VISUAL MEANS FOR ROTOR HEAT IMBALANCE IDENTIFICATION

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Abstract: Rotor heat imbalance measurement and identification is one of the main issues faced by experts during electrical machine testing. This procedure usually takes a lot of time and human resources. Proposed techniques of video processing, namely key frame extraction, ensure quick detection of problematic segments in video acquired from the object, which helps experts in making right decisions concerning the required maintenance or repair in shorter terms. Salient information in frames is analyzed using visual features of color, texture and shape of segmented areas. An overview of the proposed means for efficient elimination of redundant video information is provided. The resultant key frames presented by separate images can be appended to bench test reports.

Key words: hydrogen rotor ventilation, heat imbalance, video processing, visual features, key frame extraction, artificial intelligence.

1. Introduction

Turbine generators with hydrogen ventilation are now widely used all around the globe [1]. Worn out elements of electric machines may influence stop of operation which in turn results in tremendous effect on end consumers. Experts working in this field try to eliminate these consequences by providing on-line monitoring and problem solving while a machine is in operating mode.

To guarantee seamless uninterruptible operation, present-day expert systems along with state-of-the-art diagnostic tools can be used. They open a number of possibilities, such as data acquisition and analysis concerning rotor state without human involvement, simulation of essential procedures undertaken. Advantages of automatic measuring and analysis means are obvious: immediacy and neutrality of obtained results, centralized control and independency from personal experience, earlier problem revealing in on-line mode, digital archiving, intelligent data analysis and storage in a shortened form, without mentioning search and indexing capabilities [2].

In this paper, visual solution for on-line diagnostics is proposed, which involves artificial intelligence techniques designed for video information processing retrieved from miniature cameras installed at the object. Considering that endoscopic materials are the key visual information obtained about the state of a rotor, our goal was to shorten these materials and present them as a sequence of meaningful images, bearing important information from the whole multi-hour video. The next section observes problem statement according to preconditions available.

2. Problem Statement

From a technical point of view, elongation of turbine generator system operation time through rotor maintenance is deeply connected with ensuring sufficient level of vibration. Ensuring quite strict vibration deviation is a complicated engineering task of overcoming rotor heat imbalance. The key problem lies in a fact that heat imbalance arises only under conditions of full workload, i.e. when generator is operating. One of the reasons of imbalance consists in asymmetry of passing ability in ventilation channels, when uniform rotor heat distribution is violated because of defects in ventilation system.

Rotor winding is symmetrical in relation to central axis, and deformation is absent under uniform heating. Deformation appears with local abnormal heating influenced by blocking (or damaging) of ventilation channels. Moreover, when geometric characteristics vary in acceptable region, fluctuation of thermal conductivity coefficient arises in different consignments of materials used for slot insulation. This also may cause abnormal heating and rotor vibration [3].

Schemata of rotor ventilation system along with illustration of its defects can be observed in [4]. In practice, to detect and overcome rotor heat imbalance in a turbine generator, sum vector for each rotor pole is analyzed after corresponding passing ability measurements [3]. Ventilation system parameters are measured with standard devices, and data are pro-

cessed by experts after digitization and visualization in a form of graphics containing information about passing ability in each channel.

An alternative solution is to perform on-line (or at least near real time) video acquisition with further analysis of defects. It takes a long time for experts to watch multi-hour video fragments, instead artificial intelligence processing can be implemented, and key frames can be extracted based on the visual features present in each frame. This is the point of the next section discussion.

3. Visual Solution

Currently, there are many techniques for video processing to choose from starting from simple clustering and up to novel visual attention models and neural computing. The main drawback they all face lies in tremendous gap between the extracted low-level visual information from each frame and real human understanding of what is going on in this particular sequence of frames.

General salient frame detection procedure is observed in [5] and shown in fig. 1.

According to this, any video is primarily segmented into shots (or scenes), then visual/geometric or other types of low-level features are extracted from each frame pixel, these low-level features are transferred into mid- or high-level ones via artificial intelligence methods, namely by using comparison procedure of Voronoi tessellations proposed in [6], and then candidate key frames are chosen with further duplicate removal. As a result, key frames are got.

To check whether the results are acceptable, Dice coefficient can be calculated which is considered truthful compromise between precision and recall measures. The closer it is to 1, the better the extracted frames represent video content from the point of experts' view. Lower than 0.5 values indicate worse quality. It should be noted that the results are significantly influenced by homogeneity of initial video being analyzed along with video size and resolution. This is easily explained as increase in a number of pixels simultaneously increases entropy in each frame, thus spreading detailing of texture. Video homogeneity can be also analyzed using entropy measures (as it has been done in [6]), though there are other possibilities for checking scene variety or, on the contrary, scene stability for the whole video sequence. When speaking about video tracking, in particular rotor system endoscopic materials, a scene may not change at all for hours. So, we deal with homogeneous data where it is much harder to detect salient information than in heterogeneous data because of closer frame similarity. From another hand, just a bit stricter threshold should be taken into account.

Fig. 2 illustrates dependence of average Dice coefficient from video resolution and frame colour.

By black-and-white we mean grayscale videos. Dice coefficient for heterogeneous content provides

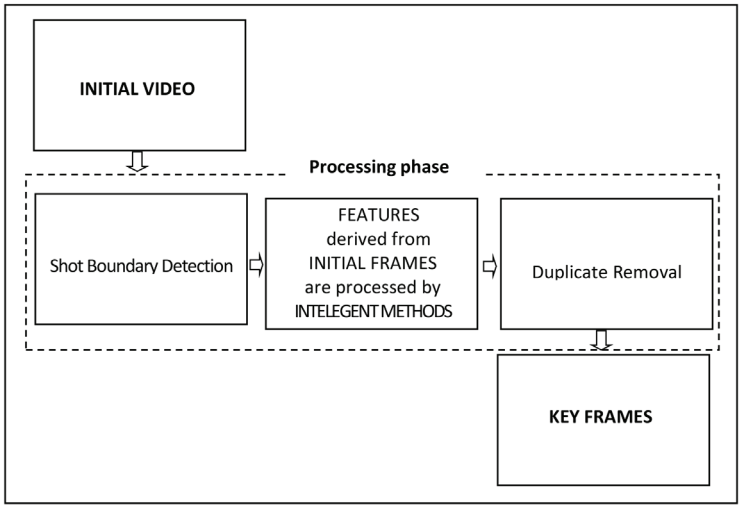

Fig. 1. Video processing schema

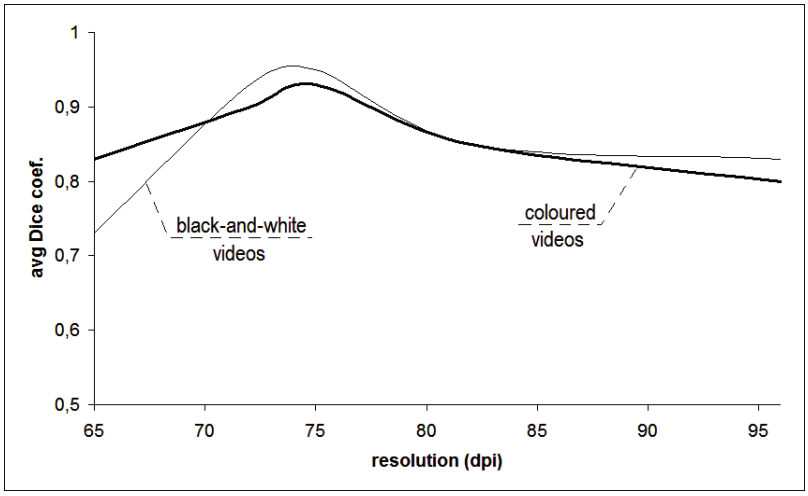

Fig. 2. Average values of Dice coefficient for different conditions of video input

much better results as stated in [6]. Specificity of application domain also influences Dice coefficient values. So, the picture may differ a bit even for homogeneous data of any other domain without speaking about heterogeneous data.

From the figure above it is clearly seen that higher resolution does not mean higher quality as well as coloured frames. Moreover, sufficient results can be obtained while processing grayscale frames. The latter, in turn, decreases processing speed and can reduce it to near real time mode (if other procedure than in [6] is implemented for initial point specification).

4. Conclusion

By analyzing a variety of existing techniques depicted in [5] the proposed one outperforms by 10-15% in quality calculated using Dice coefficient. Thus, the visual means presented here for rotor heat imbalance identification differ in clearness of the results that can be attached to bench test reports. Described here techniques and their program implementation automate calculations and help experts making right decisions in shorter terms.

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ВИЗУАЛЬНЫЕ СРЕДСТВА ДЛЯ ИДЕНТИФИКАЦИИ ТЕПЛОВОГО ДИСБАЛАНСА РОТОРА

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Аннотация: Измерение и идентификация теплового дисбаланса ротора является одной из основных проблем, возникающих перед экспертами в процессе тестирования электрической машины. Данная процедура обычно требует значительных временных затрат и человеческих ресурсов. Предложенные методы обработки видео, а именно извлечения ключевых кадров, гарантируют быстрое обнаружение проблемных сегментов в видео, полученном с объекта, что помогает экспертам более оперативно принимать решения о необходимой наладке или ремонте. Значимая информация в кадрах анализируется с помощью визуальных признаков цвета, текстуры и формы сегментированных областей. Приведен обзор предложенных средств эффективного устранения избыточной видеоинформации. Полученные в результате ключевые кадры, представленные в виде отдельных изображений, могут быть прикреплены к отчету о проведенных испытаниях.

Ключевые слова: водородная вентиляция ротора, тепловой дисбаланс, обработка видео, визуальные признаки, извлечение ключевых кадров, искусственный интеллект.

ВИЗУАЛНИ СРЕДСТВА ЗА ИДЕНТИФИКАЦИЯ НА ТОПЛИННИЯ ДИСБАЛАНС НА РОТОРИ

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Резюме: Измерването и идентификацията на топлинния дисбаланс на ротора са едни от основните проблеми, пред които са изправени експерти в процеса на тестване на електрическа машина. Тази процедура обикновено изисква значително много време и човешки ресурси. Предложените методи за обработка на видеосигналите, а именно извличане на ключови кадри, гарантират по-бързо откриване на проблемните сегменти във видеоинформацията, получена от обекта, което помага на експертите по-оперативно да вземат правилни решения относно необходимата настройка или ремонт в по-кратки срокове. Съществената информация, съдържаща се в кадрите, се анализира въз основа на визуалните характеристики на цвят, текстура и форма на сегментираните зони. Даден е обзор на предложените средства за ефективно отстраняване на излишната видеоинформация. Получените ключови кадри, представени като отделни изображения, могат да бъдат приложени към протоколите от проведените изпитания.

Ключови думи: водородна вентилация на ротора, топлинен дисбаланс, видеообработка, зрителни функции, извличане на ключови кадри, изкуствен интелект.