RGC Ref No.
(to be completed by the institution)

RESEARCH GRANTS COUNCIL

Application for Allocation from
the *Competitive* Earmarked Research Grant for 2007/2008
Application Form (CERG1)
[Please read the Explanatory Notes CERG2 carefully before completing this form]

PART I SUMMARY OF THE RESEARCH PROPOSAL
[To be completed by the applicant(s)]

1(a). Title of Project: **A Two-Dimension Rotary-Linear Switched-Reluctance Motor for the High Precision Manufacturing Industry**

1(b) i). Primary Field *Name:* *Mechatronics* *& Code:* 2199

Secondary Field *Name:* ______ *& Code:* ______

1(b) ii). A maximum of five keywords to characterise the work of your proposal (maximum 20 characters for each keyword)
Switched Reluctance, Rotary linear Motor, Position & Force Control, High Precision Actuator

2. Name(s) and Academic Affiliation(s) of Applicant(s):

	Name	Post	Unit/Department/ Institution
Principal Investigator [PI]: (with title)	**Dr. Norbert Chow CHEUNG**	**Assistant Professor**	**Electrical Engg Dept HK Polytechnic Uni**
Co-Investigator(s) [Co-I(s)]: (with title)	**Dr. Wai-Chuen GAN**	**Senior Engineer**	**ASM Assembly Automation**

3. Allocation Requested from the Earmarked Research Grant:
Total cost of the project:

(a) Staff	
i) Senior Research Assistant / Research Assistant	*HK$*558,000
ii) Undergraduate student($2,500 / month)	*HK$*
iii) Others	*HK$*
(b) Relief Teacher (required exceptionally)	HK$
(c) Equipment	HK$38,000
(d) General Expenses	HK$215,000
(e) Conference (standard rate : $12,000 per year)	HK$36,000
Less:	
(a) Institutional funding for provision of research experience for undergraduate student	HK$
(b) Other research funds secured from other sources	HK$
Net amount requested * :	HK$847,000

* *(1)* The amount may be reduced further if additional funds from other sources have been secured after submission of this application.
(2) The threshold limits for applications are $150,000 for projects in the fields of Engineering, Physical Sciences and Biology & Medicine, and $100,000 for projects in the fields of Humanities, Social Sciences & Business Studies.

4*(a)*. Nature of application *

[X] New [i.e. PI and/or Co-I(s) applying for RGC funds on this research topic for the first time]. Please give further details in Part II item 2.

[ ] Re-submission [i.e. PI and/or Co-I(s) have previously applied for RGC funds on this research topic but application not supported]. Please give further details in Part II item 4.

[ ] On-going [i.e. PI and/or Co-I(s) extending work previously funded by the RGC]. Please give further details in Part II items 2, and 7-9.

*4(b). Special funding template**

[ ] Application for Clinical Research Fellowship Scheme (Please also complete an additional form (Enclosure I) and see (Enclosure II))

[ ] Application for individual research *(see Enclosure III)*

[ ] Application for longer-term research grant *(see Enclosure IV)*

[ ] *Application for employment of relief teacher under Humanities Sub-Panel (see Enclosure V)*

[ ] *Application for provision of research experience for undergraduate student (see Enclosure VI)*

4(c). Exceptional approval - only for applicant, who is holding five or more on-going CERG, CA, AoE and PPR project grants (including projects completed but completion reports not yet submitted and funded projects but not yet commenced) one month before the deadline for submission of application. (Note : Only the PI (one per CERG/CA/PPR project) or the coordinator (one per AoE project) will be counted within this quota.)

[ ] ** Application for exceptional approval is required in this exercise*

I confirm that :

(a) none of my on-going projects under the above funding schemes has pending or approved project extension by the RGC and the AoESG under the UGC;

(b) there has been no delay in the submission of progress and completion/concluding reports under the above funding schemes since 1 February 2006;

(c) none of my projects funded by the UGC/RGC was rated as 'unsatisfactory' in the past; and

(d) all of my completed projects under the above funding schemes have been finalized with the submission of completion reports <u>before</u> submission of this application, regardless of the due dates for report submission.

* Please tick '√' as appropriate

/.... 5. Abstract

5. Abstract of research (**limited to ½ A-4 page or 200 words**, and comprehensible to a non-specialist):

Advanced consumer products and components requires high precise four-dimensional (4D) motion for manufacturing (X, Y, Z, and θ axis, as shown in Fig. 1)

To achieve precise 4D motions, most of these high-performance manufacturing machines use a geared θ axis head, and a three axis table for the X, Y, and Z axes movements. Though this is the widely used method, it has disadvantages of complex mechanical structure, frequent mechanical adjustments, high manufacturing and maintenance cost, and low reliability. Disadvantages of traditional X-Y tables have indirectly led to the high cost and difficult maintenance of these machines.

In our previous ERG project we had successfully invented a direct-drive planar switched reluctance motor that can provide high precision X-Y motions. In this project proposal, we intend to further develop the world's first rotary-linear switched reluctance motor based on switched reluctance technology. The motor will provide high precision Z-θ axis motions; it will have a very simple structure with very few mechanical parts. There is no need for mechanical alignments, rotary-to-linear couplings, and reduction gears.

Together with the X-Y planar motor, the θ-Z rotary-linear motor will form the basis of future generation of high-performance low-cost manufacturing machines.

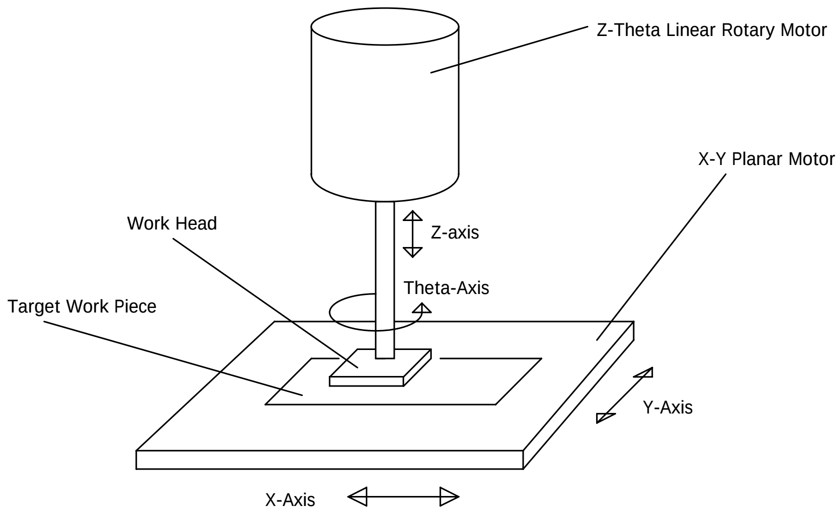

Fig. 1. The proposed θ-Z Rotary-Linear Motor

/.... PART II

PART II DETAILS OF THE RESEARCH PROPOSAL
[To be completed by the applicant(s)]

RESEARCH DETAILS
(Overall word limit: 3200 words for 1. Project Objectives, 2. Background of Research and 3. Research Plan and Methodology, excluding references.)

1. The project objectives and long-term impact:
[State the purpose of the proposed investigation, identify the key issues and problems being addressed, and state the possible outcome of the research project in terms of its relevance, significance and value]
[Please list in point form where appropriate]

The project objective

The purpose of the project is to develop a novel, high performance, direct drive, combined rotary-linear motion system for precision manufacturing applications. The rotary-linear actuator is based on switched reluctance (SR) principle, together with the X-Y planar switched reluctance motor, and it aims to replace the traditional X-Y-Z-θ table as a higher performance and lower cost alternative.

Advantages

- Using SR drive technology, the rotary-linear actuator has a simple and robust structure with low inertia and direct drive capability, and it is particularly suitable for high speed and high precision operation.
- Due to the employment of SR drive principle, manufacturing of the actuator is simple, the rotar and stator can be made from simple laminated steel sheets. The moving part is made from simple coil windings and ferrite metal pieces. Unlike DC brushless drive, no expensive and hard-to-handle magnets are required.
- Mechanical couplings, lead screws, magnets, and brushes are not required. The degree of precision is inherent into the structure, and special mechanical adjustments or alignments are also not necessary.
- Comparing to traditional DC motors-driven θ-Z tables, the proposed actuator has a much simpler structure and is less expensive. It is also more robust and more fault tolerant, and has less overheating problem. The 2D motion actuator is virtually maintenance free.

Key issues

- There is no well-established method to design a rotary-linear SR motor. No previous example on rotary-linear SR actuator design is available. Methods to model, simulate and design the rotary-linear SR actuator are required.
- All SR drives exhibit highly nonlinear characteristics due to flux behavior, hysteresis, saturation, and leakage. The linear axis needs to be driven in a hybrid force/position mode. A novel driving scheme for the proposed actuator that can produce high speed, high position accuracy, and accurate force output needs to be developed.
- The force control developed for the Z axis is also challenging for the SR linear motor. The sophisticated force control can be applied to many critical motions such as wire and die bonding operation.

Addressing the problems

- The performance and magnetic characteristics of a number of rotary-linear SR actuator designs will be investigated by using Finite Element Analysis. The structure that optimizes on the (i) high power-to-size ratio, (ii) low force ripple, (iii) low leakage and eddy loss, (iv) fast current dynamics and (v) high rotational stiffness will be selected and manufactured.
- The manufactured actuator will be tested and its electrical and mechanical parameters will be measured. A suitable control model will be developed for control simulation.
- An appropriate nonlinear/robust hybrid force/position control scheme will be proposed, simulated and implemented on a Digital Signal Processor control platform. Since the rotary-linear SR actuator is essentially a nonlinear control problem, a multi-variable feedback linearization control scheme, which includes the electrical and mechanical dynamics of the actuator system, plus adaptive compensation of unknown variable is suitable.

Project outcome and its long-term significance

- The proposed rotary-linear drive is low-cost, robust, and reliable. It contains little mechanical adjustments, and can be easily manufactured. These advantages will enable the proposed rotary-linear motion system to replace many traditional θ-Z tables driven by rotary motors and mechanical lead screws. As a result, machineries previously associated with θ-Z tables can be constructed and operated at a lower cost.
- The manufacturing cost of many electronic products (including handheld computing devices, mobile phones, semiconductor devices, integrated circuit modules, etc.) can be made cheaper when the machineries that produce the above products can be purchased and operated at a lower cost. The invention will also open up many new applications in low cost and high performance motion drive that are not feasible before (e.g. crafting Chinese characters on jewellery).

The proposed project can be a valuable contributor to Hong Kong's industry, when its present emphasis is on the development of high-tech/high value-added products, with minimum labour/overhead costs, and on lean budgets.

/.... 2. Background

2. Background of research :

[Summarize and give key references on related work, including previous and alternative approaches to the problem, in two sections: (A) work done by others; and (B) work done by you]

[For section B, if this is a new project, include the reasons and the relevant findings, if any, for undertaking this research; if this project arises from an on-going research, give an update on the progress of the research concerned]

Work done by others

Design of Two Dimensional Rotary-Linear Motors

In the past, the design of two dimensional rotary-linear motors can be divided into two main categories. The first category is to design rotary-linear motors using induction motor technology [1,11] while the second one is to design linear-rotary motors using permanent magnet synchronous motor technology [2,3,6,7] and some industrial patents can be found in [8,9,10]. The major drawbacks of using induction motor technology are the complex motor winding arrangements and the performance degradation with system parameter changes such as the rotor resistance. On the other hand, the presence of permanent magnets and cogging torques makes the permanent magnet rotary-linear motor cannot operate in high temperature environments and enjoy velocity ripple-free tracking. Recently, researchers have tried to employ ultrasonic motors in designing rotary-linear motors [4,5]; however, the complexity in motor driver design and the life-time of the motor are still the main concerns of industrial people.

If SR motor technology can be adopted in designing the rotary-linear-rotary motors, the above problems can be alleviated since the construction and winding arrangement for SR motors are easy, there are no permanent magnets and cogging force velocity ripples, and the motor driver topology is relatively simple.

One Dimensional SR Linear Direct-Drive Motion Systems

Among the few 1D linear SR drives, the most notable work on SR linear motion actuators was done by Lucidarme *et. at.* [12]. Their research work was focused on the maximisation of power and the design of magnetic circuits. Takayama *et. at.* and Liu *et. at* have [13,14] also done some work on SR linear actuator design, but their work was only limited to the investigation of force profile and magnetic behavior.

Force Control of SR Motors

Force control of SR motors is not new to literature. For example, we can find torque control for rotary SR motors [45], force control for grippers/solenoids [48] and force control of linear permanent magnet motors [49]. On the other hand, hybrid force/position was always applied in robot applications [47] for sophisticated operations. There is not much concern in applying hybrid/position control on linear SR motors until [46]. However, the magnetic coupling motor structure in [46] makes the force control to be more complex. Therefore, there is definitely a new challenge for us to apply hybrid force/position control on the proposed rotary-linear motor.

Using SR actuators as high performance motion drives

Switched reluctance motors have never been a popular choice for high precision and high-speed motion systems, because it is difficult to control and its output has high torque ripples. This is due to the fact that the actuator's characteristic is highly dependent on its complex magnetic circuit, which is difficult to model, simulate, and control. It was only until recent years which we see a general resurge of interest in the switched reluctance motor [15]. This was mostly due to the advancement of power electronics and digital signal processing, and the continuous trend of "simplifying the mechanics through complex control strategy". It must be stressed that most of these developments are directed towards general speed/torque control of rotary SR motors.

Modelling and Simulation of Complex Magnetic Characteristics of SR motors

Modelling and simulation is an essential step for the proper design and understanding of the SR actuators. It is also very important for control system design. For the modelling of magnetic circuits, piecewise linearisation and modified piecewise linearisation magnetic modelling models were proposed by Buja *et.al.*[16] and Bolognani [17]. These models are computational efficient but their accuracy is only sufficient for speed control of switched reluctance motor. Miller *et. al.* [18] proposed an improved method based on first and second order curve fitting. On the other hand, other researchers [19,20] use higher order bi-polynomial functions or complex magnetic equations to represent the 3D magnetic characteristics. The method is highly accurate, but they are too computationally intensive. All these methods have been applied to rotary SR motors only.

Control algorithms for SR motors

The SR actuator's model dynamic model is nonlinear. A suitable method to solve the nonlinear control problem is to apply geometric nonlinear control theory [21] and to view it as a multi-input nonlinear system. Ilic-Spong *et. al.* [22] has used this approach, and ends up with an algorithm which is highly complicated. It is too slow for real time control of high performance motion systems. Furthermore, the dynamic model used in the investigation is highly simplified, and it does not include friction, load variation, hysteresis, and eddy current loss. Subsequently, there has been proposals [23] which reduce the control complexity by reducing the order of the model, and decouple the current control from the mechanical model. Some proposals use a flux observer and controller to regulate the flux, which indirectly controls the motion [24]. Others employ a look up table to minimise the force ripple of the controller [25,26]. All the above control method have been applied to rotary switched reluctance motors only.

Work done by the proposer

The proposer has done extensive research on linear SR motion actuator for ripple-free high performance trajectory control [41, 42], and has made contributions to the following knowledge areas:

(i) Detail report on magnetic characteristics and control behavior of single phase direct drive SR actuator [27].

(ii) Developed a novel method for concise modelling of magnetic characteristics of single phase SR linear actuators which are suitable for rapid simulation and real time control [28,29,30].

(iii) Developed a novel control method for high precision trajectory control of the single phase SR linear actuator [31,32]. Additionally, two patents [33,34] related to this work have been awarded.

(iv) Invented a method of estimating the position for single phase SR linear actuator without the need for any physical sensors [35]. The relevant publication has received the second best paper award in the IEEE industry applications society's annual general meeting.

(v) Developed a novel SR gripper for automated manufacturing machines [36].

(vi) Developed a two dimensional planar motor using SR technology [43,44].

Additionally, the proposer has conducted numerous research activities on high performance linear motion systems for precision manufacturing automation [31,32,33], and has developed an innovative method for increasing the resolution of position sensors in high performance motion systems [34].

The proposed project is a logical continuation of the work done by the proposer. The project represents further advancement in the field of SR motion actuator. The proposed research target evolves from "1D high performance SR linear drive system" to a more complex but very useful area of "2D high performance SR planar drive system". The proposed project can produce a valuable piece of knowledge which can be translated into useful benefits to the manufacturing industry.

References

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/.... 3. Research

3. Research plan and methodology :

The project consists of 6 phases and expects to take 3 years to complete, the 6 phases are:

1.	Investigate, design, and fabricate a Rotary Linear Switched Reluctance Motor (RLSRM)	12 months
2.	Characterization of the RLSRM	4 months
3.	Installation and interface of the rotary-linear optical/inductive position sensor	6 months
4.	Develop and implement the motion control algorithm	6 months
5.	Integration and testing of the full system with rotary-linear motion profiles	4 months
6.	Full Report and knowledge dissemination	4 months

Phase One - Investigate, design and fabricate a 2D SR planar actuator - 12 months

The first phase is to investigate the magnetic structure and control characteristics of Rotary Linear Switched Reluctance Motor (RLSRM). A research worker will perform intensive investigation on the design, analysis, and performance simulation of different actuator structures and geometries (especially the on magnetic circuit). As a starting point, the RLSRM will be based on the experience obtained in our SR Planar motor. Two sets of 3-phase coil windings will be employed in the SR actuator. A finite element package (MEGA from Bath University) will be used for the study. The target is to produce a RLSRM which has the (i) highest power-to-size ratio, (ii) least force ripple, (iii) highest stiffness against rotational motion, (iv) least hysteresis and other nonlinearities, and (v) fastest current dynamics. After the study, the motor structure that produces the best performance will be chosen for further investigation, and a prototype of this motor will be manufactured in the Polytechnic University's Industrial Centre. According to previous experience with SR planar motor design and the preliminary structure of the 2D SR motor, the motor is expected to have the following specification:

Power output (X & Y axis)	80-100W	Travelling distance	100mm
Linear accuracy	±10 micron	Linear acceleration/deceleration	2.5G at 0.5kg load
Rotary accuracy	0.5 degrees	Rotary acceleration/deceleration	$90^{\circ}sec^{-2}$
Angular tooth pitch	15 degree	Linear tooth pitch	5 mm

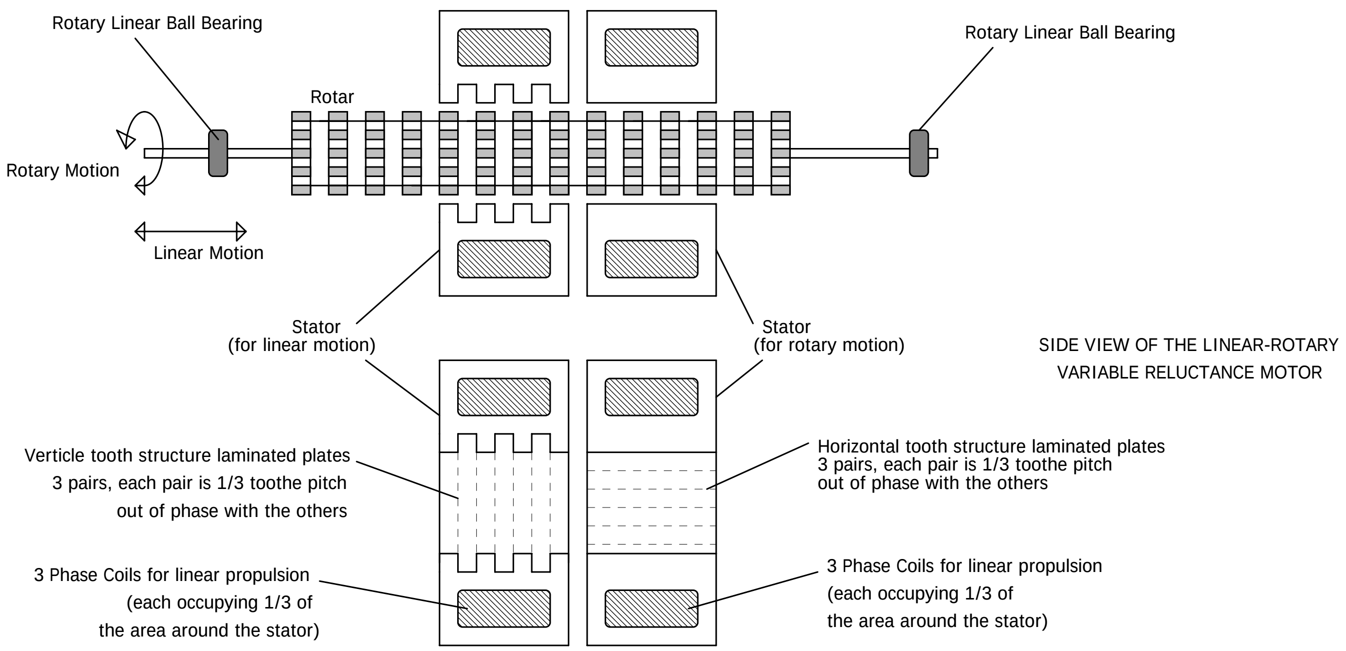

Fig. 2 Conceptual layout of the RLSRM

It must be stressed that the RLSRM is a prototype product for research and investigation purposes, and the whole project is designed to operate on a very lean research budget. According to the above specifications, the degree of precision of the first prototype may not be extremely high. However, as the fabrication accuracy of the RLSRM and the precision of the roller ball and the planar encoder increase, a much higher precision can be achieved.

Phase Two - Characterisation of the of the Rotary Linear Switched Reluctance Motor (RLSRM) - 4 months

The second phase is to characterise the RLSRM through measurements of its magnetic, electrical and mechanical properties. The following elements should be measured or deducted from the motor:

1. 3D profile of flux linkage versus current versus position/angle for a single phase.
2. Mutual inductance and intercoupling effects between phases and axis at different currents and positions.
3. Flux Leakage, hysteresis, and other losses when the moving element is at different angular positions/currents.
4. 3D profile of mechanical frictional force versus position/angle and velocity (from standstill to high speed).
5. 3D profile of force against current and position for each phase.

The amount of data resulted from the above measurements is expected to be huge. An automated and fully digital measurement technique (based on LabView) will be developed to measurement of large amount of data, employing specific measurement techniques for difficult-to-measure parameters. To aid rapid simulation and real time parameter estimation/control, the above 3D contoured profiles will be translated into concise 3D models, using a simplified and efficient modelling method. The dynamic model will initially be written in MATLAB. The dynamic characteristics of the RLSRM will be simulated under SIMULINK. The simulated result will be checked against the actual dynamic performance of the SR linear actuator to verify the accuracy of the dynamic model.

Phase Three - Development of the rotary-linear optical/inductive position interface - 6 months

To provide reliable position feedback to the controller, an effective 2D rotary-linear sensor needs to be developed. Two types of sensors will be investigated. The first type is the optical planar sensor technology that uses a similar principle as an optical mouse pointer device. The second type of sensor is to use a high frequency inductive sensing. After the investigation, the more suitable planar sensing technology will be chosen for fabrication and implementation. To provide a higher resolution, a sine-cosine waveform interpolation method is used to increase the original resolution of the sensor by 20 times. Once the planar sensor is fabricated, it is tested for accuracy and reliability.

Phase Four - Develop and implement the motion control algorithm - 6 months

Once the model is verified to be accurate and the planar sensor is developed, design and implementation of appropriate control algorithms for the RLSRM can take place. By running SIMULINK under different control/commutation algorithms and under different loads/motion-profiles, an appropriate control strategy is developed. Since the SR linear actuator is essentially a nonlinear control problem, a cascade type nonlinear decoupled control scheme, with force-current-position nonlinear compensation is proposed. Figure 3 shows the proposed control block diagram. Apart from employing the look-up table nonlinear compensation technique, a plug-in robust controller is proposed to address the robustness issue. In Fig 3, the block P_0 represents the nominal linearized plant and the block Q is designed to compensate the plant parameter variation and the external disturbance by using robust control, such as H_∞ loop shaping optimization technique. Furthermore, the blocks P_0 and Q can be implemented adaptively to further enhance the system performance. This effectively minimizes any force ripple effects due to the nonlinear characteristics of the planar motor.

The key hybrid force/position block is the main control unit in the whole system. The position control will be first performed when the object does not touch the bottom X-Y planar motor. After the object touches the ground plane, an effective and very fast force control will be replaced with the position control. This force control tries to maintain a constant force applied on the object so that certain sophisticated operations, such as insertion or bonding, can be completed successfully.

In addition, a third order motion profile generation program for high-speed start/stop motion commands of the actuator, also needs to be developed. Depending on the characteristics, adaptive friction and inertia control can be incorporated into the 2D planar actuator.

After this investigation, the SIMULINK codes will be translated to C programs, and will be used for actual implementation of the control system. Programs for the motion profile generation and PWM generation will also be developed for the overall testing. For the control algorithm implementation, a dSPACE control development system will be used. The overall set up of the RLSRM motion system is shown in Fig. 4.

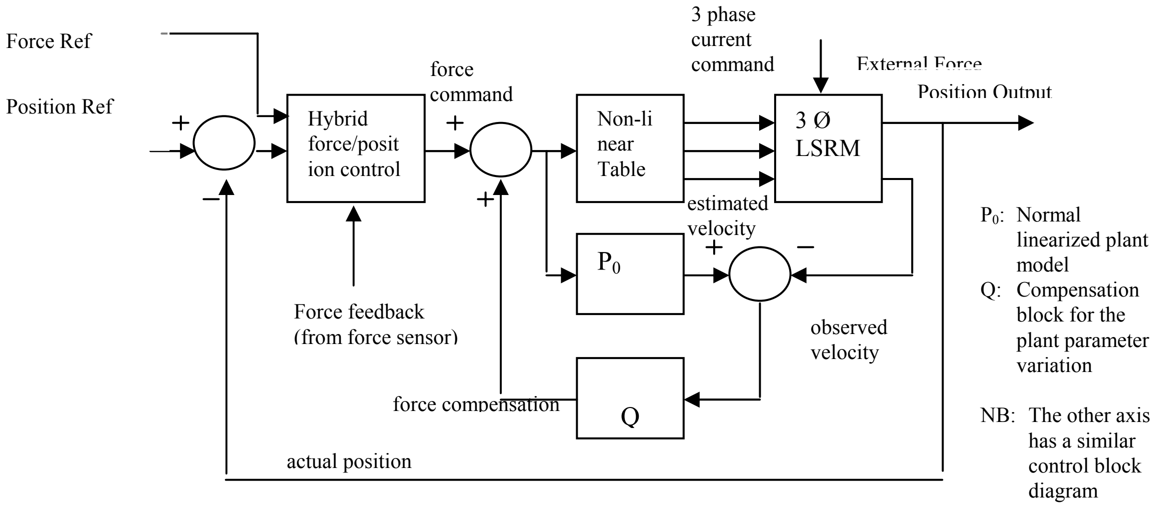

Fig. 3 The control block diagram (for one axis only)

Phase Five - Integration and testing of the full system with linear-rotary motion profiles - 4 months

Once the motion control of individual axis has been tested, the next step is to test both linear axis and rotary axis together running in synchronisation. For this purpose, specific rotary-linear trajectory profiles have to be programmed into the profile generator. The fully integrated system will be tested the following items: (i) maximum linear-rotary precision on point-to-point and contoured motions, (ii) loading versus acceleration characteristics, (iii) stiffness of both axes, and (iv)force control of the linear axis. Also, the relation between the planar sensor accuracy and the positioning accuracy of the actuator needs to be investigated.

Phase Six - Full report and knowledge dissemination - 4 months

The proposed research project will generate a lot of useful knowledge. The final stage of the project involves the collection of results, report on the findings and dissemination of this knowledge to the outside world. The findings of this project, including (i) the construction and manufacturing of the RLSRM, (ii) the fabrication of the rotary-linear sensor, (iii) the modelling, simulation and implementation of the control strategy for the rotary-linear motion system, and the (iv) overall performance of the RLSRM, are extremely useful to the academics and the industry. Details of the design will be made freely available to Hong Kong industry.

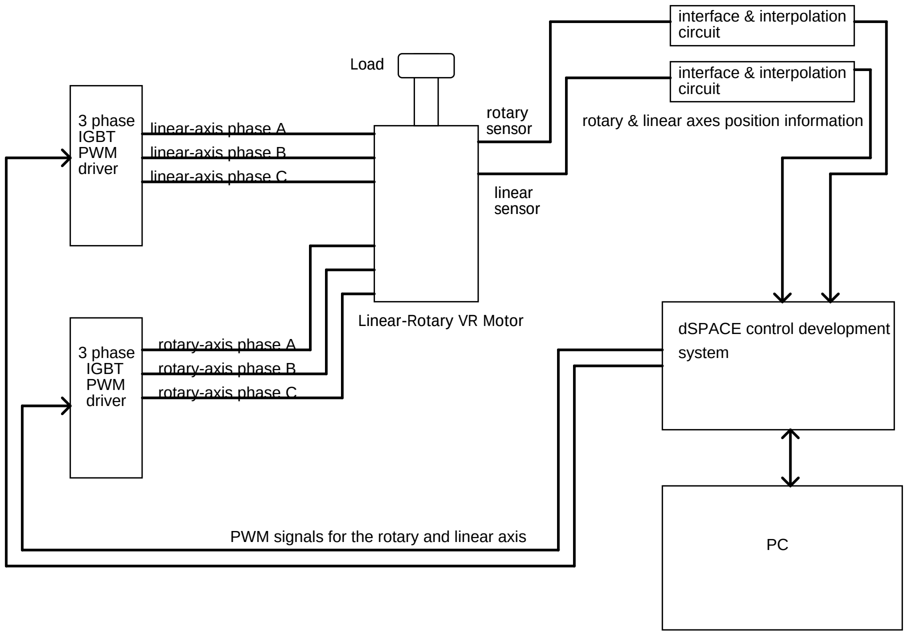

Fig. 4 Overall set up of the 2D planar SR motion system

The Expected Milestones and Deliverables

Sep 2007 - Aug 2008 Phase 1 (12 months)	• Performed investigation study on the structures of the RLSRM • Finished the design & analysis of the RLSRM & produced prototype drawings • Finished the fabrication of the RLSRM
Sep 2008 - Dec 2008 Phase 2 (4 months)	• Characterise the magnetic, electrical, and mechanical quantities of the RLSRM. • Constructed and verified the full dynamic model of the RLSRM
Jan 2009 - Jun 2009 Phase 3 (6 months)	• Investigated and proposed a suitable method of rotary-linear position sensing • Designed and fabricated the 2D sensor • Fabricated the interface/interpolation electronics and tested the whole sensing system
Jul 2009 - Dec 2009 Phase 4 (6 months)	• Performed extensive simulation on the RLSRM using MATLAB • Proposed an effective control strategy, and implemented it onto DSP hardware • Performed extensive test on the RLSRM system (single axis only)
Jan 2010 - Apr 2010 Phase 5 (4 months)	• Developed a linear-rotary motion generator software for specific motion contours • Performed tests on the whole system with 2-axes synchronized motions
May 2010 - Aug 2010 Phase 6 (4 months)	• Published a final report on the results of the investigations • Release the detail blue-prints, circuit diagrams and software of the whole system to public

/…. 4(a). Has

4(a). Has similar submission(s) been made to seek funding? Yes [ ] No [X]

If yes, please state the funding agency and the funding programme:

Reference No. :
[for RGC-funded projects only]

Title of Project [if different from Item 1 of Part I above]

Date (month/year) of application:

Outcome:

4(b). If this application is the same as or similar to one(s) submitted previously, what were the main concerns/suggestions of the reviewers then?

4(c). Please give a brief response to the points mentioned at 4(b) above, highlighting the major changes that have been incorporated in this application.

/.... 5.(a). Is

5(a). Is there similar or related research being carried out at your institution(s)?

[X] No.

[ ] Yes. Please give a brief account including names of investigators, departmental and institutional affiliations, project title(s) and nature of the project(s):

5(b). Is there similar proposal being submitted by PI or Co-Is to the RGC in this funding exercise?

[X] *No.*

[ ] *Yes. Please give the following details -*

i) Reference No(s):

ii) A brief account of the proposal(s) and an explanation on the differences between the proposal(s) concerned and this application:

5(c). Is there similar proposal being submitted by PI or Co-I(s) to other competitive funding schemes of the RGC / other public or government funding agencies?

[X] *No.*

[ ] *Yes. Please give the following details -*

i) the funding agency(ies) and the funding programme(s):

ii) Reference No(s): (for RGC funding schemes only)

iii) Proposal Title(s):

iv) a brief account of the proposal(s) including month & year of application and an explanation on the differences between the proposal(s) concerned and this application:

Important Note for 5(b) & 5(c):

It is the responsibility of applicants (both PI and Co-I) to ensure that no double funding from different funding schemes / agencies will be sought for the same / substantially similar research project. Breach of this rule or failure to declare similarity of proposals may result in disqualification of the application, which will also be taken into account by the RGC as part of the PI's track record when assessing future applications from the same PI. The RGC reserves the ultimate right to reject or disqualify future applications in serious cases.

/.... 5(d). Is

5(d). Is there similar project by PI or Co-I(s) already funded by other competitive funding schemes of the RGC / other public or government funding agencies?

[X] *No.*

[ ] *Yes. Please give the following details -*

i) the funding agency(ies) and the funding programme(s):

ii) Reference No(s): (for RGC funding schemes only)

iii) Project Title(s):

iv) a brief account of the project(s) including month & year of funding award and an explanation on the differences between the project(s) concerned and this application:

6. Plan(s) for collaboration in this application:
[Indicate the role and the specific task(s) the PI and each Co-I, if any, is responsible for.]

The PI's expertise is on the design of switched reluctance actuators and its position detection method; the Co-I's expertise is on intelligent control algorithm (including neural/fuzzy) as applied to multi-phase motor drives. They had already collaborated during the last three CERG projects: "A Robust and Low Cost Linear Motion System for Position Manufacturing Automation" (Ref: BQ312), "Sensorless Control of a High-Performance Switched Reluctance Linear Motor" (Ref: BQ831) and "Using Magnetic-Levitated Switched-Reluctance Linear Motor for High-Precision Applications" (B-Q946), and had produced fruitful results.

The PI will be concentrated on the research work of the design and fabrication of the RLSRM, and the hardware design of the multiphase SRLM driver. The Co-I will focus his research work on the position and force control of the RLSRM, using the dSPACE control hardware.

After that, the two investigators will then collaborate in the integration/implementation phase and the performance evaluation phase.

GRANT RECORD OF INVESTIGATORS

7. Details of on-going and completed research projects funded from all (RGC and non-RGC) sources undertaken by the **PI** (in a PI or Co-I capacity) in the past **five** years.
[Please attach a copy of the original abstract of each listed project]

Seq. No.	Project Title	PI/Co-I	Funding Source(s) and Amount (HK$)	Start Date	(Expected) Completion Date
1	A high performance 2D Planar Motion Drive System for Manufacturing Automation	PI	$475,000 ERG & $200,000 PolyU	Dec 2001	Dec 2004
2	Improving the Performance of X-Y Tables through Real-Time Friction Estimation and Compensation	PI	$200,000 HK PolyU	Dec 2002	Dec2004
3	Sensorless Control of a High-Performance Variable Reluctance Linear Motor	PI	$579,614 ERG	Dec 2004	Dec 2007
4	Using Magnetic-Levitated Switched-Reluctance Linear Motor for High-Precision Applications	PI	$691,373 ERG	Dec 2005	Dec 2008

/.... 8. Details

8. Details of on-going and completed research projects funded from all (RGC and non-RGC) sources undertaken by each **Co-I** (in a PI capacity) in the past **three** years.
[Please attach a copy of the original abstract of each listed project]

Seq. No.	Name of Co-I (s)	Project Title	Funding Source(s) and Amount (HK$)	Start Date	(Expected) Completion Date

9. Research output of previously funded projects (RGC and non-RGC sources), in descending chronological order, undertaken by the PI and each Co-I relevant to this application.
[Attach **one A-4 page** summary on the progress/publications/conferences/student-training, etc. of the projects, with the relevant project reference no.]

Relevant Awards

[1] **IEEE Industrial Electronics Society Best Presentation Award:** W.C. Gan and N.C. Cheung, "A low-cost linear switched reluctance motor with integrated position sensor for general-purpose three-phase motor controller," *The 27th Annual Conference of the IEEE Industrial Electronics Society IECON'01*, Denver, Colorado, USA, Dec. 2001.

[2] **Chinese Power Supplies Society Top 10 Outstanding Paper Award:** S.W. Tam and N.C. Cheung, "An all-digital high-performance drive system for linear permanent-magnet synchronous motor," *The 14th Chinese Power Supplies Society Annual General Meeting*, Beijing, China, Sep. 2001.

[3] **The Most Valued Product Development Award in 2003:** N.C. Cheung, "Development of a series of high performance linear switch reluctance motor for industry," *The Hong Kong Polytechnic University*, Feb. 2003.

Relevant Chapter of Book

[1] E Cheung and N.C. Cheung, "Switched reluctance machines and permanent magnet DC brushless machines," *Electrical Engineering Chapter from the Encyclopaedia of Life Support Science*, EOLSS, Eolss Publishers Co. Ltd., 58 St. Aldates, Oxford OX1 1ST, UK, 2001.

Relevant Journal Papers

[1] N.C. Cheung and J.F. Pan, "Using variable reluctance actuators in automated manufacturing machines," *Industrial Robot: an International Journal*, Vol. 30, No. 4, pp. 355-362, Jul. 2003.

[2] W.C. Gan and N.C. Cheung, "Development and control of a low-cost linear variable reluctance motor for precision manufacturing automation," *IEEE/ASME Trans. on Mechatronics*, Vol. 8, No. 3, pp. 326 -333, Sep. 2003.

[3] W.C. Gan, N.C. Cheung, and L. Qiu, "Position control of linear switched reluctance motors for high precision applications," *IEEE Trans. on Industry Applications*, Vol. 39, No. 5, pp. 1350-1362, Sep./Oct. 2003.

[4] K.K.C. Chan, J.M. Yang, and N.C. Cheung, "Passivity based control for flux regulation in a variable reluctance finger gripper," *IEE Proceedings, Pt-D, Electric Power Applications*, accepted for publication, 16 Sep 2003.

[5] K.K.C. Chan and N.C. Cheung, "A novel two-finger variable reluctance gripper for high-speed grasping of delicate objects: An implementation case study," *IEEE Trans. on Industrial Electronics*, accepted for publication, 29 Oct 2003.

[6] J.M. Yang, J. Wu, N.C. Cheung, and K.K.C. Chan, "Passivity based control incorporating trajectory planning for a variable-reluctance finger gripper," *Proc. of IMechE Part I: Systems and Control Engineering*, Vol. 218, pp. 99-109, 2004.

Relevant Conference Papers

[1] N.C. Cheung, "A low cost position sensor for linear variable reluctance motor," *The 3rd IEEE International Power Electronics and Motion Control Conference, IPEMC'2000*, Vol. 2, pp. 622-627, Beijing, China, Aug. 2000.

[2] N.C. Cheung, "Employing variable reluctance direct-drive motor actuators in high performance manufacturing machines," *The 3rd IEEE International Power Electronics and Motion Control Conference*, *IPEMC'2000,*Vol. 2 pp. 832-837, Beijing, China, Aug. 2000.

[3] N.C. Cheung, "A robust and low cost linear motion system for precision manufacturing automation," *The 35th IEEE Industry Applications Society Annual Meeting, IAS'2000*, Vol.1 , pp. 40-45, Roma, Italy, Oct. 2000.

[4] S.W. Tam and N.C. Cheung, "A high-speed high-precision linear drive system for manufacturing automation," *IEEE Applied Power Electronics Conference and Exposition, APEC 2001*, Vol. 1, pp. 440-444, Anaheim, California, USA, Mar. 2001.

[5] Y.R. Chen, N.C. Cheung, and J. Wu, "Sensorless drive of permanent magnet linear motors using modified Kalman filter," *IEEE Power Electronics Specialist Conference, PESC'2001*, Vol. 4, pp. 2009-2013, Vancouver, Canada, Jun. 2001.

[6] W.C. Gan and N.C. Cheung, "Design of a linear switched reluctance motor for high precision applications," *IEEE International Electric Machines and Drives Conference, IEMDC'2001*, pp. 701-704, Cambridge, Mass., USA, Jun. 2001.

[7] N.C. Cheung, Y.R. Chen, and J. Wu, "H∞ control of permanent magnet linear motor in transportation system," International Conference on Electric Machines and Systems ICEMS'2001, Vol. 2, pp. 706-709, Shenyang, China, Aug. 2001.

[8] S.W. Tam and N.C. Cheung, "An all-digital high-performance drive system for linear permanent-magnet synchronous motor," *The 14th Chinese Power Supplies Society Annual General Meeting*, Beijing, China, Sep. 2001. ***Received the Chinese Power Supplies Society Top 10 Outstanding Paper Award.***

[9] W.C. Gan, N.C. Cheung, and L. Qiu, "Short distance position control for linear switch reluctance motors: a plug-in robust compensator approach," *The 36th IEEE Industry Applications Society Annual Meeting, IAS'2001*, Vol. 4, pp. 2329-2336, Chicago, USA, Oct. 2001.

[10] W.C. Gan and N.C. Cheung, "A low-cost linear switched reluctance motor with integrated position sensor for general-purpose three-phase motor controller," *The 27th Annual Conference of the IEEE Industrial Electronics Society, IECON'01*, Vol. 1, pp.468-473, Denver, Colorado, USA, Dec. 2001. ***Received the best paper presentation award in the Mechatronics section.***

[11] Y.R. Chen, N.C. Cheung, and J. Wu, "H-infinity robust control of permanent magnet Linear Synchronous motor in high-performance motion system with large parametric uncertainty," *33rd Annual IEEE Power Electronics Specialists Conference, PESC'02*, Vol. 2, pp. 535-539, Cairns, Australia, Jun. 2002.

[12] N.C. Cheung, "A new type of direct-drive variable-reluctance actuators for industrial automation," *IEEE International Conference on Industrial Technology, ICIT'02*, Vol. 1, pp.30-34, Bangkok, Thailand, Dec. 2002.

[13] N.C. Cheung and W. C Gan , "Low-cost position sensing technique for Linear Switch Reluctance Motion system," *IEEE International Conference on Industrial Technology, ICIT'02*, Vol. 2, pp. 1179-1184, Bangkok, Thailand, Dec. 2002.
[14] J.M. Yang, N.C. Cheung and J. Wu, "Passivity based control for speed regulation in permanent-magnet linear motors," *IASTED 7th International Conference on Power and Energy Systems, PES2003 – Power Electronics and Applications PETA'03*, Palm Springs, California, USA, Feb. 2003.
[15] J.F. Pan and N.C. Cheung, "Two dimensional planar actuators for industrial automation," *The International Conference on Electrical Engineering, ICEE'2003*, Hong Kong, Jul. 2003.
[16] N.C. Cheung, J.F. Pan and J.M. Yang, "A novel 2D variable reluctance planar actuator for industrial automation," *The 10th European Conference on Power Electronics and Drives*, *EPE 2003,* Toulouse, France, Sep. 2003.
[17] Y.R. Chen, J. Wu, N.C. Cheung and J.F. Pan, "H_∞ state estimation of permanent magnet linear synchronous motors using a linear matrix inequality approach," *The 5th International Conference on Power Electronics and Drives, PEDS 2003*, Vol. 1, pp. 275-278, Singapore, Nov. 2003.

10(a). Is the PI a new appointee within two years of appointment to his/her first substantive academic / research position in a university at the time of submission of the proposal?

Yes [ ] No [X]
(If yes, please submit the proposal in green-colour paper.)

10(b). Curriculum vitae (CV) of applicant(s).
[For the PI and each Co-I, attach **one A-4 page** CV with personal particulars, academic qualifications, positions held and publication records. Please present publications in two sections: most representative publications (ten at maximum), and research-related prizes and awards.]

Pls. See Appendix 1

/.... 11. Expected

PROJECT FUNDING

11. Expected duration of this project (in months) [ ]

Proposed start date: [ ] Estimated completion date: [ ]

12. Estimated cost and resource implications:

	Year 1 HK$	Year 2 HK$	Year 3 HK$	Total HK$
(a) Staff				**$558,000 (staff total)**
Rank No. Salary per month	$186,000			$186,000
1		$186,000		$186,000
$15,500/year1			$186,000	$186,000
Research $15,500/year2				
Assistant $15,500/year3				
(b) Relief Teacher (see Explanatory Notes)				**$0 (relief teacher total)**
Rank Months Salary per month				
NIL	$0	$0	$0	$0
(c) Equipment (please itemize and provide quotations for each item costing over HK$200,000)				**$38,000 (equipment total)**
Motion sensor and motion monitoring system – for system integration testing	$38,000			$38,000
(d) General expenses (please itemize)				**$215,000 (g. expenses total)**
- Fabrication cost of the SRLM	$69,000			$69,000
- Ventura Real time extension (RTX) OS, and component integrator**	$30,000			$30,000
- dSPACE 1104 control development system, incl. interface card & S/W	$35,000			$35,000
- Laminated plates cutting (stamping)	$12,000			$12,000
- Copley digital PWM driver (×2)	$19,000			$19,000
- Proximity sensors & position	$18,000			$18,000
encoders	$10,000	$2,000	$2,000	$14,000
- Material cost for motor & fixture	$5,000	$8,000	$5,000	$18,000
- Electronic components, wirings, power supplies, drivers, and other misc. costs				
(e) Conference expenses (see Explanatory Notes)	$12,000	$12,000	$12,000	**$36,000 (con. total)**
Total	$434,000	$208,000	$205,000	**$847,000**

13(a). Justifications for each category/item of the budget in Item 12 above:
[Detailed justifications should be given in order to support the request]

The research cost of $847,000 for a project of such a high complexity is already a very good value for money, given that the knowledge derived from this project is extremely useful to industry.

Staff

The work in this project involves full time work from a person with expert knowledge in control, machines design, software development, and power electronics circuits. It is expected that only a research assistant (or a research student) with MSc qualification and strong knowledge in control/machine/power electronics can fulfil this requirement. 3 years is an absolute minimum for a research student to complete the proposed tasks in this project.

Equipment

A high-precision motion recorder system is required to measure the speed and accuracy of the motion actuator. The system includes a proximity sensor and a linear encoder, with accuracies of 0.5 micron. The recorder can record the position accuracy and the motion dynamics of the target under measurement, and display the motion profiles in real time.

General Expenses

Manufacturing and material costs are required for the production of the actuator and the fixture. This includes stamping and lamination of the magnetic circuit (on the moving platform), casting of the aluminium support components by CNC machines, precision fabrication of the toothed table base, and mounting of high precision roller ball bearings, and accuracy testing of the table by laser interferometer. Note that all the fabrication work requires high precision, and high precision CNC tools are involved.

The actuator requires complex real time control, some of the higher complexity floating point routines will be calculated in the Pentium computer in real time and then downloaded it onto the dSPACE board; therefore a PC based real time OS is very useful to the project development. Additionally, the real time OS can initiate routines to capture useful operation data and display it in real time. The Real Time Extension (RTX) and the Component Integrator is one of the most popular Window based real time OS available.

The dSPACE controller board is a RISC based controller board. It provides adequate computing power for the control and commutation of the direct drive SRLM, plus the control of the active loading system. It has direct interface with MATLAB and SIMULINK (via Real time Workshop), and it is very convenient for rapid hardware prototyping of real time motion systems. On-line change of control parameters, and monitoring of trajectory motion path are possible. Since the actuator requires synchronised multi-axis motion control with complex nonlinear control algorithm, a higher performance model DS1104 based on the Power PC chip is required.

Two Copley Controls digital drivers are needed for driving the two sets of three phase coils of the actuator. The digital drivers have fully isolated digital inputs, and they can be directed connected to the a.c. mains. No power transformers are required. Hence they are very suitable for direct connection to the dSPACE control card.

Electronic component cost includes power modules, inductors, current transducers, high speed opto-coupler, power supplies, and other necessary circuit components to build the proposed system. Since the project includes the fabrication of a high precision sensor, two optical sensor heads (with lens) manufactured by HP are required .

Conference expenses

During the course of project investigation and development, the principal investigator will attend three international conferences (once per year) to disseminate the knowledge and the new findings.

/….13(b). Existing

13(b). Existing facilities and major equipment already available for this research project:

14. Other research funds already secured for this research proposal:

Source | Amount (HK$)*

* This amount will be reduced from the total requested.

NIL

15. Allocation from Earmarked Research Grant requested: **HK$ 847,000**
[The amount shown here should be the same as shown in Item 3 of Part I above]

16. Other research funds to be or are being sought for this research proposal [If funds under this item are secured, the amount of the Earmarked Research Grant to be awarded may be reduced]:

Source | Amount (HK$)

NIL

/….17. Research

ANCILLARY INFORMATION

17. Research ethics/safety approval:
[The primary responsibility of seeking the relevant approval rests with the PI. The PI's institution is required to complete and sign Part III of this application form to certify whether the relevant approval has been given]

(a) Please tick '√' the appropriate boxes to confirm if approval for the respective ethics and/or safety issues is required and has been obtained from the PI's institution.

		Approval not required	Approval obtained	Approval being sought
(i)	Human research ethics[1]	X	☐	☐
(ii)	Animal research ethics	X	☐	☐
(iii)	Biological safety	X	☐	☐
(iv)	Ionizing radiation safety	X	☐	☐
(v)	Non-ionizing radiation safety	X	☐	☐
(vi)	Chemical safety	X	☐	☐

(b) If approval is required by other authorities, please indicate the names of the authorities and the prospects of obtaining such approval. If not applicable, please put down "N.A.".

N/A

/.... 18(a). List

[1] *Including ethics involving human subjects in social science research (e.g. potential physical or psychological harm, discomfort or stress to human subjects in a research project, subjects' privacy etc.)*

18(a). List of proposed reviewers:

Points to note before completion:-

- This is NOT a compulsory section. This list serves as a reference for the RGC Panel. The named reviewer(s) may or may not be chosen to review the application.
- Applicant(s) can nominate none or a maximum of five reviewers. They should preferably be experts whom the applicant(s) has no relationship with. If however the applicant(s) i.e., the PI as well as the Co-I(s), decide to nominate reviewers with a past or present relationship, a declaration on the association must be made. It is the responsibility of the PI and the Co-I(s) to ensure that all relationships are fully and accurately declared. Failure of PI and / or Co-I(s) to disclose fully or accurately the relationship will result in disqualification of the application, which will also be taken into account by the RGC as part of the track record of the concerned PI / Co-I(s) when assessing future applications from the same PI / Co-I(s) in the capacity of PI. The RGC reserves the ultimate right to reject or disqualify future applications in serious cases.
- Please DO NOT put down here the name(s) of any reviewer(s) whom the applicant(s) may wish to exclude from being invited for assessment.

(i) Title/Name/Post/Institution:

Address/Tel./Fax/E-mail:
Area of Expertise:

(ii) Title/Name/Post/Institution:

Address/Tel./Fax/E-mail:
Area of Expertise:

(iii) Title/Name/Post/Institution:

Address/Tel./Fax/E-mail:
Area of Expertise:

(iv) Title/Name/Post/Institution:

Address/Tel./Fax/E-mail:
Area of Expertise:

(v) Title/Name/Post/Institution:

Address/Tel./Fax/E-mail:
Area of Expertise:

/.... 18(b). Declaration

18(b). Declaration of any past and present relationship between the investigator(s) i.e., PI and Co-Is, and the nominated reviewers **[minimum one tick (√) per reviewer]**:

Nature of relationship (please elaborate in 18(c))	Reviewer (i)	(ii)	(iii)	(iv)	(v)
Advisor or Advisee in research studies/research projects					
Colleagues in the same organization (please specify if in the same department)					
Collaborators in research projects/programmes					
Co-authors of papers/patents/publications					
Partners or co-organizers of major events					
Long-time personal friends					
Others (please specify)					
None					

18(c). Elaboration on the nature of the relationship declared in Section 18(b) (e.g. when and where the relationship was / is developed, name / nature of project, publications or events involved):

19. DATA ARCHIVE POSSIBILITIES

Is the proposed project likely to generate data set(s) of retention value?
Yes [X] No [ ]

If yes, please describe the nature, quantity and potential use of the data set(s) in future.

1. The Blueprint of the Linear Motor's Design
2. The Software Control Code

Are you willing to make the data set(s) available to others for reference twelve months after the publication of research results or the completion of this proposed project?
Yes [X] No [ ]

I/We understand that the RGC only considers data archiving requests after the completion of the RGC-funded project, and the Council has full discretion in funding the archiving requests. Data sets archived with RGC funds will require users to acknowledge the originator and the RGC. The originator will also be provided with copies of all publications derived from the use of the data.

/…. 20. I/We

20. I/We certify that I/we have completed this application form in accordance with the Explanatory Notes CERG2. The information given is complete and accurate to the best of my/our knowledge.

Name of Principal Investigator : Norbert C. CHEUNG Signature : _______________ Date : 25 Sep 2006

Name of Co-investigator : Wai-Chuen GAN Signature : _____________ Date : 25 Sep 2006

Name of Co-investigator : ____________________ Signature : __________________ Date :____________

(Add more names if necessary)

/.... PART III

PART III INSTITUTIONAL ENDORSEMENT AND DECLARATION OF RESEARCH ETHICS/SAFETY
(To be completed by the appropriate authority of the PI's institution)

1. INSTITUTIONAL ENDORSEMENT
(* Please tick '√' as appropriate)

I confirm that:

Staff eligibility requirement for CERG

(a) the application has been evaluated and endorsed by the institution for submission to the RGC;

(b) the PI, in the staff grade _____ , meets fully the stipulated staff eligibility requirement for CERG;

where the PI is newly appointed, the institution has formally entered into a contract of service with him/her on or before 31 October 2006 and the contract requires him/her to report duty on or before ____.

(c) the PI is/will be employed on permanent term * [ ] or fixed term contract *# [X]

if the PI is/will be employed on a fixed term contract, the PI will still be eligible for an CERG grant at the time of funding award being made in June 2007 and for at least the first year of the project's planned duration;

(d) The PI is/will be a visiting scholar *# [ ] NOT a visiting scholar * [X]

where the PI is a visiting scholar, he/she has a full-time employment with the institution covering at least one year or the expected duration of the project whichever is the longer;

(e) the institution will inform the RGC as soon as the PI ceases to be eligible to apply, receive or hold an CERG grant, and will withdraw the application, or if funded by the RGC, terminate/conclude the project as appropriate;

(f) the institution understands that the CERG grant, if given, will be withdrawn if the project does not start within one year of the funding award or the PI leaves the UGC sector within six months of project commencement. The institution should report to the RGC as soon as possible when a PI proceeds on no-pay leave / professional leave for a continuous or cumulative period exceeding 183 days within the project period;

Eligibility rules of multiple grants

(g) the PI*

[X] *meets the eligibility rule of multiple grants as stipulated in the explanatory notes of CERG2 ;*

[ ] *does not meet the eligibility rules of multiple grants but makes a request for the exceptional approval of the RGC to allow him / her to apply in this exercise. The institution endorses the PI's request and certifies that the PI fulfils ALL the conditions specified at Part I Item 4(c);*

Longer-term research grant (only for the case where PI has selected this item at Part I 4(b))

(h) *the PI meets** [ ] *or does not meet** [ ] *the eligibility requirement for longer-term research grant as set out in the Supplementary Notes for Applicants of CERG for Longer Term Research;*

/.... Individual

Individual research (only for the case where PI has selected this item at Part I 4(b))

(i) the PI meets ☐ or does not meet* ☐ the eligibility requirement for funding support of individual research as set out in the Supplementary Notes for Applicants of CERG for Individual Research;*

*(j) the institution will * ☐ or will not* ☐ facilitate arrangements for time-off for applications for individual research;*

Relief support under Humanities Sub-Panel (only for the case where PI has selected this item at Part I 4(b))

(k) the salary for the relief teacher proposed by the PI exceeds ☐ does not exceed* ☐ the salary of Staff Grade 'G' as set out in the Supplementary Notes for Applicants of CERG for Research Support under Humanities Sub-Panel;*

Institutional Commitments

Allowance for undergraduate student helper (only for the case where PI has selected this item at Part I 4(b))

(l) the institution is committed to providing a monthly allowance of $1,250 to the undergraduate student helper up to a maximum period of ten months if this proposal is funded as set out in the Supplementary Notes for Applicants of CERG for Undergraduate Student Allowance;

(m) adequate supervision, research facilities and training provisions will * ☐ or will not * ☐ be in place to meet the need of RPg student(s) so employed under the research grant if this application is supported by the RGC / * ☐ No RPg student will be trained in this proposed project; and

(n) the research project under this application is * ☐ or is not * ☐ in line with the role of the institution.

Notes on (m):
The primary duty of the Principal Investigator of the RGC grant is to complete the project according to plan and that the training of RPg students should not be used to justify any delay of project completion nor unsatisfactory project performance.

/. … 2. DECLARATION

2. DECLARATION OF RESEARCH ETHICS/SAFETY
(Please tick '√' as appropriate)

I have examined the research proposal and confirm that the approval of the appropriate authority(ies) has been/will be obtained in respect of the following :

		Approval not required	Approval obtained	Approval being sought#
(i)	Human research ethics[2]	X		
(ii)	Animal research ethics	X		
(iii)	Biological safety	X		
(iv)	Ionizing radiation safety	X		
(v)	Non-ionizing radiation safety	X		
(vi)	Chemical safety	X		

Where such approval is required but has not yet been obtained, the institution will ensure that it will be obtained without delay. The institution understands that if no confirmation of such approval is provided to the RGC by 30 April 2007, the RGC will regard this *C*ERG application as being withdrawn and will stop processing it.

Signature : ______________________

Name : ______________________
(in BLOCK letters)

Designation : ______________________

Date : ______________________

[2] *Including ethics involving human subjects in social science research (e.g. potential physical or psychological harm, discomfort or stress to human subjects in a research project, subjects' privacy etc.)*