GOVERNMENT POLYTECHNIC COLLEGE

MATTANNUR-670702

(Department of Technical Education, Kerala)

SEMINAR REPORT ON

HAWK-EYE

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GOVERNMENT POLYTECHNIC COLLEGE

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(Department of Technical Education, Kerala)

CERTIFICATE

Certified that seminar work entitled “ ***HAWK-EYE*****”***is a bonafide work carried out by* **“*KASYAP K*”** *in partial fulfilment for the award of Diploma in Electronics Engineering from Government Polytechnic College Mattannur during the academic year* 2021-2022.

SeminarCo-ordinator **Head ofSection**

InternalExaminer **ExternalExaminer**

DECLARATION

I hereby declare that the report of *the* ***HAWK-EYE*** work entitled which is being submitted to the Govt. Polytechnic College Mattannur, in partial fulfilment of the requirement for the award **of *Diploma in Electronics Engineering*** *i*s a confide report of the work carried out by me. The material in this report has not been submitted to any institute for the award of any degree.

Place:Mattannur **KASYAP K**

Date:

ACKNOWLEDGMENT

I would like to take this opportunity to extend my sincere thanks to people who helped me to make this seminar possible. This seminar will be incomplete without mentioning all the people who helped me to make itreal.

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ABSTRACT

Many sports have become very reliant on monitoring systems such as Hawk-Eye in Tennis; this paper has looked into just how accurate the technology is, and assessed the effectiveness of the technological approaches used to implement the system. The level of accuracy is vital for sport monitoring systems, in a number of sports such as Line Calling Decisions in Tennis. Even a small margin of error can affect the decision of whether the ball is called in or out. As many high profile sporting industries have placed a great deal of dependence upon this technology, if it were to prove inaccurate, the sporting world would incur devastating consequences. As governing bodies would then be under a large amount scrutiny, from all over the world. Players, coaches and even spectators would all start to question the decisions made using this technology made in past. And as these were designed to rule out human error in such cases as line calling, any major failings found in the technology would render them useless.

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CHAPTER 1

INTRODUCTION

The game of cricket has attained great commercial importance and popularity over the past few years. As a result, there has been felt a need to make the game more interesting for the spectators and also to try and make it as fair as possible. The component of human error in making judgments of crucial decisions often turns out to be decisive. It is not uncommon to see matches turning from being interesting to being one sided due to a couple of bad umpiring decisions. There is thus a need to bring in technology to try and minimize the chances of human error in such decision making. Teams across the world are becoming more and more professional with the way they play the game. Teams now have official strategists and technical support staff which help players to study their past games and improve. Devising strategies against opponent teams or specific players is also very common in modern day cricket. All this has become possible due to the advent of technology. Technological developments have been harnessed to collect various data very precisely and use it for various purposes. The HAWKEYE is one such technology which is considered to be really top notch in cricket. The basic idea is to monitor the trajectory of the cricket ball during the entire duration of play. This data is then processed to produce lifelike visualizations showing the paths which the ball took. Such data has been used for various purposes, popular uses including the LBW decision making software and colourful wagon wheels showing various statistics. This paper attempts to explain the intricate details of the technology which goes behind the HAWKEYE. We first start off with a general overview of the system and an outline of the challenges that we might face, then move on to the details of the technology and end with various applications where one sees this technology being put to use.

CHAPTER 2

HISTORY

The Hawkeye system was invented by a young British computer expert Paul Hawkins, and was launched in 2001. It was first used in television coverage of sporting events such as Test cricket, and has now reached the stage of being used by officials in tennis to assist in adjudicating close line calls.

Fig 2.1 Paul Hawkins

The Nasdaq-100 Open in Miami was the first tour event to officially use the technology. The 2006 US Open was the first Grand Slam event to feature the system, followed by the 2007 Australian Open. At the Australian Open, only center court matches utilize the technology.

In 2020, in response to the need to reduced the number of people on the court, the U.S. Open tennis tournament replaced human line judges on 15 of 17 match courts with Hawk-Eye Live, an advanced system that makes automated line calls in real time. This Hawk-Eye Live system features 18 cameras, six of which are used by a review official to monitor foot faults. The system uses recorded voices to make its calls, which shout "out," "fault" or "foot fault." The courts using Hawk-Eye Live at the U.S. Open will have only a chair umpire to call the score after the system makes the call, and they will take over only if the system malfunctions.

Before hawk-eye there was no video system that could be used to replay the bowlers/batter action for the third umpire. There was also no tracking system that could provide television broadcasters with the ability to show the consistency of the bowling and batting as well as other measurements that come with the hawk-eye technology.

The radar gun is another technology that was used to measure the speed of the ball in cricket. However this technology is only able to measure the speed of the ball by using a transmitter and a receiver. The hawk-eye technology has introduced the ability to be able to not only measure the speed but the direction, the swing and many other features. The introduction of this into cricket was the first of its kind and no other technologies have been able to measure all these things.. Hawk-eye was originally used for brain surgery and missile tracking before being introduced into sport.

CHAPTER 3

HAWK-EYE: A GENERAL OVERVIEW

Cricket is a ball game played within a predetermined area. A system comprising of video cameras mounted at specific angles can be used to take pictures. These pictures are then used to locate the position of the ball. The images are then put together and superimposed on a predetermined model to form a complete visualization of the trajectory of the ball. The model includes, in this case, the pitch, the field, the batsmen and fielders etc. For this to be possible, we need to sample images at a very high rate and thus need efficient algorithms which can process data in real time. Such technologies are widely used today in various sports such as Tennis, Billiards which also fall in the category of ball games played within a restricted area. Our discussion will mostly contain applications which specific to the game of cricket, however in some cases, we will mention how similar techniques are applied in other games.

3.1 General issues

There are various issues which crop up when one tries to design and implement such a system. In the game of cricket, the general issues are:

1. The distance at which the cameras see the pitch and the ball are dependent on the dimensions of each ground and can vary greatly.

2. Just the individual images don‟t help too much; for the system to be of practical use, one must ensure that it can track the 3D trajectory of the ball with high precision. In order to get this accuracy, the field of view of each camera should be restricted to a small region – this means one needs more cameras to get the coverage of the entire field.

3. Fielders and spectators might obstruct the camera‟s view of the ball and the ball might get „lost‟ in its flight in one or more of the cameras. The system should be robust enough to handle this, possibly by providing some redundancy.

4. The ball might get confused with other similar objects – for instance, with flying birds or the shadow of the ball itself. The image processing techniques used need to take care of these issues. Luckily, there are techniques which are easy to implement and are well known to the Image Processing community on the whole, to take care of these.

5. To help in judging LBW calls, the system needs to be made aware of the style of the batsman – whether he is right or left handed. This is because the rules of LBW are dependent on the position of the stumps and are not symmetrical about the middle stump. Thus, the system needs to detect whether a particular ball has pitched outside the leg stump of a batsman or not.

6. To determine the points at which the ball makes contact with the pitch, the batsmen or other objects is very hard. This is because we don‟t really know these spots beforehand and the model and the real pictures taken by cameras need to be merged to give such a view.

CHAPTER 4

WORKING

We will see how the HAWKEYE technology successfully treats each of these issues and provides a robust system to be used in practice. The top-level schematic picture of the system and its various parts is as shown below (each colour represents a block of steps which are related):

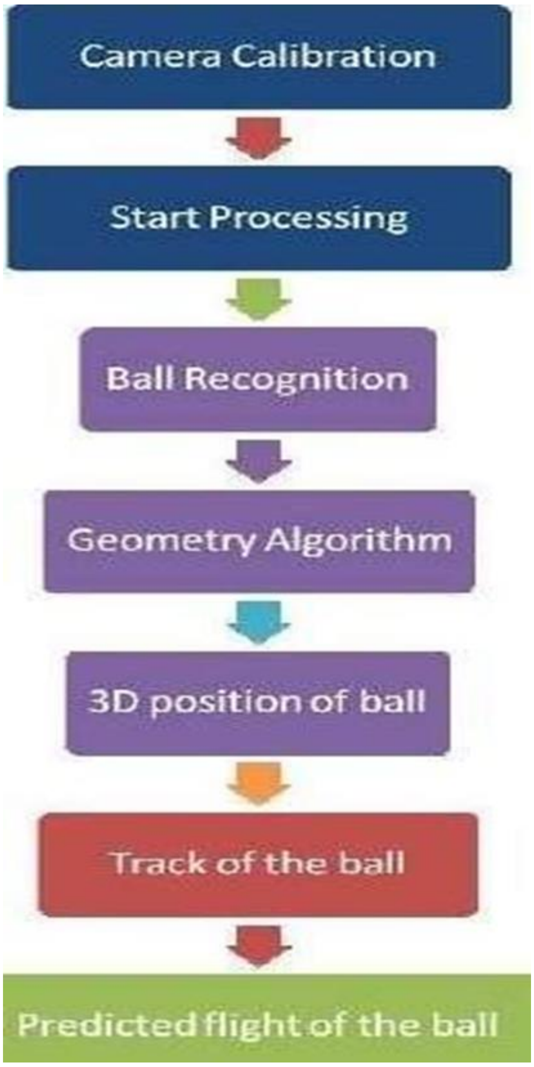

Fig 4.1 Hawk-eye flow diagram

The figure above shows precisely the steps that are involved in the computation. The process is started with some calibration of the cameras. This is required to deal with the problem raised in 1 above, about the non-uniform distance of the cameras from the playing area. After this basic calibration is done and the system is up and running, we can start processing the video input which we get from the cameras. In each of the images obtained, the first aim is to find the ball init. Once this is done, a geometric algorithm is used to look at multiple images (which are 2D) and then combine them cleverly to get the co-ordinates of the ball in 3D 10 space. This process is now repeated for multiple times every second (typically at the rate of 100 times per second). Thus, we have the position of the ball in 3D space at many moments in every second. The final step is to process these multiple positions and find a suitable fitting curve which best describes the flight of the ball.

As we have sampled the positions of the ball at very short time intervals, the flight of the ball can be very accurately determined. A description of the exact algorithms involved in the entire process will be skipped here. We instead try to give an intuitive description of each step in great detail, so as to give the reader a feel of what goes into the system, without plunging into the gory details.

CHAPTER 5

TECHNICAL DETAILS

In this section, we go into the technical details of the steps involved in the HAWKEYE system. The process, as done before, can be broken down into the following steps (we will divide the process into these seemingly disjoint steps so that it is easy to explain the details, however many of the steps are overlapping):

5.1 The cameras

Typically, for a cricket field, 6 cameras are used. These cameras are placed around the field at roughly the places as indicated in the diagram below:

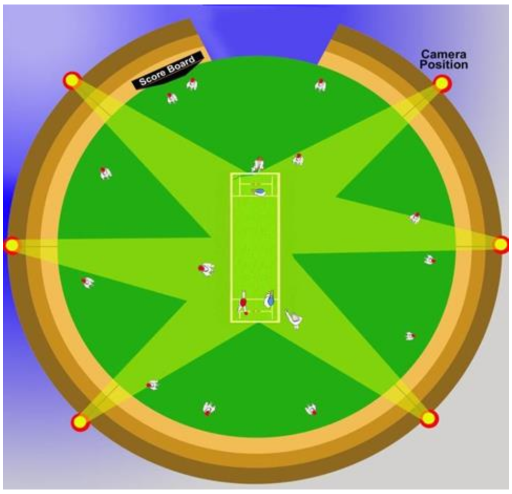

Fig 5.1 Camera setup

As one can see, the 6 cameras in use are positioned at roughly 60 degree from each other. They are placed high in the stands, so that there is lesser chance of their view being blocked 11 by the fielders. There are two cameras, one each looking at the wickets directly in sideways fashion. These 6cameras are calibrated according to the distance they are at from the pitch. In order to get good accuracy, one needs to restrict the view of each camera to a smaller region. This means each camera image would show a more prominent picture of the ball and hence the ball will be located more accurately. However, we also need to keep in mind that the whole field of play has to be covered by just the 6 cameras which are available. This puts some limitation on how restricted the view of a camera can be. Nevertheless, the accuracy obtained by using 6 cameras is acceptable to the standards prevalent today.

Some further setting up is essential for the system to work correctly. The cameras need to be fixed to some frame of reference, which is defined very conveniently in terms of the wickets on the pitch, and the line joining them. This is useful when we want to use an automated program to merge images from different cameras to form one 3D image.

5.2 Preparation before starting to process

Additional features might be loaded into the system to enable it to process the data in a more reliable and useful manner. These might include a statistical generator, which is used to produce statistics based on the data collected. These are the statistics which we see on television during and after the match for analysis. Such statistics can also be used by teams and players to study their game and devise strategies against their opponents. Indeed, the raw data about the paths of the ball might be too much for any human to digest and such statistics turn out to be easier to handle and understand. The statistics generator might also aid in storing data such as the average velocity of the ball. This data is crucial as it can help the ball detection algorithm to predict the rough location of the ball in an image given the position in the previous image. Such considerations are useful to reduce the computations involved in the processing of the data collected from the video cameras. Once such additional machinery is setup correctly, we are all set to start collecting data and start processing it to churn out 12 tangible statistics and visualizations. It might be noted at this stage that there is some more information which might be required to process the data correctly. We will point out such things at later points in the paper, where it fits in more appropriately.

5.3 Colour Image Processing Job

An algorithm is used to find the pixels corresponding to the ball in the image obtained. The information which is used in order to achieve this is the size and shape of the ball not on its color. A blob detection scheme can be used to detect around object in the image. Blob detection methods are aimed at detecting regions in a digital image that differ in properties, such as brightness or color, compared to surrounding regions. Geometric Algorithm is used to look at multiple images and then combine them cleverly to get the coordinates of ha ball in 3D.

CHAPTER 6

PRINCIPLE OF HAWK-EYE

6.1 Triangular Method

Triangulation is a process of determining the location of a point by measuring angles to it from either end fixed at baseline rather than measuring distances to the point directly.

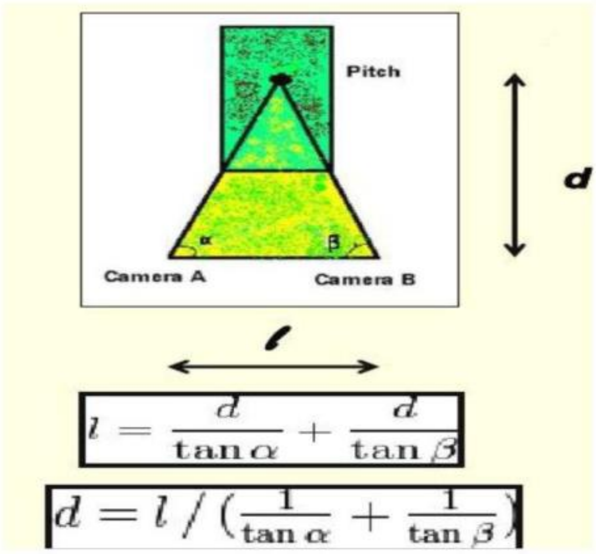

Fig 6.1 Triangulation

Let us consider the simple case in which we assume the cameras to be mounted at ground level, positioned with their vision parallel to the ground. We wish to get information about the 3D position of the ball from the positions (x1,y1) and (x2,y2) obtained by resolving the ball from 2D images from Cameras 1 and 2 shown in the image below. The ball is actually at the position shown by the red circle, at some height above ground.

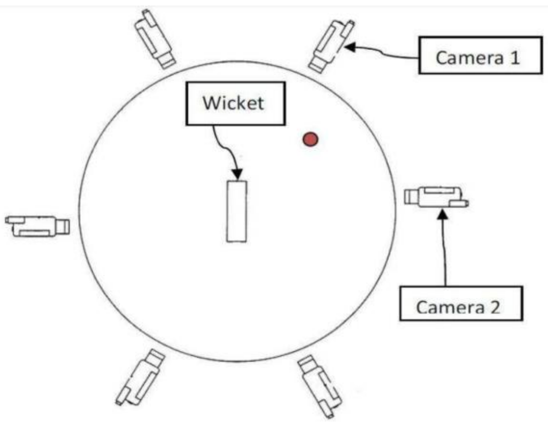

Fig 6.2 Ball position

The view in the cameras will look something like the one shown below. The view below shows the picture as seen by Camera 2 in the figure above.

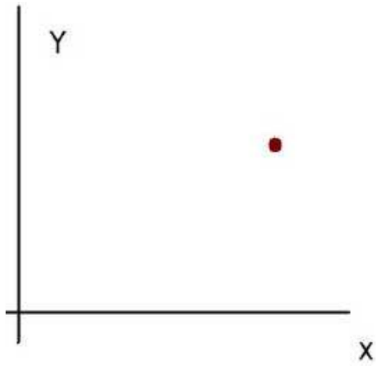

Fig 6.3 Camera 2 result

In this simplistic scenario, the height of the ball above the ground is given directly by the y co-ordinate in the images, y1 and y2.Both these values should ideally be equal, but we might want to take the average in case they are not exactly equal. Now, the one parameter we need to determine is the depth of the ball as measured by Camera 2. Once we have that information, we will have all the data to infer the position of the ball in 3D space with respect to the pitch. Note that we know the positions of the cameras with respect to the pitch in advance. Let us assume that the radial angle, as seen from the wickets marked in the figure, between Camera 1 and Camera 2 is θ and the radius of the field is. Then, the depth of the ball as seen from Camera 2 is as follows: Depth = $r-(r \cos(\theta) + x1|\sin(\theta))$.

Thus, we see that knowing the co-ordinates of the ball in two cameras, we can get the position of the ball in 3Dspace with respect to one of the cameras and thus, with respect to the wickets. In the realistic case, the cameras are mounted high above the ground and thus, finding the height of the ball above the ground is not as trivial as it was here. One needs to rotate the axis correctly in order to do the calculations that were simple here as it concerned only planar geometry. In real life, cricket grounds are not perfectly circular and hence even that has to be taken into consideration. We do not go into those details here, but just note that it is standard mathematics to get the 3D co-ordinates of the ball given the information in two images.

The Geometric Algorithm described with the help of an example above provides us with a ready recipe to find the 3D position of the ball in space. We just use this method and as a result, now have the position of the ball as captured at that instant, in 3D space, with respect to any of the reference points we had considered while setting up the system

CHAPTER 7

APPLICATIONS

7.1 Cricket

In Cricket, It is indeed very helpful in making crucial decisions which might otherwise become very difficult to predict. For instance, the decision of Leg before wicket has been one of the most crucial ones and is indeed very difficult to determine, but this beautiful technology judges it based on the following three criteria:

1. The position where the ball is pitched.
2. The area of contact along the leg of the batsman.
3. The traced path of the ball before the batsman.

So, in this very way, bowlers can highly benefit from it and it can even change the entire momentum and scenario of the match. Well, the benefits are not only limited to the bowler, but batsmen also have their piece of cake. Because, with the help of the analysis of records, they can get a very clear view of all the balls faced by them and many other parameters, like the speed of the ball, crucial hits, etc can be judged which will make the batsmen proud of their strike and ready for the upcoming challenges.

7.2 Tennis

Tennis no doubt is one of the most popular and expensive sports in the world, so every ball hit by the racket counts a lot. And yes, almost everyone will agree to me on the fact that one of the most difficult to judge the situation in this aport is to determine whether the ball hit by any of the players is inside the line or not, as a small error in making this decision can even cause a match or even championship, or even a major championship to the other player, and that is indeed just like catching up Corona while staying completely locked down within the four walls of the room. But thankfully, this sharp technology does justice to this issue, and unlike Cricket, 10 highly powerful cameras are used in the Tennis court, so that the dropping of the ball can be measured accurately. And not only this, but it is also employed for broadcasting in some of the tennis events.

7.3 Football

The most popular and crazy sport is also impressed by this majestic technology and so it has also employed it. We know that it is very difficult as well as very important to track the proper path of ball towards the goal in order to confirm whether it is a goal or not. The hawk-like sharp cameras leave no room for queries and complaints when it comes to tracking those adrenaline rushing shots by Ronaldo, Messi, or any other great star of this sport. With the help of this technology, one can verify whether the ball has crossed the goal line in its aerial flight or by making contact with the ground. Not only this, the judgement of line crosses that result in a throw, goal kick, corner, and much more can also be done.

7.4 basketball

Basketball is also not far behind and Hawkeye technology has also given its green signal for employing this cool technology. In Basketball, the most goosebumps giving moments are of the last 2 minutes and that very time is judged using it. The last two minutes are carefully inspected and reviewed using this mesmerizing technology as the super cameras record every possible action of the game, so it becomes very easy to determine the final outcome of the match. And also, it also helps to check if any basket was made after the time is up, as it could change the entire scenario of the match.

CHAPTER 8

ADVANTAGES & DISDVANTAGES

8.1 Advantages

1. Hawk-Eye technology allows match authorities to take a blunder free decision.

2. Hawk-Eye has eliminated the uncertainty of the players and onlookers about the decision of the match referee.

3. Officials can take decisions quickly during the game itself, rather than later in retrospect.

4. Help players to study their past games and Improve

8.2 Disdvantages

1. It is highly expensive.
2. It is not 100% accurate.
3. It slows down the game to allow for review and taking of the decisions whenever required.
4. Like any technology it can fail
5. There can be bugs (for example saying in when showing a ball is out)

CHAPTER 9

FUTURISTIC ASPECTS

Sony Electronics Returns to NAB Show In-Person and Virtually with Updates Focused on Imaging, IP, Cloud and Visualization Workflows. Sony Electronics is proudly unveiling and showcasing a broad range of products and services, to empower broadcast, to cinematic and live event content creation. These innovations align with leading industry trends in the Imaging, Internet Protocol (IP), Cloud and Visualization realm.

The future of hawk- eye technology looks bright as it has been used in various applications in a very short duration after its introduction. For eg: use of goal line technology has been proposed in football

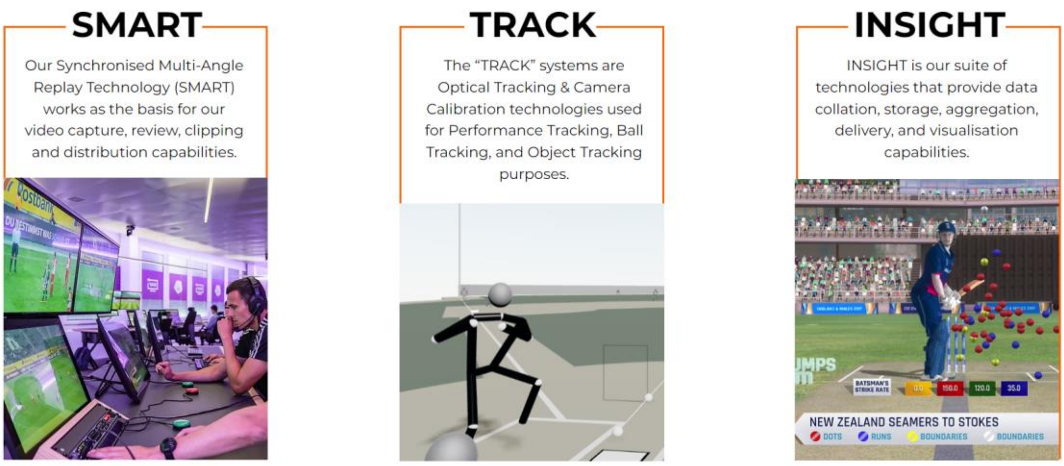

Fig 9.1 Three integratable anchor technologies

CHAPTER 10

CONCLUSION

We have looked at various aspects of the HAWKEYE technology. Initially, we outlined the main problems which one could encounter while trying to implement such a system for a sport like cricket. Then, we looked into the details of each step of the process which finally gives us the wonderful looking graphics that we see on TV during cricket analysis shows. We got a fair understanding of the algorithms and mathematics which goes into the system. With the help of examples, we looked at the applications which the technology finds in modern day sport, with cricket being our main focus. We got an understanding of how the graphics can be produced, using the setup, which also was described in detail. We have thus seen that the HAWKEYE is a great innovation, which puts technology to good use in the field of sports. The technology is used widely these days, in sports such as Tennis and Cricket. The accuracy which can be achieved with the use of the system is making the authorities think seriously about reducing the human error component involved in important decisions. As the system runs in real time, there is no extra time required to see the visualizations and graphics. The system is also a great tool which can be used by players, statisticians, tacticians, coaches to analyze previous games and come up with strategies for subsequent ones.

CHAPTER 11

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By: Bal Singh Baljinder, Dureja Gaurav DOI: 10.2478/v10237-012-0006-6