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The 11th OAPS TASK FORCE MEETING

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Outline

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- **Student Journal of Tsinghua University 清华大学学生学报**
- Newly added: 21 Journal papers of 2013



SRT Project Report

清华大学

SRT 结题报告

题目：耦合与主动复合抓取机器人

系 别： 机械工程系
 专 业： 机械工程及自动化
 姓 名： 李博闻
 指导教师： 张文耀 副教授
 班 级： 06 9 班
 学 号： 2009011506

2012 年 9 月 10 日

DSEA Hand: Directly Self-adaptive Robotic Hand towards Robot Grasping and Singularity

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Abstract: Humanoid robotic hand is one of most amazing research fields in robotics. There are two important requirements to robotic hands on the one hand, a hand has a good kinematic appearance and more and more joints almost all of common objects, on the other hand, the same hand is very simple in structure, very easy to control and very low in cost. Most of present humanoid robotic hands could not balance above two aspects. A novel under-actuated robotic hand is developed which can achieve the above requirements perfectly, which is called "Directly Self-adaptive Under-actuated Hand, DSEA Hand". The key of the DSEA Hand is special and simple structure of its fingers, each of which is composed with multiple-link parallel mechanism mechanism, multiple springs and only one motor with a reducer. The DSEA Hand has 5 fingers, 10 joints (DOF) and only 1 motor. All fingers in the DSEA Hand are similar. The DSEA Hand has joints and all of the other four fingers. It has three joints. Self-adaptation for joint grasping performance is brought to the main function of the DSEA Hand from analysis and grasping experimental results that the characteristics of under-actuated hands make them very expressive and handling they widespread application. (Decrease hands are not complete in structure and control), and especially in cost. This is all one of important challenges for robotic hands used under outdoor and complex environments.

There are two important requirements to robotic hand on the one hand, a hand has a good kinematic appearance and more and more joints almost all of common objects, on the other hand, the same hand is very simple in structure, very easy to control and very low in cost. Most of present humanoid robotic hands could not balance above two aspects. A technology named under-actuated is invented to meet the requirements. The "under-actuated" means that the number of degrees of freedom is a combination is larger than number of actuators, such as muscles. Some under-actuated robotic hands have developed in last decades. Some typical under-actuated hands is shown in Figure 1. SARA Hand^[1] by Seoul University, DSEA Hand^[2] by Tsinghua University, Stark Hand^[3] and iCub^[4] Palm Hand, etc.

1 Introduction
 In recent years, kinds of robot have been widely applied in industrial production. To carry out a variety of service activities, a robot needs at least one hand that can grasp and manipulate various objects^[1]. Humanoid robotic hand is one of most amazing research fields in robotics. Change as a kind of end effectors which are the most widely used in everyday life and industrial production. Clamps, as used in industry, robot fingers have to not only have precise joints. Clamps also not have too adaptive for different target objects and cannot adapt to different shapes of objects. Hence, clamps are not good candidates for universal end effectors.

From the early 1980s, a lot of achievements have been made in the field of humanoid hand research. A generally decrease hand has at least 3 joints on each and each decrease finger has 2-4 joints of freedom (DOF). Motion of distance hand's joints are actively driven by muscles. Sensors and control circuits are the basic components of a distance hand. Examples of distance hand include Shadow Hand^[2], DLR series hand^[3], UII hand^[4], Shadow series hand^[5], DLR series hand^[6] by DLRG, Citron series hand^[7], DA/VIIT series hand^[8] by Hanyou Institute of Technology. Distance hands highly depend on the sensors, algorithms and control systems. The

characteristics of under-actuated hands make them very expressive and handling they widespread application. (Decrease hands are not complete in structure and control), and especially in cost. This is all one of important challenges for robotic hands used under outdoor and complex environments.



Figure 1 shows typical under-actuated hand developed.

These solutions on the robotic hand focus in control, sensing, such as humanoid skull touch with robotic skin materials^[9]. However, more important achievements have obtained in expressing humanoid's existence by an active system including grasp and expression of emotion through hand gestures.

This paper developed a novel under-actuated robotic hand which can achieve the above requirements perfectly. This hand is called "Directly Self-adaptive Under-actuated Hand, the DSEA Hand."

In Figure 3, when finger has grasped the target object, the third shaft, the second phalanx, the fourth shaft and the first phalanx are fixed together as a rigid body. According to the grasp analysis, relative to the joint A, the following relationship is arrived at:

$$\begin{aligned} \dot{f}_1 &= \dot{f}_2 = \dot{f}_3 = \dot{f}_4 = \dot{f}_5 \\ \dot{f}_1 &= \dot{f}_2 = \dot{f}_3 = \dot{f}_4 = \dot{f}_5 \\ \dot{f}_1 &= \dot{f}_2 = \dot{f}_3 = \dot{f}_4 = \dot{f}_5 \\ \dot{f}_1 &= \dot{f}_2 = \dot{f}_3 = \dot{f}_4 = \dot{f}_5 \\ \dot{f}_1 &= \dot{f}_2 = \dot{f}_3 = \dot{f}_4 = \dot{f}_5 \end{aligned}$$

$$\begin{aligned} \dot{f}_1 &= \dot{f}_2 = \dot{f}_3 = \dot{f}_4 = \dot{f}_5 \\ \dot{f}_1 &= \dot{f}_2 = \dot{f}_3 = \dot{f}_4 = \dot{f}_5 \end{aligned}$$

$$\begin{aligned} \dot{f}_1 &= \dot{f}_2 = \dot{f}_3 = \dot{f}_4 = \dot{f}_5 \\ \dot{f}_1 &= \dot{f}_2 = \dot{f}_3 = \dot{f}_4 = \dot{f}_5 \end{aligned}$$

So far, as functions of θ_1 and θ_2 . When $\theta_1=90^\circ$ Yes, $\theta_2=90^\circ$ Yes, $\theta_3=90^\circ$ Yes, $\theta_4=90^\circ$ Yes, $\theta_5=90^\circ$ Yes, the range of θ_1 is from 0° to 90° . The relationships of θ_1, θ_2 and θ_3 are shown in Figure 4(a). Set f_1 as function of θ_1 and θ_2 . The relationships of f_1, θ_1 and θ_2 are shown in Figure 4(b). The conclusions from these figures are listed below:

- When θ_1, θ_2 and θ_3 increase, f_1, f_2 and f_3 will respectively change slightly.
- For $\theta_1, \theta_2, \theta_3, \theta_4, \theta_5$ and θ_6 of any value, f_1, f_2 and f_3 will always remain positive and the value of them are large enough to grasp fully safely.

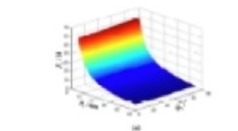


Figure 4 shows the relationship of f_1, f_2 and f_3 with the variables of θ_1, θ_2 and θ_3 .

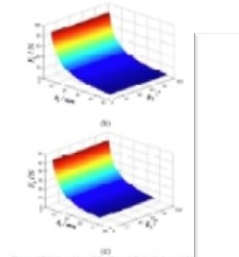


Figure 5 Relationship of f_1, f_2 and f_3 with the variables of θ_1, θ_2 and θ_3 .

4 Design of DSEA Hand
 At the beginning of this article, Stanford planning finger module designs of DSEA Hand is introduced. This covers the structural design of 2-joint DSEA finger and 3-joint DSEA finger. Briefly, working process group motion are analyzed above in detail. This section is up with the structural analysis and component design of DSEA Hand.

4.1 DOF and self grasping
 The DSEA Hand has 5 fingers, 4 of them are 2-joint DOF and other 1 is 3-joint DOF. The division of hand is shown in Figure 6(a), with it is directly self-adaptive under-actuated joint. That it is active joint 3 fingers with one embedded motor reduce and gear transmission inside.

The DSEA Hand has 5 fingers, 4 of them are 2-joint DOF fingers and another 1 is 3-joint DOF finger. 2-joint DOF fingers have the same structure as different with 1 motor driving 3 joints, while the third has 1 in driving 2 joints. DOF planning of hand is shown in Figure 6(b), dark red lines stand for active joint DOF and cylinders stand for DSEA joint DOF.

Table 1 is the dimension comparison between the index finger and a robot one Self-adaptive UA hand. It shows the size of a hand's head, with a length of 22h (table length of 120mm, palm width of 100mm, 3 thickness of 20mm with initial angle range of 0° to 90° all joints). In Table 1, PPT stands for first phalanx length, PFF stands for first phalanx breadth, SP1 stand second phalanx length, SP2 stands for second phalanx breadth, TPL stands for third phalanx length and stands for third phalanx breadth.

The finger has only one embedded motor to drive 2 joints of it. The motor is fixed to the base. The first shaft is located within the base and revolves both within the base and the lower part of the first phalanx; the second shaft is located further from the base and revolves within the upper part of the first phalanx and the second phalanx. The second phalanx is fixed with the second shaft. The output shaft of motor is fixed with the first gear box. The second hand gear is fixed with the first shaft. The first gear meshing with the second hand gear. The first pulley is fixed with the first shaft, the second pulley is fixed with the second shaft and the third pulley fixed with the third shaft. The first belt connects the first pulley and

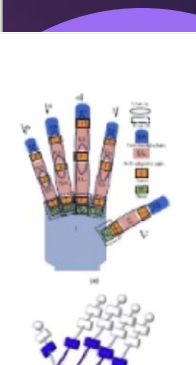


Figure 6 (a) DOF and self grasping diagram. (b) Dimension comparison diagram.

Table 1 Dimension comparison between the index finger and a robot one Self-adaptive UA hand.

Parameter Index	UA hand	Index finger	Index finger	Index finger	Index finger
Phalanx length	22h	22	19	25	22h
Finger length	29	23	27.5	21	27
Finger breadth					

4.2 Structure design of 2-joint and 3-joint DSEA finger
 Figure 7 shows the components of the 2-joint DSEA finger developed. One joint of it is DSEA joint. The 2-joint DSEA finger is 1.3 times the size of human hand's breadth, whose finger length is 190mm, finger width is 120mm. Finger thickness is 20mm and relative angle range of all joints is 0° to 90° .

The finger has only one embedded motor to drive 2 joints of it. The motor is fixed to the base. The first shaft is located within the base and revolves both within the base and the lower part of the first phalanx; the second shaft is located further from the base and revolves within the upper part of the first phalanx and the second phalanx. The second phalanx is fixed with the second shaft. The output shaft of motor is fixed with the first gear box. The second hand gear is fixed with the first shaft. The first gear meshing with the second hand gear. The first pulley is fixed with the first shaft, the second pulley is fixed with the second shaft and the third pulley fixed with the third shaft. The first belt connects the first pulley and

the second pulley and the second belt connects the second pulley and the third pulley. In addition, the first spring connects the base and the first phalanx while the second spring connects the first phalanx and the second phalanx.

the second pulley and the second belt connects the second pulley and the third pulley. In addition, the first spring connects the base and the first phalanx while the second spring connects the first phalanx and the second phalanx.



Figure 7 Components of 2-joint DSEA finger. (a) From ordinary view. (b) Side view. (c) 3D model. (d) Top view. (e) Bottom view. (f) Side view. (g) Top view. (h) Bottom view. (i) Side view. (j) Top view. (k) Bottom view.

Design of the 3-joint DSEA finger developed is shown in Figure 8. The 3-joint DSEA finger has the same design principle like 2-joint DSEA finger. This finger has one embedded motor to drive 3 joints of it. The first 2-joint DSEA finger is 1.3 times the size of human hand's breadth, whose finger length is 190mm, finger width is 120mm. Finger thickness is 20mm and relative angle range of all joints is 0° to 90° . Every DSEA finger can grasp objects independently and self-adaptively.



Figure 8 Components of 3-joint DSEA finger. (a) From ordinary view. (b) Side view. (c) 3D model. (d) Top view. (e) Bottom view. (f) Side view. (g) Top view. (h) Bottom view. (i) Side view. (j) Top view. (k) Bottom view.

4.3 Grasping process of 3-joint DSEA finger
 Figure 9 shows the grasp process of a 3-joint DSEA finger. The process of the 3-joint DSEA finger grasping a cylinder object is introduced below. At the beginning of grasping process, the motor inside the base starts and drives the

Student Journal of Tsinghua University

电负载健身器的开发与研究

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摘要 电负载健身器由于其原理限制, 负载时负载不均匀、不可变; 我们在此基础上提出了电负载健身器原理, 着重考虑电负载健身器, 实际可变为健身过程。本文首先对电负载健身器项目的研究设想, 介绍机械结构的设计与搭建、自行设计的交流电压磁变多相整流变频器, 以及电机控制算法的实现。

关键词 电机 电机控制 电力电子

1 项目理念

目前, 电负载健身器主要针对健身器材多采用重物作为负载, 因此存在启动惯性而无法实现均匀负载的健身过程。为了解决这一问题, 本项目概念性的提出利用电负载作为健身负载的思路。通过增加输入减速箱, 无刷电机条件, 并且通过对电机转速的控制(接入电路的电负载), 实现对健身负载的控制和调整。

2 研究过程

2.1 机械结构设计

- 框架结构: 以铝合金型材为主, 向上自己设计的连接件。
- 传动系统: 减速装置, 橡胶轮, 滑轮组等。
- 三相交流电源同轴伺服电机的控制。
- 购买变频器组件, 组装电路系统, 为系统提供可靠供电。
- 伺服电机驱动器的安装, 电气连接, 参数配置, 以及上电调试。
- 搭建电机控制试验电路, 对电机进行测试。试验用实时数据采集系统。
- 实现无负载时某参数传感器数据到计算机。
- 可以用于系统调试后的分析工作。
- 第一套试验电机参与测试。

2.2 方案改进

在第一套试验机的测试过程中, 我们发现了

一个严重的问题: 在上行行程, 可以按期望的方式控制电机; 然而, 在下行程, 电机输出控制及反力矩波动, 试验被迫停止。经我们反复排查, 发现问题由电机型号急的驱动造成的。经过生产厂确认, 该驱动器并不支持此项目所需的方式。若采用其他驱动器替代, 则存在如下问题:

1. 所用的伺服电机自带的高分辨率编码器采用有源的, 把通信协议, 与其他驱动器不兼容。
2. 对于该电负载健身器使用自功率限制(1KW), 目前市场上还没有能支持所需控制方式的产品。

进一步研究后, 我们初步发现, 问题并不在驱动器的硬件设计, 而在于驱动器内部的控制算法, 但驱动器是一个不可分割的整体, 尽管我们尝试了多种方法, 仍未能完全“破解”其核心控制单元。在查阅了相关的电力电子方面的资料, 并请教有相关领域经验的老师之后, 我们决定将目标重新设定为“自己设计、制造满足系统要求的三相永磁交流电机伺服驱动单元”。不仅仅是商业产品, 我们看到的有关文献往往面向的是更大功率的负载(例如采矿设备), 使用的技术手段并不适用于我们(如反馈电网), 因此基本只能从原理出发, 靠自己开发、摸索。

首先, 我们研究了三相交流永磁同步电机的驱动方式与控制算法, 并进一步设计驱动原型系统, 搭建驱动原型所用到的电力电子器件, 并搭建驱动原型电路。之后完成了测试用控制板设计以及驱动原型测试。最后, 通过整合控制器、驱动器, 在原型的基础上进一步设计, 并改进控制算法,

电机运行策略, 最终基本达成转矩控制。

3 技术实现

3.1 机械部分

此部分的目的为实现零重力健身运动。我们选择方案为: 搭建框架, 在上安装电机、减速箱等; 电机通过减速机、胶套带动滑轮, 通过滑轮上的滑轮, 向手施加助力。

3.1.1 框架设计

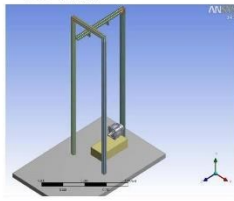


图1 框架原理

框架采用工业用T型铝型材及其专用连接件。其主要部分进行有限元强度分析, 刚度、强度均满足要求。

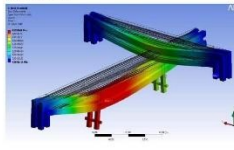


图2 有限元分析

电机直接安装在框架底座上, 并与减速机连接在一起, 形成一个整体。减速机直接安装在底座定位孔处, 因此设计上图形连接;

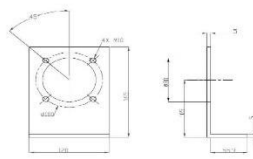


图3 连接硬件图

减速机输出轴通过胶套带动滑轮, 设计如下:

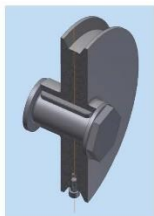


图4 胶套三维模型

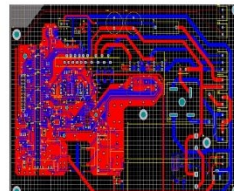
3.1.2 电机安装

将零件组装至基础工业训练中心加工完件后, 我们购买了定制的铝合金型材以及连接件, 开始机械结构的组装, 并完成机械结构的联调。

3.2 电路部分

将控制器、驱动器、变频器集成在一起, 以实现更底层的电机控制。

方案: STM32F1系列32位单片机或小系统运行控制、驱动算法, 选用专用电力电子芯片驱动三相IGBT全桥, 使用电压传感器检测电机相电压进行反馈控制。



3.3 算法部分

3.3.1 速度检测器

为了便于转速, 我们采用速度检测器对编码器输出进行分析, 其原理如图6所示。



图6 速度检测原理

输入为编码器计数值, 输出为估计的转速。K可调节观测带宽, 速度检测器的传递函数为转/秒为角度/度, 并经过速度检测器得到输出。速度检测器的传递函数:

$$\left(1 + \frac{1}{s}\right)K = Y$$

$$Y \left(1 + \frac{K}{s}\right) = KU$$

$$Y = \frac{KsU}{s + K}$$

$$\text{则有: } Y = \frac{Ks}{s + K} \cdot \frac{w}{K} = \frac{w}{K} \cdot \frac{s}{s + 1}$$

即为低通滤波的转速信号。为处理编码器计数溢出问题, 改进了算法, 加入了额外的控制逻辑, 最终速度检测器如图10。即当发生计数溢出(上溢与下溢)时, 当前数据不使用, 并更新积分值以及与之关联当前值范围。

为验证算法, 该速度检测器能较好地估计转速。

3.3.2 SVM/M算法

SVM/M算法将给定的两相电压向量转化为三相电压PWM占空比。算法根据电压向量选择最速的IGBT及其开通时间。给定旋转的单位向量作为电压向量的输入, 输出占空比为三相驱动波形, 符合理论估计。

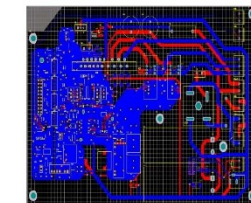


图7 PCB

检查后, 制作、焊接电路, 如图8所示。



图8 电路实物

先在测试条件下测试, 通过试, 搭建测试电路。三相电压输出良好的负载波形, 三相线电压是良好的正弦, 说明变频器工作正常。

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■ Historical Statistics of OAPS papers

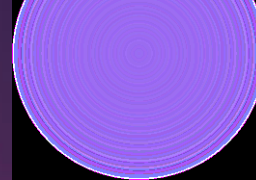
Year	Thesis VA1	Thesis VA2	Thesis VA3	Other	Total
2005	28	14	41	10	93
2006	23	20	18	11	72
2007	101	27	23	3	154
2008	75	48	40	4	167
2009	48	54	56	8	166
2010	37	58	68	10	173
2011	50	60	49	7	166
2012	90	20	67	7	184
2013	61	40	68	24	193
Subtotal	513	341	430	84	1368

VA1-Campus network access

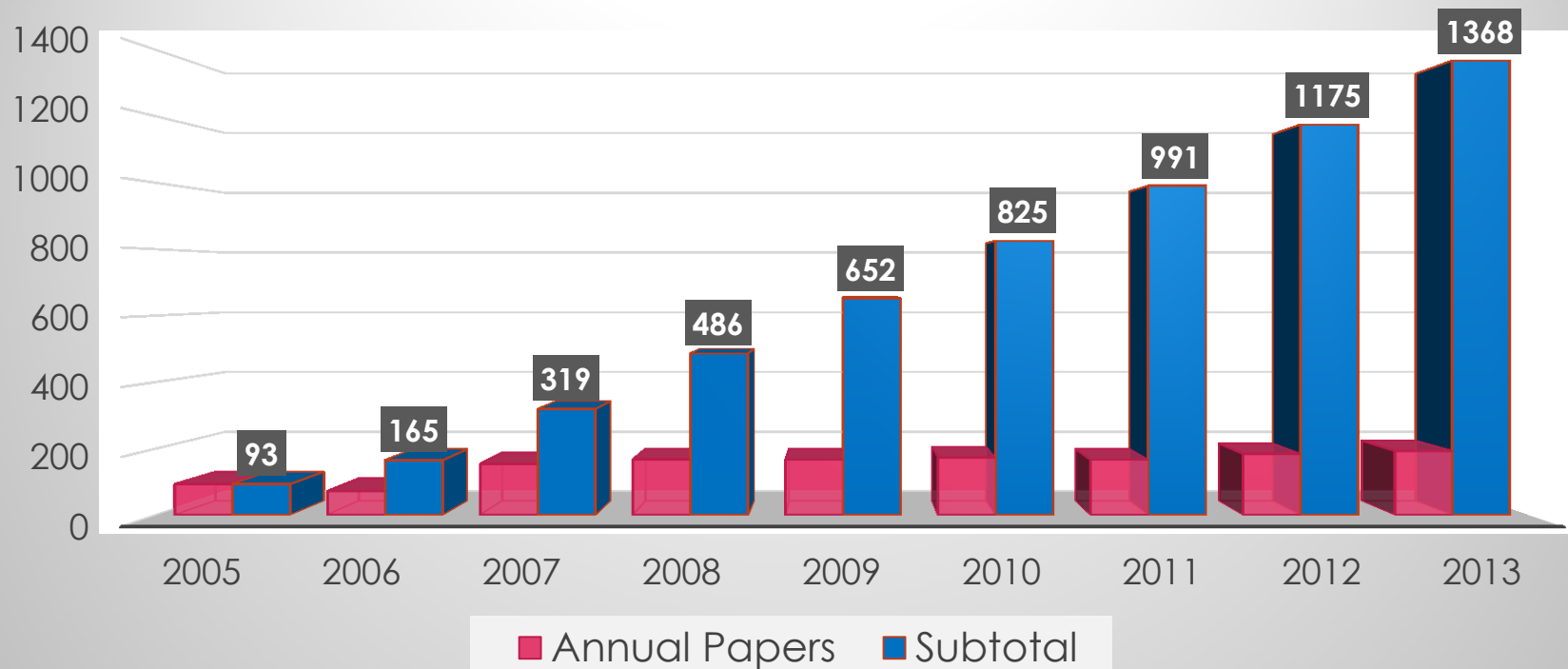
VA2-OAPS members access

VA3- Internet access

Progress of Tsinghua OAPS



Tsinghua OAPS Papers



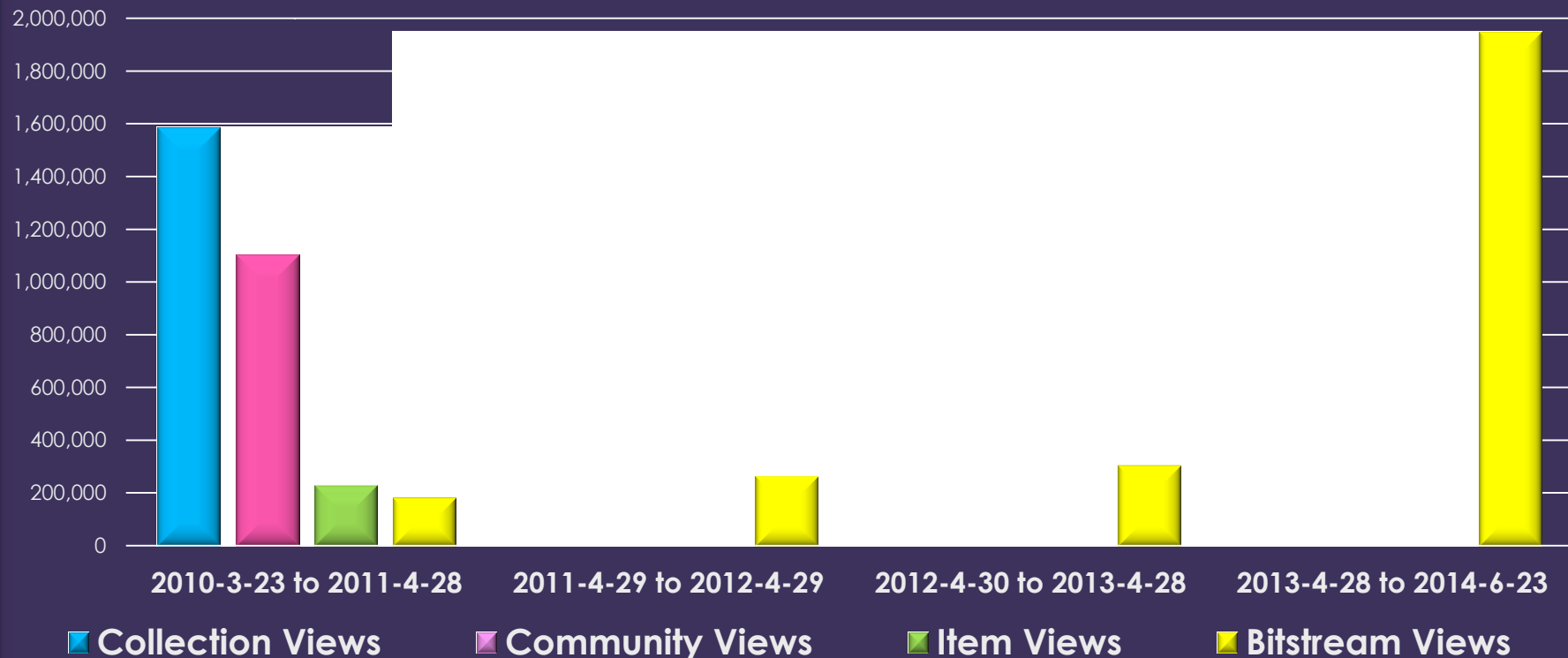
Tsinghua OAPS - Usage Statistics

Usage statistics for Tsinghua OAPS Site: 2013-04-28 to 2014-06-23

Point of View	Amount
全文浏览篇数 (Bitstream Views)	1,948,091
记录浏览次数 (Item Views)	722,109
从机构途径查看 (Community Views)	136,268
从资源集合途径查看 (Collection Views)	346,672
检索次数 (Searches Performed)	45,344
用户登录 (User Logins)	1,718

Tsinghua OAPS - Usage Statistics

Tsinghua OAPS Usage (2010.3 - 2014.6)



Metadata & Usage for OAPS Portal



Metadata and Usage for OAPS portal

The image shows a screenshot of the OAPS Portal website. The header features the OAPS logo and the text "Outstanding Academic Papers by Students" and "Promoting Academic Achievement and Collaborative Learning Through". A navigation menu includes "Home", "About", "Membership", "Organization", "OAPS Papers", "Annual Meeting", and "Contact".

Annotations on the page include:

- A yellow box labeled "12 members" points to the "Membership" section, which lists 12 member institutions.
- A yellow box labeled "8 Websites" points to the "OAPS联盟成员网站" (OAPS Alliance Member Websites) section, which lists 8 linked institutions.

Membership (12 members)

- [Chulalongkorn University Library](#)
- [City University of Hong Kong Library](#)
- [Feng Chia University Library](#)
- [National United University Library](#)
- [Nanyang Technological University Library](#)
- [Seoul National University Library](#)
- [Shanghai Jiao Tong University Library](#)
- [University of Macau Library](#)
- [University of Southern California Libraries](#)
- [Tsinghua University Library](#)
- [Waseda University Library](#)
- [Xiamen University Library](#)

8 Websites

OAPS联盟成员网站
(Linked Institutions)

- [香港城市大学\(CityU\)](#)
- [台湾逢甲大学\(FCU\)](#)
- [南洋理工大学\(NTU\)](#)
- [厦门大学\(XMU\)](#)
- [上海交通大学\(SJTU\)](#)
- [清华大学\(THU\)](#)
- [日本早稻田大学\(Waseda University\)](#)
- [台湾国立联合大学\(NLU\)](#)

Metadata and Usage for OAPS portal

Communities in DSpace

Choose a community to browse its collections.

[City University of Hong Kong 香港城市大学](#) [365]

[Feng Chia University 台湾逢甲大学](#) [966]

[Nanyang Technological University 南洋理工大学](#) [99]

[Shanghai Jiao Tong University 上海交通大学](#) [236]

[Tsinghua University 清华大学](#) [1368]

[Waseda University 日本早稻田大学](#) [2]

[Xiamen University 厦门大学](#) [116]

Total items:

3295

(Jun 20, 2014)

**National United
University**

台湾联合大学 [143]

Metadata and Usage for OAPS portal

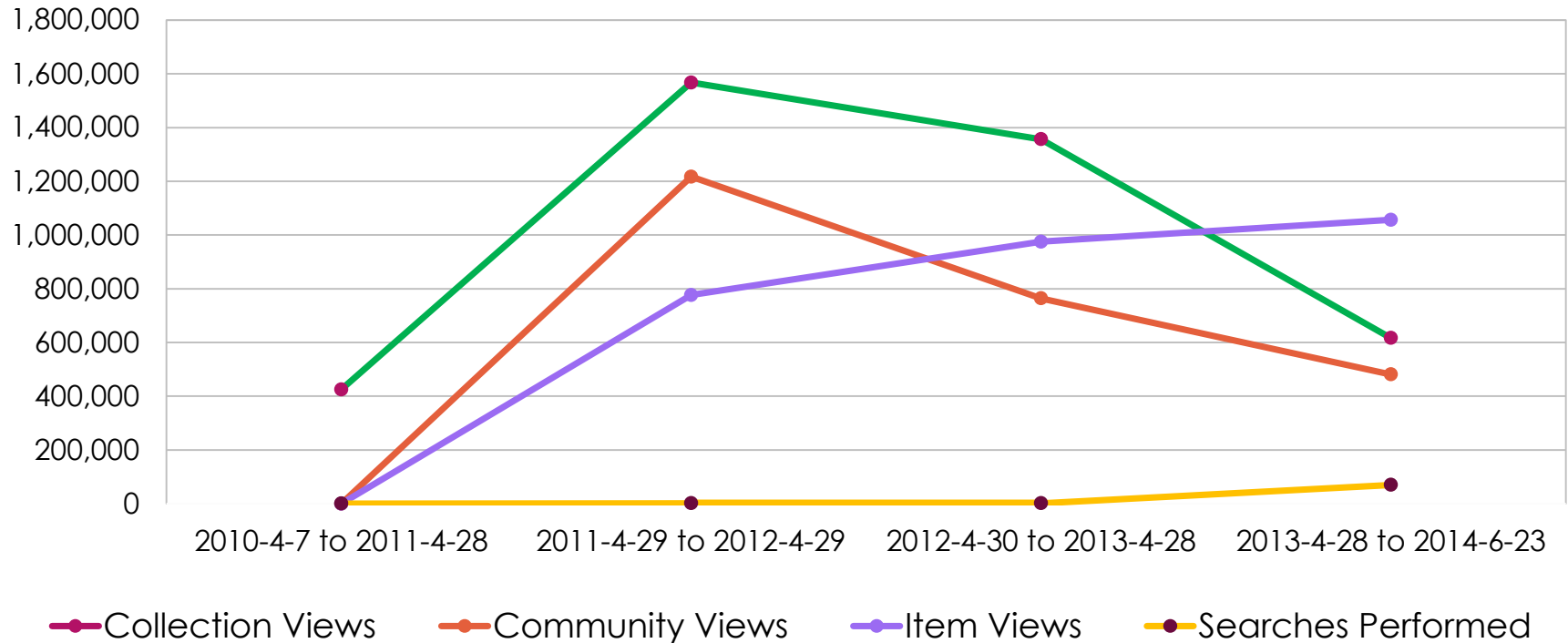
Usage statistics for OAPS portal : 2013-04-28 to 2014-06-23

Point of View	Amount
记录浏览次数 (Item Views)	1,056,660
从机构途径查看 (Community Views)	480,949
从资源集合途径浏览 (Collection Views)	616,639
检索次数 (Searches Performed)	69,638

OAPS联合网站上没有论文的全文，所以没有全文的浏览数据

Metadata and Usage for OAPS portal

Usage of OAPS Portal



Future development



Future development

一、OAPS联合宣言（马六甲宣言）

Joint Agreement on OAPS, 2013, Malacca

几条需要进一步落实的内容：

- ◆成立OAPS联盟，……制定组织章程和联盟标准；
- ◆鼓励各种模式的融合与合作，……积极发展联盟成员；
- ◆常设联络机构的作用是什么？如何发挥？（中国大陆地区-清华；台湾地区-逢甲；东南亚地区-南洋理工；美洲地区-南加州大学；跨地区联络处-香港城大）

Future development

二、成员：

发展新成员的目标、数量；原有成员的稳定性、参与度

三、OAPS论文数量：

还需要继续提高

四、OAPS作品使用率：

可以采取哪些措施提高OAPS作品的可见度和使用率？

Future development



To play OAPS role, need to take measures to actively promote OAPS Portal :

1. The members need to set up a link of OAPS portal in own website
2. To promote and introduce OAPS via journals or website
3. Pay more attention to improve OAPS usage

Thanks

谢谢大家

