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Embedded approach for a Riemannian-based framework of analyzing 3D faces

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Abstract— **Developing multimedia embedded applications continues to flourish. In fact, a biometric facial recognition system can be used not only on PCs abut also in embedded systems, it is a potential enhancer to meet security and surveillance needs. The analysis of facial recognition consists offoursteps: face analysis, face expressions' recognition, missing data completion and full face recognition.**

This paper proposes a hardware architecture based on an adaptation approach foran algorithm which has proven good face detection and recognition in 3D space. The proposed application was tested using a co design technique based on a mixed Hardware Software architecture: the FPGA platform.

Keywords—Facial analysis, face detection, Facial expressions, 3D face recognition, embedded architecture, elastic analysis algorithm, Riemann geometry, Curve analysis

I. INTRODUCTION

One of the main reasons of designing multimedia embedded applications is the lack of resources and the variation of the external conditions such as noise.

As a challenging multimedia embedded application, we focus on designing an automatic facial recognition system. In fact, it has many advantages compared to other biometric analysis. In recent years, the optimized facial recognition has witnessed a flurry of research interest in cyber community. Compared to 2D recognition, the 3D one has more than one advantage, but itsweakness is still the imperfections of digitalized facesand the changes of facial expression. Recently, one interesting approach of 3D face analysis is focused on changes in facial expressions while the presence of occlusions or a relatively small data are missing.

In this paper, we detail in a first time a complete framework of analyzing Riemann facial shapes [1] whose target is to handle large events, occlusions and missing parts. Henceforth, in a second step, we provide the basic tools for statistical analysis of the shapes in facial surfaces. Then, we present the proposed embedded platform and the different assessments applied to validate it.

The rest of this paper is organized as follows. Section 2 presents relate the different mathematical tools used in the used Riemannian framework and the brief overview of multimedia embedded applications. Section 3 presents the proposed hardware approach. In Section 4, we focus on the elasticity motivation of the applied framework. Experimental results are summarized in Section 5 .We close the paper with a conclusion in Section 6.

II. RELATED WORK

A significant attention in this part is kept to radial curves and elastic onessince the applied framework is based on radial facial curves studied using elastic shape analysis. The second part of related works talks about embedded systems. Nowadays, the embedded applications evolution makes multimedia implementation easier. That's why we will present a state of art of different used approaches and platforms.

A. MOTIVATION OF RADIAL curves

The algorithms derived from the analysis of curves and shapes are very sophisticated so every efficient changes in facial expressions affect different areas of a facial surface differently. For example, during a smile, the upper half of the face is relatively unchanged while the lip areas change much, and when a person is detected, the effect is often the opposite. If they are appropriately selected, the curves have the potential to capture regional forms and that is why their role becomes important. The location of shapes represented by the facial curves is an important reason for their selection

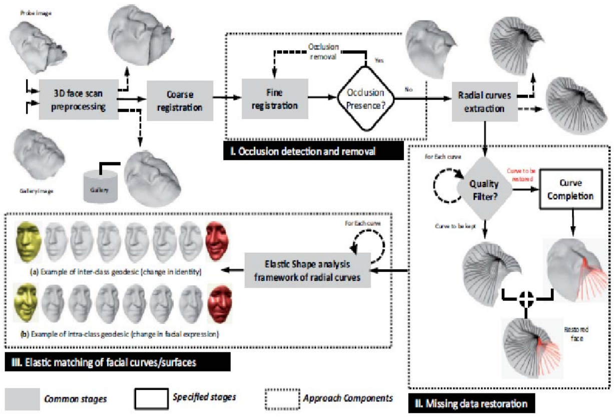

Fig1: overview of the proposed method

However, the radial curves with the originpoint have enormous potential due to the nose is in many ways the focal point of a face. It is relatively easy and effective to detect the nose tip (compared to other parts of the face) and extract radial curves, with the tip of the nose as the center, in a completely automated fashion. It is much more difficult to automatically extract other types of curves, such as those used by the designers (the outlines of the cheeks, the borderline between the eyes and the front head, etc.) Different radial curves pass through different regions and hence, may be associated with different facial expressions. For example, the difference between the shapes of the radial areas in the half top of the face can be vaguely assigned to intergroup variability, while for the curves passing between the lips and cheeks may be largely due to changes in the expressions.

B. *Riemannian Geometry*

The recent years have seen the development of several approaches to describe the shapes of the 2D curves. We can mention, the approaches based on Fourier descriptors, or those based on time and based on the central axes. However, none of these methods has been able to describe the shape of the curves conceptually orin cyber technologypoint of view. A very recent and promising approach is to consider the space shapes as a full geometry that resembles a Riemannian manifold on which we can use the “classic”tools of the Riemannian geometry. Recent updates from Michor and Mumford [1] and Klassen and al. [2] in the case of plane curves show a powerful performance from this approach. Joshi and al. [3] recently proposed a generalization of this work to curves defined in Rn.

C. *Presentation of Curves in R3*

We suppose the facial curves (levels and radials) are curves in R3. Their settings are β: S1 → R3, assuming that the curve is non-singular, in other words ‖ β (t) ‖ ≠ 0 for all t, the standard used herein is the Euclidian norm known by R3 ‖ ‖ Note that the settings of the curves are in a curvilinear abscissa . To analyze the shape of the curve β, we use SRVF (Velocity Square Root Function) function setting:

$$q(t) \doteq \frac{\dot{\beta}(t)}{\sqrt{\|\dot{\beta}(t)\|}} .$$

With q (t) as a special feature that captures the form of β The classic elastic metric to compare the form.

D. *Radial Curves Analysis in R3*

We define the set of open curves {βα} in R3 by βα

$$\mathcal{C} = \{q : I \to \mathbb{R}^3 | \|q\| = 1\} \subset \mathbb{L}^2(I, \mathbb{R}^3)$$

$$\mathbb{L}^2(I, \mathbb{R}^3)$$

The metric on the tangent space C becomes a Riemannian manifold. In particular, the elements of C have a single standard L^2, C is a hyper sphere in Hilbert space L^2 (I, R3). In order to compare the shapes of two radial curves, we calculate the distance between them in C with the selected metric. This distance is defined as the length of the geodesic connecting the two points in C. C is a sphere, the geodesic path and its length can beanalytically calculated. The geodesic distance between any two points q1, q2 ∈ C is given by:

$$d_c(q_1, q_2) = cos^{-1}(\langle q_1, q_2 \rangle) ,$$

And the geodesic path α: [0, 1] → C, is given by:

$$\alpha(\tau) = \frac{1}{\sin(\theta)} (\sin((1-\tau)\theta)q_1 + \sin(\theta\tau)q_2)$$

It is easy to see that several elements of C can represent different curves of the same shape. Alas, although the shape of a 3D face does not change after a rotation in R3, the SRVFs functions change. Another similar situation arises when the settings of the curve is readjusted again, the readjustment change SRVF of the curve, but not its shape. To manage this variability, we define the orbits of the rotation group SO (3) and readjust the settings of group £ as equivalent classes in C. Here £ is the set of guidelines that preserve diffeomorphism I and the elements of £ are considered asthe settings readjustment function.

E. *Multimedia Embedded Applications*

The evolution of microelectronics and embedded platforms makes the multimedia embedded applications easier to develop and to implement on platforms.

The codesign techniques are very relevant in the domain of embedded system. To find an adequacy between Hardware implementation and Software application become an important part for embedded system.

Embedded systems is a mixture between Hardware platforms represented by a SoC such as FPGA, ARM, ASIC … and an adequate Software used to make easier

The design of embedded systems usually results from a trade-off between antagonist constraints, which are related to design cost, chip area, power consumption, and real-time or high QoS considerations.[4]

The embedded systems are required in many applications domains. From multimedia application such as augmented [5] and virtual reality [6] to network domain [7]

From industrial and military use to health [4] and medicine domains the embedded systems and adaptation techniques take place.

This paper is presented as an implementation of Riemannian algorithm on an FPGA platform.

III. ELASTICITY MOTIVATION

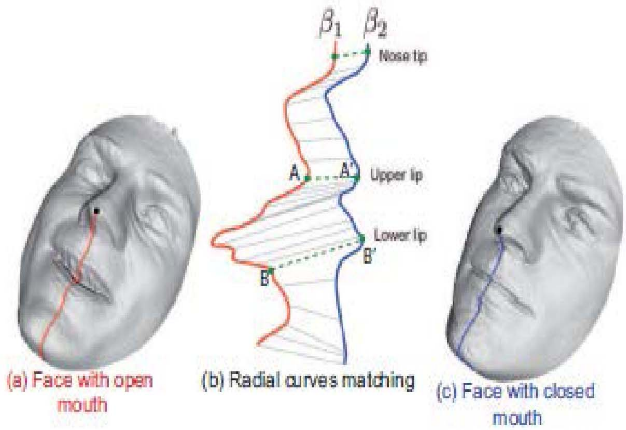

Fig 2*: example of matching radial curves extracted from two sides of the same person:*

Consider the two parametric curves shown in Figure 2; named β1 and β2. Our task is to automatically match points on these radial curves related to two different facial expressions. The facial expression on the left has an open mouth while in the facial expression on the right the mouth is shut. To compare their shapes, we must save points thanks to these curves. We would like to have a matching geometric features through the curves as much as possible. In other words, the lips should match the lips and chin must match the chin. Clearly, if we force a setting adjustment and an arc length connection points that have the same distance from the starting point, then the matching result will not be optimal. Points A and B on β1 do not match points A'and B' on β2 as they are not placed at the same distances along the curves. For the curves, the problem of optimal recording is actually the same as the optimal setting readjustment. This means that we need to find a readjustment function γ (t) so that the point β1 (t) is registered with the point β2 (γ (t)) for all t. The question is how to find an optimal β1 from γ and β2? From random. Keep in mind that the space of all these yS has infinite dimension because it is the function space. This recording is accomplished by solving an optimization problem using the dynamic programming algorithm, but with an objective function that is developed from a Riemann metric. Thechosen metric, called an elastic metric, has a special property that the same setting readjustment of two curves does not change the distance between them. Alas, allows us to set the readjustment of a random curve and to optimize over the tuning of the other. This optimization leads to a good distance (geodesic distance) and optimum deformation (geodesic) between the shapes of the curves.

Screen the quality of the curve:

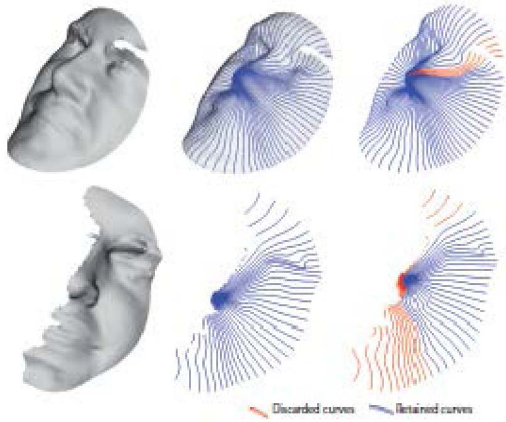

Fig 3: Curve quality filter: broken and short curves detection examples

Involving non-frontal 3D scans, some areas may be partially hidden due to the self-occlusion. Using these curves in the face recognition can seriously degrade the recognition performance and, therefore, they must be identified and discarded. To detect rejected curveswe introduced a quality filterthat uses the continuity and the length of the curve. A curve should be a continuous piece and have a certain minimum length, say 70mm, to pass the quality filter. Discontinuity or shortage in a curve leads to either missing data or a big noise. Once the quality filter is applied and the high qualitycurves are selected, we can perform the face recognitionoperation using only the remaining curves. Let β represents a curve of the face, we define the Boolean function quality (quality (β) = 1) if β passes through the filter and (quality (β) = 0) otherwise. Recall that during the preprocess step, there is a provision phase to fill the holes. Sometimes the missing parts are too large to be filled accurately using linear interpolation. For this reason, we need the quality filter that isolate and eliminate the curves associated with these parts.

IV. EMBEDDED APPLICATION CONFIGURATION

As presented, we propose an approach based on embedded adapted architecture. As mentioned for the application, the complexity of the algorithm and the use of multiple comparisons between configurations allow to use two architectures.

A. *Microblaze or Power PC architecture*

Using Xilinx ML 507 platform, we proposed monoprocessor architecture. Two possibilities can be used: Power PC (PPC hardcore processor) architecture or Microblaze processor architecture.

1. Microblaze processor architecture:

The Microblaze is a Softcore. Working on a frequency of 150 MHz. The proposed architecture contains accelerators that compare the recognition using Riemannian framework. The complexity of the algorithm takes the accelerator heavy in slices number and the execution as long as the software one. To try to improve this approach we implement the same work using Power PC processor.

2. Power PC processor architecture

The Power PC is a Hardcore. Working on a frequency of 400 MHz. Using the same architecture than Microblaze we obtain a result 25% better. This result is due to the processor frequency and the use of the FSL buses that are faster than PLB one used with the Microblaze.

In spite of this result, the use of the embedded single processor architecture is not useful with the two ML 507 processors.

B. *ARM architecture*

To validate this approach, we try this monoprocessor implementation using the ARM processor that exists on the Zynq platform of Xilinx. The ARM A9 processor existing on the Zynq platform is tested with the same accelerator to know if it is better to implement monoprocessor architecture than software one or not.

A comparison between software implementation using a Embedded Linux software and the mixed HW/SW application is proposed.

V. EXPEIMENTAL RESULTS AND DISCUSSION

In this part of the paper, we present the different experimental results assessed to validate the proposed Riemannian framework.

A. *Profiling analysis*

Alignment between the probe and the gallery. This situation occurs if the face is partially blocked by external

Table 1: Comparison of Recognition results for different methods on GavaBDB.

	Lee [9]	Moreno [10]	Maboor [11]	Haar [12]	Mosawi [13]	Our applied method
Neutral	*96.67 %*	*90.16%*	-	-	-	*100%*
Expressive	*93.33 %*	*77.9%*	*72%*	-	-	*94.54%*
Netural + Expressive	*94.66 %*	-	*78%*	-	*91%*	*95.9%*
Rotating looking down	-	-	*85.3%*	-	-	*100%*
Rotating looking up	-	-	*88.6%*	-	-	*98.36%*
Overall	-	-	-	*98%*	*81.67%*	*96.99%*
Scans from right side	-	-	-	-	-	*70.49%*
Scans from left side	-	-	-	-	-	*86.89%*

As mentioned in Table1, a comprehensive summary of the results is obtained in GavaBDB help. It is clear that the adopted method outperforms the most approaches in recognition rate. Note that there is no prior literature result on 3D face recognition using secondary analyzes from this database.

B. *Implementation results:*

The analysis is done on two architectures:

• Arch 1: SOC: single-processor MicroBlaze or PowerPC

• Arch2: ARM architecture

We conducted the following identification experiences: FRGCv2 is the protocol that collects scans and keep them in a gallery. The first (466 scans) and the rest are saved in the database. We obtained 98.02% recognition rate in rank-1 which is competitive compared to the previous methods.

Table 2: Illustration of different approaches and their effectiveness.

Methods	Based on curves		Based on selection features	
	Haar [12]	Berreti[14]	Wang [9]	Haar[12]
Rank-1	97%	94.1%	98.3%	97.2%
Applied method	98.02%			

Table 2 shows the results ofprevious recognition approaches (based on curves, based on selectionfeatures and others). Using a combination of curves (levels and radial) selected using the developed system, the proposed algorithm gives a higher performance compared to most of previous approaches. Wang et al. [8] obtained the best result 98.3%, this means that their approach has recognized ten faces more than our approach. Calculated on the Map Shape Difference between faces.

Table 3: Illustration of performances analysis and timing of all curves compared to selected curves

Performances	ALL		Selected	
	Row-1*	Time(s)	Row-1*	Time(s)
Radials	88.65%	1.6	89.04%	0.48
Levels	66.51%	1.04	85.65%	0.20
Fusion	91.81%	2.64	98.02%	0.68

C. Embedded application results:

The previously proposed algorithms are simulated on the Xilinx Zynq and Xilinx ML 507 platforms.

1. Xilinx ML 507 implementation results :

In Table 4, we proposed the algorithm used fusion with selected curves implemented on SW, HW/SW on PPC and HW/SW on Microlaze.

Table 4 : Comparison of obtained results

Proposed approach	Execution time
SW	1.215 s
HW/SW using Microblaze	1.205 s
HW/SW using PPC	0.911s

As mentioned previously, the implementation of a mixed architecture is not adequate because it consumes so much energy and the obtained gain is not enough important to implement only one processor system.

2. Xilinx Zynq implementation results :

In Table 5, we proposed the algorithm used fusion with selected curves implemented on SW, HW/SW on ARM A9.

Table 5 : Comparison of obtained results

Proposed approach	Execution time
SW	1.003s
HW/SW using ARM	0.981 s

The HW/SW using an only one processor does not present an important gain to be used. To remedy to this problem, it is better to use multiprocessor architectures.

VI. CONCLUSION

The ever increasing multimedia applications opens new challenges when considering the fact of designing the corresponding embedded system. Nevertheless, the complexity of the multimedia application has an impact on finding an efficient application quality.

In this paper, we presented a framework for statistical shape analysis of facial surfaces. We provide some obtained results on 3D facial recognition system designed to manage and adapt to changes in the facial expressions, pose variations and occlusions between gallery and probe scans. Then we present the co design of this adopted application, its implementation and some experimental tests assessed to validate it. To improve this work an approach based on multiprocessors architecture will be proposed for the future works. Using a multiprocessor architecture based on ARM processors we will propose the best HW/SW architecture to improve the implementation of elastic analysis algorithm in 3D facial recognition using the Riemannian Algorithm.

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