼非定常气动参数变化的实时高精度预测.

关键词：门控循环单元（GRU）；多层感知机；扑翼；气动参数预测；深度学习；计算流体力学

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Rapid prediction of unsteady aerodynamic characteristics of flapping wing based on GRU

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Abstract: Traditional computational fluid dynamics surrogate model cannot effectively simulate the highly nonlinear fluid, and existed deep learning-based surrogate models are difficult to deal with temporal sequence information effectively. Based on the gated recurrent units (GRU) and the multilayer perceptron, a two-dimensional airfoil of a flapping-wing aircraft was studied to establish a model for rapid predict unsteady aerodynamic parameters of the flapping-wing. The real-time prediction for the highly unsteady and nonlinear aerodynamic parameters of the flapping wing was realized. The computational fluid dynamics method was used to obtain the aerodynamic parameters of the flapping two-dimensional airfoil and the parameters were used as samples to train the prediction model. The flapping amplitude, the frequency, the swing angle and the motion time of the flapping wing were fed into the prediction model, and the lift, the drag and the moment in the relevant condition could be quickly output. Experimental results showed that the established prediction model has high accuracy and fast calculation speed. The prediction model could realize real-time high-precision prediction for unsteady aerodynamic parameters of flapping wings.

Key words: gated recurrent units (GRU); multilayer perceptron; flapping wing; aerodynamic parameter prediction; deep learning; computational fluid dynamics

仿生扑翼飞行器在扑动过程中产生的气动力具有强非定常、非线性特性，了解气动特性是进行扑翼优化设计与控制的基础，如何快速获得准确的气动特性，是扑翼飞行器的设计难点[1]. 计算流体力学（computational fluid dynamics, CFD）方法是扑翼气动模拟的主要方法，该方法的准确性依赖计算网格. 由于扑翼扑动过程涉及复杂的动网格或变形网格问题，容易导致 CFD 计算失败，且

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