UDC 004.932.2

# IMAGE INVARIANT RECOGNITON METHODS IN THE SPACE OF PROJECTIONS

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Image recognition methods based on invariant features of projections are investigated. Influence of geometrical distortions on Radon space is shown, systems of invariant features for recognition based on Radon transform and classical moment invariants are suggested. Computer modeling results on the real images are shown.

*Keywords: Radon transform, projection, invariant features, moment invariants, recognition.*

## INTRODUCTION

Artificial intelligence applications in the tasks of the automatic image processing, analysis and pattern recognition attract greater attention of researchers. It can be explained by the development of computer technologies, which enables the decision of complex practical problems, related to the image analysis and interpretation [1]. Solution of similar tasks often becomes difficult because of external influences, different background and local covering by noise components. One of methods, which can avoid these problems is Radon transform (RT), that presents an image as a set of projections [1-3]. The advantages of this method are the high level of Radon transform features informing, good noise immunity (because of integral properties), as well as rapid realization possibility of projections processing [3-6]. Mostly RT (or its separate projections) is the base for the subsequent invariant feature systems construction. The known approaches, which use RT, need improvement from the point of view of necessity of influence transform estimations, sufficient quality recognition provision and features construction for the variety of practical applications.

The purpose of this paper is the development of invariant pattern recognition methods with changeover to the space of one-dimensional projections.

## 1. INFLUENCE OF IMAGE GEOMETRICAL DISTORTIONS ON RADON TRANSFORM

The research of distortions influence on Radon transform gives the possibility of corresponding mathematical models construction for their compensating with the purpose of reaching invariance. We will designate $a_1, a_2$ as image movement parameters along coordinate axes, $\varphi$ – is the rotation corner, $\alpha, \beta$ – are scaling parameters. We consider traditionally, that geometrical transforms do not bring image brightness function outside the range $D$ of its definition. The essence of RT consists in the integration of image brightness function $B(x, y)$ along lines under different projecting corners $\theta \in \Theta$, that can be formally written down like:

$$R(p,\theta) = \int_x \int_y B(x,y)\delta(p - x\cos\theta - y\sin\theta)dxdy ,$$

where $p$ – is the distance from the center of coordinates to the fixed line which projecting is carried out, $\theta$ – is the rotation corner of coordinate axes. Recognition procedure can be properly written down as a sequence of input image reflections into the invariant feature system and further into one of reference etalons:

$$Rec: I \to B_E ,\ Rad: B \to I ,\ B_{input} : B_E \to B ,$$

where $Rec$ is a recognition operator, $Rad$ is Radon transform operator, $I = \{I_1, I_2, \ldots, I_k\}$ – is the system of invariant features, $B_E = \{B_1, B_2, \ldots, B_n\}$ – is the set of etalons, $B = \langle a_1, a_2, \varphi, \alpha, \beta \rangle$ – is an input image under the action of distortions or transforms.

The result of the most widespread geometrical transforms influence (movements, rotating and scaling) on RT $R(p,\theta)$ can be estimated as [4]:

$$R(p,\theta,a_1,a_2) = \int_{x'} \int_{y'} B(x',y')\delta(p - x'\cos\theta - y'\sin\theta + a_1\cos\theta + a_2\sin\theta)dx'dy' \quad (1)$$

$$R(p,\theta,\varphi) = \int_{x'} \int_{y'} B(x',y')\delta(p - y'\sin(\theta-\varphi) - x'\cos(\theta-\varphi))dx'dy' \quad (2)$$

$$R(p,\theta,\alpha,\beta) = \frac{1}{\alpha\beta}\int_{x'} \int_{y'} B(x',y')\delta(p - \frac{x'}{\alpha}\cos\theta - \frac{y'}{\beta}\sin\theta)dx'dy' \quad (3)$$

$$R(p,\theta,\alpha) = \frac{1}{\alpha}\int_{x'} \int_{y'} B(x',y')\delta(\alpha p - x'\cos\theta - y'\sin\theta)dx'dy' \quad (4)$$

where $B(x, y)$ and $B(x', y')$ – are initial and distorted images accordingly, $R(p,\theta,\langle P\rangle)$ – is the RT of the distorted image $B$ with parameters $\langle P\rangle$.

Under combination of rotating and movement transforms, we have an expression:

$$R(p,\theta,a_1,a_2,\varphi) = R(p + a_1\cos(\theta-\varphi) + a_2\sin(\theta-\varphi), \theta-\varphi)$$

For the combination of homogeneous scaling and moving, we get:

$$R(p,\theta,\alpha,a_1,a_2) = \frac{1}{\alpha}R(\alpha p + a_1\cos\theta + a_2\sin\theta, \theta) .$$

Under combination of homogeneous scaling and rotation transforms, we have:

$$R(p,\theta,\alpha,\varphi) = \frac{1}{\alpha}R(\alpha p, \theta-\varphi) .$$

In the most difficult situation with simultaneous presence of moving, rotating and homogeneous scaling, we have common formal expression like that:

$$R(p,\theta,\alpha,\varphi,a_1,a_2)=\frac{1}{\alpha}R(\alpha p+a_1\cos(\theta-\varphi)+$$
$$+a_2\sin(\theta-\varphi),\theta-\varphi).$$

## 2. INVARIANT FEATURE SYSTEMS

Combining of RT with the known invariant features construction methods (moment invariants, Fourier transform invariants etc.) based on one-dimensional projections processing makes it possible to speed up the recognition process. Let us consider the method of construction and comparison of invariant feature system based on RT and moment invariants.

In accordance with (1), image displacement comes over to displacement of each one-dimensional projection to the value of $a_1\cos\theta+a_2\sin\theta$ at fixed value of $\theta=\hat{\theta}$, in its turn, central moments $\mu_k$ of order $k$ are invariant to displacements. Thus, expressions like:

$$\mu_k=\int_{p'}(p'-\frac{m_1}{m_0})^k R(p',\hat{\theta})dp',\ m_0=\int_{p'}R(p',\hat{\theta})dp',$$
$$m_1=\int_{p'}(p'-a_1)R(p',\hat{\theta})dp',\ k=0,1,2,...$$

are invariant to displacements for all RT projections.

The systems of invariant features for other transform types we can build from ratio $I_k=m_k/(m_0)^z$, where $m_k=\int_p p^k R(p,\hat{\theta})dp$, $m_0=\int_p R(p,\hat{\theta})dp$ with fixed $\hat{\theta}$ parameter. Here $z$ parameter provides a scale-invariance in accordance with (3), (4). Taking into account properties of RT and (4) we have:

$$m_0=\int_{p'}\frac{1}{\alpha}R(p',\hat{\theta})\frac{1}{\alpha}dp',\quad m_k=\int_{p'}(\frac{p'}{\alpha})^k\frac{1}{\alpha}R(p',\theta)\frac{dp'}{\alpha}.$$

Making substitution of $m_0, m_k$ values in expression for $I_k$, we will get $z=(k+2)/2$. As a result, the invariant features system to combination of homogeneous scaling and moving looks like:

$$I_k^{\alpha,a_1,a_2}=\mu_k/(\mu_0)^{\frac{k+2}{2}}. \qquad (5)$$

In the more general case in operations of heterogeneous scale changing with parameters $\alpha$ and $\beta$ it is suggested to use the system on the basis of expressions $M_k/(m_0)^z, M_k=\int p^k(R(p,\hat{\theta}))^z dp$ like this:

$$I_k^{\alpha,\beta,a_1,a_2}=\int_p(R(p,\hat{\theta}))^{k+1}(p-\frac{m_1}{m_0})^k dp/(\mu_0)^{k+1}. \qquad (6)$$

As we can see, ratios (5) and (6) are based on separate projections of RT only. At the same time, the rotation influence results in displacement of projections space (that follows directly from (2)). For the features construction in case of rotating presence it is possible to fix the $p=\hat{p}$ value and use a few projections of image. We will notice, however, that the use of complete projection information for all $p$ values in this case is more justified because of greater noise immunity level. Invariant systems in conditions of moving, rotating and scaling presented simultaneously can be constructed as:

$$I_k^{\alpha,\varphi,a_1,a_2}=\int_{\theta\in\Theta}I_k^{\alpha,a_1,a_2}(\theta)d\theta,$$
$$I_k^{\alpha,\beta,\varphi,a_1,a_2}=\int_{\theta\in\Theta}I_k^{\alpha,\beta,a_1,a_2}(\theta)d\theta. \qquad (7)$$

Experimental error of the (7) system is about 3-4%.

The method of construction and comparison of image invariant features systems based on RT and moment invariants consists of the following stages: RT implementation; $m_k,\mu_k,M_k$ functionals determination; calculation of required invariant values (5)-(7) depending on the type of transforms; pattern values matching based on selected proximity measure.

## 3. EXPERIMENTAL RESULTS

Research of quantitative parameters of recognition quality was made on the test sets of binary images [5, 6] and images of the real scenes. Average probability of recognition (at the amount of templates in a database from 10 to 30 size of 64x64) in the conditions of transforms is from 0.9 to 1.0 with recognition time using the only projection of about 0.4 sec.

Experimental research of the suggested recognition methods have been carried out on the example of a vehicle license plate images (fig. 1). Because of rotation distortion absence a system of (6) features was used, time of single character processing was about 0.12 sec. (including segmentation, selection, invariant features construction and searching in the database). Size of etalon database contained 279 images (16 font types of size 36), value of binary threshold was equal to 149 and was found in the interactive mode.

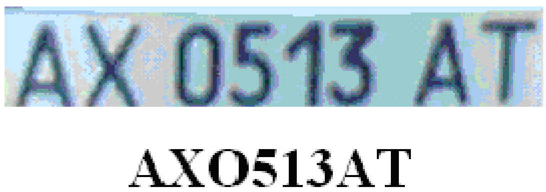


Fig. 1. Example of license plate recognition

Fig. 2 shows an example of invariants type (6) usage for the solution of a news feed updating time on a website recognition task. Suggested method can be realized on the basis of training or self-training for recognition of a great number of classes of objects on different types of images.

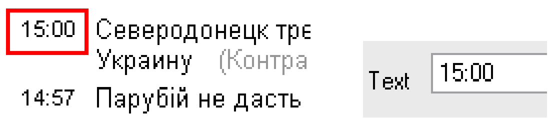


Fig. 2. Example of updating news time recognition

## CONCLUSION

Application of Radon transform and its functional processing allow to build the systems of effective invariant features, suitable for visual objects recognition on images. Change-over to the space of one-dimensional projections allows to improve the speed parameters in comparison to the systems of classic two-dimensional processing [4]. Analysis of several projections can increase reliability of recognition procedure and noise immunity of invariant features. Experimental research confirmed efficiency of suggested methods for solution of real computer vision tasks [5, 6].

The scientific novelty of the paper are suggested methods of construction and comparison of image invariant features system based on the space of projections and moment invariants which give an opportunity of properties flexibly managing in the recognition system (speed performance, noise immunity, accuracy level, number of invariants) with engaging additional projection information into the process.

Research prospects are related to the construction of suggested methods modifications in case of local type noise influences.

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УДК 004.932.2


**Методы инвариантного распознавания изображений в пространстве проекций** / А.В. Гороховатский // Прикладная радиоэлектроника. 2010. № 4. С. 00–00.

В статье исследуются методы инвариантного распознавания образов на основе проекционных признаков. Показано влияние геометрических искажений на радоновский образ. Предложены системы инвариантных признаков для распознавания на основе преобразования Радона и классических моментных инвариантов. Приведены результаты компьютерного моделирования на реальных изображениях.

*Ключевые слова: преобразование Радона, проекция, инвариантные признаки, моментные инварианты, распознавание.*

Табл.00. Ил.02. Библиогр.: 06 назв.


УДК 004.932.2


**Методи інваріантного розпізнавання зображень в просторі проекцій** / О.В. Гороховатський // Прикладна радіоелектроніка. 2010. № 4. С. 00–00.

В статті розглянуто методи інваріантного розпізнавання зображень на основі проекційних ознак. Наведено вплив геометричних викривлень на радонівський образ. Запропоновано системи інваріантних ознак для розпізнавання із використанням перетворення Радона та класичних моментних інваріантів. Наведено результати комп’ютерного моделювання на реальних зображеннях.

*Ключові слова: перетворення Радона, проекція, інваріанті ознаки, моментні інваріанти, розпізнавання.*

Табл. 00. Іл. 02. Бібліогр.: 06 найм.