Investigating Video Compression Technique using H.265 and its Effectiveness in Maintaining Perceptual Quality: A Review

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Abstract— **With the abundant rise of demand of multimedia streaming, the sizes of the multimedia files are encountering increasing difficulties while streaming on existing network using conventional video compression technique e.g. H.263 and H.264. Hence, very recently, H.265 or commonly known as High Efficiency Video Coding (HEVC) has been introduced to overcome the issues that couldn't be practically mitigated by H.263 and H.264. The prime purpose of HEVC is to mitigate the bandwidth problem while streaming heavier multimedia files as it has got exceptional compression capability. However, due to novelty, HEVC is yet to discover its effectiveness with respect to retention of perceptual quality of Ultra High Definition (UHD) or commonly known as 8K in current era and its significant impact on traffic behaviour will need to be analyzed. Hence, this paper discusses about the conventional H.264 and then introduces H.265 and discusses about all significant literatures in past addressing such issues with a purpose of extracting research gap. The manuscript introduces the reader about HEVC and analyzes the extent of research contribution in past to mitigate the compression issues by highlighting the most common techniques used for compression.**

Keywords-component; H.265, H.264, HEVC, Compression, 4K, 8K, UHD

I. INTRODUCTION

In recent decades there is an incredible growth in the online video watching over the Internet and also in wireless handheld devices [1][2]. The high bit rates that result from the various types of digital video make their transmission through their intended channels very hard. Even entertainment video with modest frame rates and dimensions would require bandwidth and storage space far in excess of that available. Video compression is used in many existing and emerging products. It is the heart of the digital television set-top boxes, DSS, HDTV decoders, DVD players, Video conferencing, Internet videos and other applications. These applications benefit from video compression in the fact that they may require less storage for achieved video information, less bandwidth for the transmission of the video from one point to another or a combination of both.

Video compression or video encoding [3] is the process of reducing the amount of data required to represent a digital video signal, prior to transmission or storage. The complementary operation, decompression or decoding, recovers a digital video signal from a compressed representation, prior to display. Digital video data tends to take up a large amount of storage or transmission capacity and so video encoding and decoding, or video coding, is essential for any application in which storage capacity or transmission bandwidth is constrained. High-Efficiency Video Coding (HEVC) is currently the newest video coding standard of the ITU-T Video Coding Experts Group (VCEG) and the ISO/IEC Moving Picture Experts Group (MPEG). The main goal of the HEVC standardization effort is to enable significantly improved compression performance relative to existing standards – in the range of 50% bit rate reduction for equal perceptual video quality [4]. HEVC promises to reduce the overall cost of delivering and storing video assets while maintaining or increasing the quality of experience for the viewer. Essentially, these are the two benefits of HEVC in the streaming space. The first relates to encoding existing SD and HD content with HEVC rather than H.264, enabling cost savings and/or the ability to stream higher quality video to lower bitrate connections. The second relates to opening up new markets for ultra-high-definition (UHD) videos. This research proposal discusses about the retention of higher quality of video file and traffic management when a video is compressed using HEVC over wireless mobile network. HEVC was designed to substantially improve coding efficiency compared to H.264/MPEG-4 AVC HP, i.e. to reduce bitrate requirements by half with comparable image quality, at the expense of increased computational complexity. HEVC was designed with the goal of allowing video content to have a data compression ratio of up to 1000:1. Depending on the application requirements HEVC encoders can trade off computational complexity, compression rate, robustness to errors, and encoding delay time. Two of the key features where HEVC was improved compared to H.264/MPEG-4 AVC was support for higher resolution video and improved parallel processing methods [5].

This paper reviews the existing standards and extracts the substantial flaws in existing protocols (H.264) in performing video compression in Section 2. Section 3 discusses about the fundamentals of H.265 with its potential features discussed in Section 4. Section 5 discusses about the cumulative study with in-depth analysis of effectiveness of some of the significant contributions in the past. Finally the research gap is briefed in Section 6 followed by conclusion in Section 7.

II. EXISTING STANDARD

AVC (Advanced Video Coding) is a video compression format, and is currently one of the most commonly used formats for the recording, compression, and distribution of video content. The final drafting work on the first version of the standard was completed in May 2003.

H.264/MPEG-4 AVC is a block-oriented motion-compensation-based video compression standard developed by the ITU-T Video Coding Experts Group (VCEG) together with the ISO/IEC JTC1 Moving Picture Experts Group (MPEG) [6]. The project partnership effort is known as the Joint Video Team (JVT). The ITU-T H.264 standard and the ISO/IEC MPEG-4 AVC standard (formally, ISO/IEC 14496-10 – MPEG-4 Part 10, Advanced Video Coding) are jointly maintained so that they have identical technical content.

H.264 is perhaps best known as being one of the video encoding standards for Bluray Discs; all Bluray Disc players must be able to decode H.264. It is also widely used by streaming internet sources, such as videos from Video, YouTube, and the iTunes Store, web software such as the Adobe Flash Player and Microsoft Silver light, and also various HDTV broadcasts over terrestrial (ATSC, ISDB-T, DVB-T or DVB-T2), cable (DVB-C) and satellite (DVB-S and DVB-S2).

The recent video coding standard H.264 [7], part of an activity on-going since 1997 named H.26L, was developed by the Joint Video Team (JVT), an alliance formed by the former ITU-T VCEG and ISO MPEG-4 groups. This new standard is not application-specific, and performs significantly better than the available ISO MPEG-4 Part 2 standard [8] and ITU-T Recommendation H.263 [9] in terms of compression, network adaptation and error robustness. With the H.264 standard there is a back to the basics approach, where a simple design using well known block coding schemes is used. In the design of this codec, the Video Coding Layer was separated from the Network Adaptation Layer in order to enable a modular development of each of its components. Due to its general purpose nature, some mechanisms were included on both encoder and decoder envisioning enhanced performance in lossy environments, such as wireless networks or the Internet. By tuning certain parameters, the user can obtain a trade-off between compression rate and error resilience. The most commonly used methods to stop temporal propagation of errors when no feedback channel is available are the random intra macro block updating and the insertion of intra-coded pictures (I-frames). While intra frames reset the prediction process, avoiding error propagation, their use has a generally high bandwidth cost, causing also severe bit rate variations. The use of random intra macro block updating is more effective than I-frames because it not only aids in generating streams with more constant bit-rate, but can also provide better results by statistically resetting the error for each of the macro blocks. Another method which is sometimes used is called Flexible Macro block Ordering (FMO), whereby the sender can transmit macro blocks in non-scan order. This method, although similar to slice interleaving, provides greater flexibility and can be tuned to be more effective in terms of error resilience because of increased fine grain control on macro block ordering. It aims essentially at dealing with packet loss bursts by spreading errors throughout the frame, a process which eases the decoder's error-concealment task. Multi-frame prediction is another tool targeting to increase both compression performance and error-resilience. This is achieved by using more than one reference frame in the prediction process. As exposed in [10], this technique is particularly useful after the loss of a full frame when some of the previous reference frames are available, enabling partial motion compensation. Concerning the decoder, it plays a fundamental role in error resilience since it is responsible for error concealment tasks. With that purpose, it keeps a status map for macro blocks which indicates, for each frame being decoded, weather a certain macro block has been correctly received, lost or already concealed. The methods used vary between intra and inter frames. For intra frames, the task mainly consists of performing a weighted pixel averaging on each lost block in order to turn it into a concealed one. For inter frames, there is a process of guessing the adequate motion vector for lost macro blocks, although intra-style methods can also be used. For a more complete description of such methods please refer to [11].

III. ABOUT H.265

The High Efficiency Video Coding (HEVC) standard is the most recent joint video project of the ITU-T Video Coding Experts Group (VCEG) and the ISO/IEC Moving Picture Experts Group (MPEG) standardization organizations, working together in a partnership known as the Joint Collaborative Team on Video Coding (JCT-VC) [12]. The first edition of the HEVC standard is expected to be finalized in January 2013, resulting in an aligned text that will be published by both ITU-T and ISO/IEC. Additional work is planned to extend the standard to support several additional application scenarios, including extended-range uses with enhanced precision and color format support, scalable video coding, and 3-D/stereo/multiview video coding. In ISO/IEC, the HEVC standard will become MPEG-H Part 2 (ISO/IEC 23008-2) and in ITU-T it is likely to become ITU-T Recommendation H.265. Video coding standards have evolved primarily through the development of the well-known ITU-T and ISO/IEC standards. The ITU-T produced H.261 [13] and H.263 [14], ISO/IEC produced MPEG-1 [15] and MPEG-4 Visual [16], and the two organizations jointly produced the H.262/MPEG-2 Video [17] and H.264/MPEG-4 Advanced Video Coding (AVC) [18] standards. The two standards that were jointly produced have had a particularly strong impact and have found their way into a wide variety of products that are increasingly prevalent in our daily lives. Throughout this evolution, continued efforts have been made to maximize compression capability and improve other characteristics such as data loss robustness, while considering the computational resources that were practical for use in products at the time of anticipated deployment of each standard.

The major video coding standard directly preceding the HEVC project was H.264/MPEG-4 AVC, which was initially developed in the period between 1999 and 2003, and then was extended in several important ways from 2003–2009. H.264/MPEG-4 AVC has been an enabling technology for digital video in almost every area that was not previously covered by H.262/MPEG-2 Video and has substantially displaced the older standard within its existing application domains. It is widely used for many applications, including broadcast of high definition (HD) TV signals over satellite, cable, and terrestrial transmission systems, video content acquisition and editing systems, camcorders, security applications, Internet and mobile network video, Blu-ray Discs, and real-time conversational applications such as video chat, video conferencing, and telepresence systems. However, an increasing diversity of services, the growing popularity of HD video, and the emergence of beyond- HD formats (e.g., 4k×2k or 8k×4k resolution) are creating even stronger needs for coding efficiency superior to H.264/ MPEG-4 AVC's capabilities. The need is even stronger when higher resolution is accompanied by stereo or multi-view capture and display. Moreover, the traffic caused by video applications targeting mobile devices and tablets PCs, as well as the transmission needs for video-on-demand services, are imposing severe challenges on today's networks. An increased desire for higher quality and resolutions is also arising in mobile applications. HEVC has been designed to address essentially all existing applications of H.264/MPEG-4 AVC and to particularly focus on two key issues: increased video resolution and increased use of parallel processing architectures. The syntax of HEVC is generic and should also be generally suited for other applications that are not specifically mentioned above.

As has been the case for all past ITU-T and ISO/IEC video coding standards, in HEVC only the bit stream structure and syntax is standardized, as well as constraints on the bit stream and its mapping for the generation of decoded pictures. The mapping is given by defining the semantic meaning of syntax elements and a decoding process such that every decoder conforming to the standard will produce the same output when given a bit stream that conforms to the constraints of the standard. This limitation of the scope of the standard permits maximal freedom to optimize implementations in a manner appropriate to specific applications (balancing compression quality, implementation cost, time to market, and other considerations). However, it provides no guarantees of end-to-end reproduction quality, as it allows even crude encoding techniques to be considered conforming. To assist the industry community in learning how to use the standard, the standardization effort not only includes the development of a text specification document, but also reference software source code as an example of how HEVC video can be encoded and decoded. The draft reference software has been used as a research tool for the internal work of the committee during the design of the standard, and can also be used as a general research tool and as the basis of products. A standard test data suite is also being developed for testing conformance to the standard.

The video coding layer of HEVC employs the same hybrid approach (inter-/intrapicture prediction and 2-D transform coding) used in all video compression standards since H.261. Fig. 1 depicts the block diagram of a hybrid video encoder, which could create a bitstream conforming to the HEVC standard.

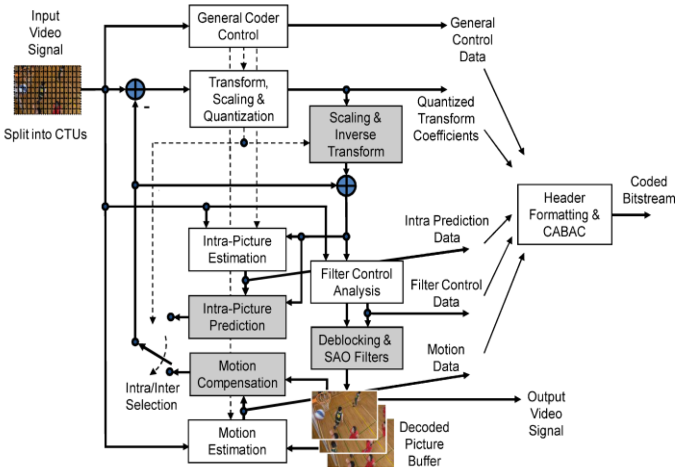

Figure.1: Typical HEVC video encoder (with decoder modeling elements shaded in light gray).

IV. FEATURES OF HEVC

The various features involved in hybrid video coding using HEVC are highlighted as follows:-

1) *Coding Tree Units and Coding Tree Block (CTB) Structure:* - The core of the coding layer in previous standards was the macro block, containing a 16×16 block of luma samples and, in the usual case of 4:2:0 color sampling, two corresponding 8×8 blocks of chroma samples; whereas the analogous structure in HEVC is the coding tree unit (CTU), which has a size selected by the encoder and can be larger than a traditional macro block. The CTU consists of a luma CTB and the corresponding chroma CTBs and syntax elements. The size $L \times L$ of a luma CTB can be chosen as L = 16, 32, or 64 samples, with the larger sizes typically enabling better compression. HEVC then supports a partitioning of the CTBs into smaller blocks using a tree structure and quad tree-like signaling [19].

2) *Coding Units (CUs) and Coding Blocks (CBs):*- The quad tree syntax of the CTU specifies the size and positions of its luma and chroma CBs. The root of the quad tree is associated with the CTU. Hence, the size of the luma CTB is the largest supported size for a luma CB. The splitting of a CTU into luma and chroma CBs is signaled jointly. One luma CB and ordinarily two chroma CBs, together with associated syntax, form a coding unit (CU). A CTB may contain only one CU or may be split to form multiple CUs, and each CU has an associated partitioning into prediction units (PUs) and a tree of transform units (TUs).

3) *Prediction Units and Prediction Blocks (PBs):*- The decision whether to code a picture area using inter picture or intra picture prediction is made at the CU level. A PU partitioning structure has its root at the CU level. Depending on the basic prediction-type decision, the luma and chroma CBs can then be further split in size and predicted from luma and chroma prediction blocks (PBs). HEVC supports variable PB sizes from 64×64 down to 4×4 samples.

4) *TUs and Transform Blocks*:- The prediction residual is coded using block transforms. A TU tree structure has its root at the CU level. The luma CB residual may be identical to the luma transform block (TB) or may be further split into smaller luma TBs. The same applies to the chroma TBs. Integer basis functions similar to those of a discrete cosine transform (DCT) are defined for the square TB sizes 4×4,

8×8, 16×16, and 32×32. For the 4×4 transform of luma intra picture prediction residuals, an integer transform derived from a form of discrete sine transform (DST) is alternatively specified.

5) *Motion Vector Signaling:-* Advanced motion vector prediction (AMVP) is used, including derivation of several most probable candidates based on data from adjacent PBs and the reference picture. A merge mode for MV coding can also be used, allowing the inheritance of MVs from temporally or spatially neighboring PBs. Moreover, compared to H.264/MPEG-4 AVC, improved skipped and direct motion inferences are also specified.

6) *Motion Compensation:-* Quarter-sample precision is used for the MVs, and 7-tap or 8-tap filters are used for interpolation of fractional-sample positions (compared to six-tap filtering of half-sample positions followed by linear interpolation for quarter-sample positions in H.264/MPEG-4 AVC). Similar to H.264/MPEG-4 AVC, multiple reference pictures are used. For each PB, either one or two motion vectors can be transmitted, resulting either in unproductive or bipredictive coding, respectively. As in H.264/MPEG-4 AVC, a scaling and offset operation may be applied to the prediction signal(s) in a manner known as weighted prediction.

7) *Intrapicture Prediction:-* The decoded boundary samples of adjacent blocks are used as reference data for spatial prediction in regions where inter picture prediction is not performed. Intra picture prediction supports 33 directional modes (compared to eight such modes in H.264/MPEG-4 AVC), plus planar (surface fitting) and DC (flat) prediction modes. The selected intrapicture prediction modes are encoded by deriving most probable modes (e.g., prediction directions) based on those of previously decoded neighboring PBs.

8) *Quantization Control:-* As in H.264/MPEG-4 AVC, uniform reconstruction quantization (URQ) is used in HEVC, with quantization scaling matrices supported for the various transform block sizes.

9) *Entropy Coding:-* Context adaptive binary arithmetic coding (CABAC) is used for entropy coding. This is similar to the CABAC scheme in H.264/MPEG-4 AVC, but has undergone several improvements to improve its throughput speed (especially for parallel-processing architectures) and its compression performance, and to reduce its context memory requirements.

10) *In-Loop Deblocking Filtering-:* A daglocking filter similar to the one used in H.264/MPEG-4 AVC is operated within the interpicture prediction loop. However, the design is simplified in regard to its decision-making and filtering processes, and is made friendlier to parallel processing.

11) *Sample Adaptive Offset (SAO):* A nonlinear amplitude mapping is introduced within the interpicture prediction loop after the deblocking filter. Its goal is to better reconstruct the original signal amplitudes by using a look-up table that is described by a few additional parameters that can be determined by histogram analysis at the encoder side.

V. EXISTING STUDY

This section briefly discusses about the most recent and significant contribution of the past researchers in mitigating the video compression techniques using H.265.

Zhao et al. [20] focused on the integration of two state of the art topics in video coding ¡ HEVC, which is the newly arrived video coding standard; and SSIM, which has recently become a top candidate to replace the traditional PSNR measure as the perceptual criterion in the evaluation and optimization of video codec’s.

Shraboni et al. [21] studied the performance of this mobile video telephony application. They model video quality as a function of input network parameters and derive a feed-forward Artificial-Neural-Network that accurately predicts video quality given network conditions ($0.0206 \leq MSE \leq 0.570$).

Persee [22] described the algorithms and the tools developed for the task 3 within the PERSEE project. The target of this task is to propose a new representation and encoding method of the “classical” (i.e. 2D) video signal, taking into account the perceptual quality of the reconstructed signal.

Cintra et al. [23] presented a very low-complexity DCT approximation obtained via pruning. The resulting approximate transform requires only 10 additions and possesses performance metrics comparable with state-of-the-art methods, including the recent architecture presented. By means of computational simulation, VLSI hardware realizations, and a full HECV implementation, they demonstrated the practical relevance of their method as an image and video codec.

Anjanappa et al. [24] observed that there is a slight improvement seen only for horizontal and vertical modes. The performance drop in most cases could be due to many reasons: Uses of non-integer transform coefficients which results in the decrease in accuracy of reconstructed output. The number of prediction modes is just 9 in case of H.264 and 33 in case of HEVC. The DCT/DST combinations are used for less number of prediction directions in the former case.

Capelo [25] focused on the study, implementation and assessment of a novel coding technique related to the important transform coding module, always present in the omnipresent predictive video coding architectures. With this objective in mind, the state-of-the-art on transform coding is reviewed and the adopted transform coding technique is presented. Since the adopted transform coding technique is intended for integration in the emerging HEVC standard, the new coding tools introduced by this video coding standard are also studied. Finally, a video coding solution using the adopted transform coding technique combined with the HEVC framework is developed, implemented and evaluated.

Table 1 Summary of Existing literatures for video compression

Authors	Problem Focused	Technique Used	Finding	Remark
Yang et. al.[34],[2014]	Resolution	Quality-efficient de-interlacing	Magnified sub-frames and PSNR	Couldn't achieve 8K resolution
Namuduri et. al.[35],[2014]	H.264 codec	Motion Activity and Motion Vectors	R-D analysis	Complex and higher bit-rate
Hannuksela et.al[36],[2013]	Advanced video coding	DIBR	Multi-view Video Coding	Higher complexity
Sze et.al.[37],[2013]	Throughput	CABAC encoding	Rate distortion and Throughput	Throughput is less
Dey [38],[2013]	Compression issue	SNMVM	Bit rate reduction	Still not sufficient for mobile phones
Ramalla et al.[39],[2013]	Quality of compressed video	LDPC codes	Quality(PSNR)	Reduced GOP percentage
Cai et al.[40],[2013]	Encoding Optimization	DCT	Bit-rate	Not completely optimized for wireless applications
Li et al.[41],[2013]	Perceptual video coding	Bit allocation strategy	EWPSNR	Other regions may suffered with less bits
Ohm et al.[42],[2012]	Compression comparison	JM 18.2 and HM 5.0	coding efficiency	HEVC performance is high than H.264
Dias et al.[43],[2009]	Multi-core H.264/AVC encoder	P.264	Bit rate saving	Required more hardware resources
Moshe et al.[44],[2009]	Motion estimation algorithm for h.264	Walsh–Hadamard projection kernels	Mean SAD per macro-block	Larger macro block is limited to 16x16

Bossen et al. [26] presented a complexity-related aspects that were considered in the standardization process are described. Furthermore, profiling of reference software and optimized software gives an indication of where HEVC may be more complex than its predecessors and where it may be simpler.

Lv et al. [27] described the derivations of fractional-pel interpolation filters in HEVC and H.264/AVC in detail, and compare them on properties of frequency responses. They find that the half-pel interpolation filters in HEVC and H.264/AVC are very similar, but the low-pass properties of quarter-pel interpolation filters in HEVC are much better than those in H.264/AVC.

Beltrao et al. [28] proposed a fast algorithm for estimating blocks directions before applying directional transforms. The encoder identifies predominant directions in each block, and only applies the transform referent to that direction.

Li et al. [29] illustrated an intra frame compression scheme for high quality depth images. The scheme is based on lossless coding of edge-contours, uniform sparse sampling and smooth in painting. The goals are to retain the inherent distribution of depth images with good quality, and to investigate the quality of rendered views in comparison to state of the art compression methods.

Hu et al. [30] presented a new coding tool called Edge Mode is proposed for HEVC intra coding, aimed at improving coding efficiency for screen content video. A set of edge modes that correspond to edge positions are identified based upon intra prediction directions. Then, a simplified scheme is developed to select the best edge mode.

Stankowski et al. [31] illustrated the accumulation of distortion caused by multiple encoding and decoding of the same material with constant QP value has been investigated. The main observation is that quality loss introduced by multiple encoding and decoding saturates after several cycles. On average, after 40 encoding-decoding cycles the quality losses and bitrate changes are negligible.

Hu et al. [32] elaborated on the video source model and compare the performance of the newest high performance video codec, the High Efficiency Video Codec (HEVC/H.265), to their rate distortion curves.

Laude et al. [33] proposed reference picture filtering in the context of scalable video coding. Thereby, they assume a system with two layers, one layer is the high quality enhancement layer (EL), the other layer is called base layer (BL) and is a (2×vertically and horizontally each) downscaled version of the EL. Given that their adaptive filters can be derived implicitly based on BL information no signaling of coefficients or indices is needed. Table 1 gives further more studies that has also attempted to mitigate the issues of video compression, however the limitations of the existing system can be seen in the table itself.

VI. RESEARCH GAP

After reviewing the literatures discussed in the previous section, following research gaps are explored.

- As HEVC is a new protocol published in last year (2013), so at present, no standard and potential studies exist in literature archival.
- The implementation of HEVC encoders claims to attain the 50% of better compression as compared to H.264 in video-on-demand (VoD) applications. However, this evidence is yet to find in the literatures as majority of the literatures uses VLSI hardware. However, no computational model is found to evaluate the HEVC standard till date.
- Very few work was found to adopt HEVC on wireless mobile networking platform to check the efficiency of HEVC algorithm and its potential to mitigate the loading impact of dynamic traffic system (especially in wireless environment).
- A closer study pertaining to retention of perceptual quality of 8K video with less download time and optimized bandwidth is required while attempting to stream on 3G network is required as currently the literatures doesn't provide any evidence for any solution against such issues

CONCLUSION

The current trend in video consumption clearly shows that the already large quantity of video material distributed over broadcast channels, digital networks, and packaged media is going to increase in the coming years. Though H.264 is succeeded in providing a good motion picture in Television, High Definition Television (HDTV), and Full High Definition Television and even to web based applications. But it requires higher bit rate and hence it is failed to deliver high definition videos to mobiles and to tablets. H.265/HEVC has a new reference picture set (RPS) concept for the management of reference pictures. Whereas preceding standards signaled only relative changes to the set of reference pictures (making it vulnerable to missing a change due to lost/corrupted packets), H.265/HEVC signals the (absolute) status of the set of reference pictures. Similarly, H.265/HEVC improved error resilience through a new video parameter set (VPS) concept for signaling essential syntax information for the decoding. Referring to the research gap from previous section VI evidently proves that the domain requires to be further more investigated as standard benchmarked is not yet reached in this field of study. Hence, this fact lays the basic foundation of motivation to carry out the research work.

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