Emerging Topics from Special Sessions at CASE 2012

The Precise Measurement Technology and Their Applications

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Outline

1. Introduction of Xi’an Jiaotong University (XJTU)
2. EEG signal processing and its application on robotics
3. Optical fiber sensors and its applications
1. Introduction of XJTU-1

- XJTU is located in ancient capital city of Xi'an, a famous historical city, also a position center of China.
1. Introduction of XJTU-2

- Xi'an Jiaotong University, a national key university under the direct jurisdiction of the Ministry of Education, is one of the country's oldest institutions of higher learning. Founded in Shanghai in 1896 as Nanyang Public, it was renamed Jiaotong University in 1921. In 1956, at the direction of the State Council, the university was moved to Xi'an, and renamed Xi'an Jiaotong University (XJTU).

- As one of the country's national key universities, it was included in the first group of universities singled out for high priority development under the country's seventh and eighth five year plans. It was also included in the first group of universities to benefit from Project 211 and Project 985, with the goal of becoming a world class university.

- Under a plan adopted by the State Council in April, 2000, the original Xi'an Jiaotong University was merged with the Xi'an Medical University and the Shaanxi Institute of Finance and Economics to form the new Xi'an Jiaotong University.
1. Introduction of XJTU-3

- Today, Xi'an Jiaotong University is a comprehensive research university offering programs in nine areas—science, engineering, medicine, economics, management, art, law, philosophy and education—with a major emphasis on science and engineering.
- It includes 20 schools, eight undergraduate residential colleges, and eight affiliated teaching hospitals.
- XJTU has a faculty and staff of more than 5500, of which 2500 are full-time teachers, including over 1500 professors and associate professors. The faculty includes 21 academicians—nine members of the National Academy of Sciences and twelve members of the National Academy of Engineering—among whom twelve are members of both.
- XJTU has a current enrollment of more than 30,000 full-time students, including over 13,000 masters and doctoral candidates. The university offers 78 undergraduate majors, and awards masters degrees in 200 disciplines and Ph.D. degrees in 115. Among these, there are 8 which are designated as first-order key disciplines by the Chinese government, and 37 which are designated as second-order key disciplines.
- In addition, 115 disciplines are recognized as key disciplines at the provincial and ministerial level. XJTU offers Master degrees 18 areas, including engineering, clinical medicine, business, and MPA; it has 20 research facilities for post-doctoral students, four national key laboratories, four national special laboratories, two national engineering research centers and 59 key research centers and laboratories at the provincial and ministerial level.
1. Introduction of Xi’an Jiaotong University

Schools and Colleges

- School of Science
- School of Mechanical Engineering
- School of Energy and Power Engineering
- School of Software Engineering
- School of Human Settlement and Civil Engineering
- School of Aerospace
- School of Economics and Finance
- School of Public Policy and Management
- School of Law
- Jinhe Center for Economic Research
- School of Continuing Education
- Pengxang College
- Songlan College
- ChungYing College
- Chongshi College
- School of Mathematics and Statistics
- School of Electrical Engineering
- School of Electronic & Information Engineering
- School of Materials Science & Engineering
- School of Life Science & Technology
- School of Medicine
- School of Management
- School of Humanities & Social Sciences
- School of Foreign Studies
- Physical Education Center
- School of International Education

- Wenzhi College
- Qide College
- Lizhi College
- Nanyang College
1. Introduction of XJTU-5

- My research group is belong to School of Mechanical Engineering, and the Research Center for Bio-Mechatronics is constructing.
  - School of Mechanical Engineering is one of the oldest and reputed faculties of Xi’an Jiaotong University.
  - In the school, there are 3 first class subjects authorized to offer 6 doctoral programs and 7 master’s degree programs. The school has also a State Key Laboratory of Manufacturing System and a Post-doctoral Research Station of Mechanical Engineering which is among the first established post-doctoral research stations in China.
  - At present, the school has about 200 teaching and administrative staff members, including 60 professors, 3 chief committee men of the State Teaching Instruction Committee for Basic Courses and 10 committee members of the State Instruction Committee for Specialty Basic Courses.
  - The school is composed of 4 departments, 3 teaching offices of basic courses, 2 experiment centers, 12 research institutes, and 1 training center. Over the past five years, 5 state-level and 47 province- and ministry-level awards for teaching and research fruits have been obtained by the school. At present, the fund or outlay on scientific research has reached up to 10 million a year.

- The school has established comprehensive system for the fostering, education and management of graduates.
- At present, there are 200 master degree candidates and the same number of PhD candidates in the school.
- Being one of the earliest units to carry out the enrolling and fostering of masters of engineering, the school can provide the program for masters of engineering in mechanical engineering and material science.
- Since 1998 the enrolled students pursuing master of engineering have reached 240
2. EEG signal processing and its application on robotics

2.1 Bioelectrical signals in human body
2.2 Basic characteristics of EEG
2.3 Measurement systems of EEG
2.4 Feature extraction and recognition methods of EEG
2.5 EEG’s applications in robotics
2.1 Bioelectrical signals in human body
(EEG, EMG, ECG, EOG, etc.)
ECG

• ECG, electrocardiography, represent a body bioelectrical signal from heart beat.
• The ECG signal is mainly applied in the detection and investigation of body cardio-disease.
EMG

- EMG, electromyography, represent a body bioelectrical signal from muscle activities.
- EMG signals are extensively applied in the control of the body prosthesis, such as prosthetic hand, prosthetic leg and human assistant hand, etc.
- EMG signal is a strong body bioelectrical signal, but its feature depends on measuring positions on a human body.
EEG

- EEG, electroencephalography, represent spontaneous electrical brain activities.
- EEG signals were successfully applied in the some diagnosis of human mental diseases and brain diseases, also effectively applied in the some pattern recognitions of brain activities adapted to the alteration of external environment and the other intelligent requirement, etc.
- EEG signal is dynamic, stochastic, non-linear, and non-stationary. It is also weaker than EMG signal.
2.2 Basic characteristics of EEG

2.2.1 EEG history
2.2.2 Time-domain characteristics
2.2.3 Frequency-domain characteristics
2.2.4 Complication of feature extraction
2.2.1 EEG history

- The presence of electrical current in the brain was discovered by an English physician, Richard Caton, in 1875. It was not until 1924 that Hans Berger, a German neurologist, used his ordinary radio equipment to amplify the brain's electrical activity so that he could record it on graph paper. Berger noticed that rhythmic changes (brain waves) varied with the individual's state of consciousness.
2.2.2 Time-domain characteristics

- A normal EEG signal, recorded from the scalp in international 10/20 system, will have an amplitude between 0.1 and about 200 µV.
2.2.3 Frequency-domain characteristics

- **Alpha wave** (8-13Hz)
- **Beta wave** (14-26Hz, high 27-40Hz)
- **Theta wave** (4-7Hz)
- **Delta wave** (0.5-4Hz)

The waves above 40 Hz are regarded as noise signals from EMG.
2.2.4 Complication of feature extraction

- While the EEG monitors brain activities, a person's intent could in theory be understood. The skull muffles much of the brain activity, and since everything a person is thinking, doing, seeing and hearing, and from eye blinks to muscle movements, is encoded into the EEG signals, the number of variables researchers have to cope with is considerably large.
- So it is a challenge to distinguish the patterns related to the inspected phenomenon for researcher. People usually hope to isolate task-related brain patterns with a good degree of accuracy, and then a computer could translate the patterns into commands to achieve or to control these tasks.
2.3 Measurement systems of EEG

2.3.1 The early analogue recording system

2.3.2 The modern digital measurement system

2.3.3 The two channel EEG measurement system
2.3.1 The early analogue recording system

The some electrodes, placed on the scalp in international 10/20 system, output raw signals.

The raw signals should be amplified in differential input by high-gain amplifier.

At last, the amplified signal is recorded in the paper by a pen-record device.
2.3.2 The modern digital measurement system

- 21 electrode points
- Multi-channel output signals

- 16 channel signals
- 20,000-gain amplifier
- 1.8-36 Hz bandwidth filter
- 1KHz sampling rate
- 12 bits resolution
- Serial port output

- Serial port input
- Windows system
- Waveform display
- Spectrum display
- Program in C, C++, VC, VB
2.3.3 The two channel EEG measurement system
2.4 Feature extraction and recognition methods of EEG

2.4.1 Time domain analysis;
2.4.2 Spectral feature analysis;
2.4.3 Time-frequency analysis;
2.4.4 Recognition methods based on artificial neural network
2.4.1 Time domain analysis

- Some parameters in time domain can be obtained, such as the biggest amplitude, the smallest amplitude, the mean value of signal amplitudes, etc.
2.4.2 Spectral feature analysis

The spectral feature vector with five segments can be obtained as follows.

\[ x = (0.644, 0.153, 0.086, 0.090, 0.028) \]
2.4.3 Time-frequency analysis

----Wingers distribution
2.4.3 Time-frequency analysis

----wavelet feature
2.4.4 Recognition methods based on artificial neural network-BP

<table>
<thead>
<tr>
<th>Activity</th>
<th>$y_1$</th>
<th>$y_2$</th>
</tr>
</thead>
<tbody>
<tr>
<td>Grasping a football</td>
<td>0</td>
<td>0</td>
</tr>
<tr>
<td>Grasping a smallbar</td>
<td>0</td>
<td>1</td>
</tr>
<tr>
<td>Grasping a cylinder</td>
<td>1</td>
<td>0</td>
</tr>
<tr>
<td>Grasping a hard paper</td>
<td>1</td>
<td>1</td>
</tr>
</tbody>
</table>
2.4.4 Recognition methods based on artificial neural network-LVQ (Learning Vector Quantisation)
2.4.4 Recognition methods based on artificial neural network-FNN
2.4.4 Recognition methods based on artificial neural network-MSNN
2.5 EEG’s applications in Robotics

2.5.1 Anthropomorphic control of neuro-prosthesis
2.5.2 Brain-actuated control of mobile robot
2.5.3 Direction control of walking-assistant robot
2.5.4 Possible application for exoskeleton robot-Previous recognition of human body posture
2.5.1 Anthropomorphic control of neuro-prosthesis—idea/Dr. Rechard in 2000
2.5.1 Anthropomorphic control of neuro-prosthesis – the system for Prosthesis Hand drived by BCI set up in 2008
2.5.1 Anthropomorphic control of neuro-prosthesis—achievements and main results

Offline accuracy 85%, Online accuracy 65%

Arm movement  Hand grasping  Hand opening
2.5.2 Brain-actuated control of mobile robot—presented by Italian scholar in 2004
2.5.2 Brain-actuated control of mobile robot - the system for Unmanned Vehicle driven by BCI set up in 2009
2.5.2 Brain-actuated control of mobile robot: achievements and main results

The highest recognition rate is 82.5%
The average recognition rate of 74.375%

Run forward  Turn right  Turn left
2.5.3 Direction control of walking-assistant robot - electric wheelchair presented by Japanese scholar in 2005
2.5.3 Direction control of walking-assistant robot – the current research by my research group in 2010-1

Function and technical characteristics
2.5.3 Direction control of walking-assistant robot – the current research by my research group in 2010-2
2.5.3 Direction control of walking-assistant robot—the current research by my research group in 2010-3

Double-motor differential control

Motor 1 rotation speed

Motor 2 rotation speed

Motor 1 driving circuit

Motor 2 driving circuit

PWM duty ratio tuning

Fuzzy reasoning

PID control arithmetic

Movement relation setting

Current detection

Position detection

DSP control circuit

Protection circuit

Speed reference

Display control circuit

\[
R = \frac{d \times F_1}{V_n}
\]

\[
V_{out} = \sqrt{V_x^2 + V_y^2}, \quad V_{out} < V_{max}
\]

\[
V_{out} \geq V_{max}
\]
2.5.4 Possible application for exoskeleton robot-
Previous recognition of human body posture

America Lockheed Martin
HULC Exoskeleton
In 2009

Japanese Power Assist Suit in 2008

Chinese Assist robot in 2010
3. Optical fiber sensors and its applications

3.1 The Measurement Principle of the Reflective Fiber-Optical Displacement Sensor

3.2 The measurement technology for the plate film thickness

3.3 The measurement technology for the lubricant film thickness for the slide bearing

3.4 The measurement technology for the Blade Tip Clearance of Aero-Engine

3.5 The measurement technology for identifying the Dynamic Posture of Person Body
3.1 The Measurement Principle of the Reflective Fiber-Optical Displacement Sensor

The light-pass amount of the output fiber can be computed by the geometry relation presentation.
3.2 The measurement technology for the plate film thickness

The sampling circuit for the photo-electrical signal

The static property curve of the measurement system
3.3 The measurement technology for the lubricant film thickness for the slide bearing-1
3.3 The measurement technology for the lubricant film thickness for the slide bearing-2

- Dynamic test results can be drawn, the minimum thickness of the experimental system to measure is 30 μm ~ 130 μm, the position angle of the minimum film thickness is generally between 255 ° ~ 270 °.

- Through comparisons with the minimum film thickness and position angle which obtained theoretically by calculation, two-point measurement approach based on displacement sensor of two-circle reflective coaxial fiber is feasible and correct.
3.4 The measurement technology for the Blade Tip Clearance of Aero-Engine-Equipment

a) The fibre displacement sensor has the advantages than the traditional displacement sensor, such as anti-electromagnetic interference, small size, light weight, fast response, high sensitivity, non-contact measurement in the severe working environment and so on.
b) The probe can be made very tiny and can be embedded in the shroud easily. One probe is typically can provide a full characterization of blade tip clearance, as shown in figure
An example profile of seven blades from a disk with 32 blades moving at 3674 RPM is shown. The scale in the Y direction has been significantly stretched to accentuate the clearance measurement. This data was sampled at 25 kHz, yielding a distance measurement every 0.01mm.
3.4 The measurement technology for the Blade Tip Clearance of Aero-Engine-Results

A typical normal blade plot at 2506 RPM. The radar chart shows the individual blade clearances measured by the probe for several fan speeds. The plot shows that the individual blade tip clearances decrease as the fan speed is increased. The clearance decrease is biggest at 5500 RPM because the speed close to critical speed of the rotor test rig.
3.5 The measurement technology for identifying the Dynamic Posture of Person Body

It can be seen from the chart that the fiber tape is fixed on the low or up limb of the experimenter. Firstly it is the pose initialization. Then through the function of the fiber sensor, the angle and other information are received by the Data Acquisition Unit. Next, the data transfer from the Data Transfer Unit to the microprocessor which will be responsible for calculating, control and display. The last and most intuitive unit is the Display Unit. The result is about Synchronization time difference 10.8 ms; Angular resolution 0.5°; Position resolution 1.0-3.0 mm.
That is all for today.

Thank you very much for your attention!
That is all for today.

Thank you very much!