

Motion Signalling Solutions for Cycling Jacket

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Abstract – The prototype of cycling belt has been drawn up with LED stop signals, which are activated by the accelerometer placed in the central back pocket. The results of approbation have shown that the sensor does not provide the proper functioning of signals, due to a high level of riding movements.

Using Motion Capture technology and bicycle exercise equipment, the research of oscillation of anthropometric points on the back has been carried out. The accelerometer should be placed between scapulae to design the cycling jacket.

Furthermore, the research of choice and integration of light emissive elements has been carried out.

Keywords – accelerometer, motion capture, wearable electronics.

I. INTRODUCTION

Due to a fast-rising number of cyclists, the safety problems of cyclists become topical [1]. The cyclist's visibility can remarkably be improved by integrating not only the light reflective, but also light emissive elements (LEDs, electroluminescent strips and wires) in the cycling suit (Fig. 1).

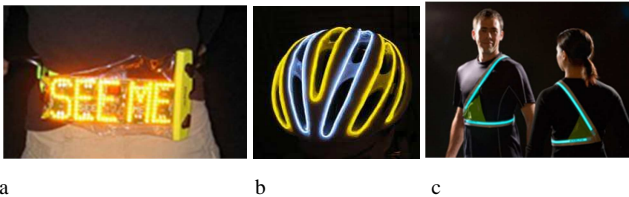


Fig. 1. Light emissive elements in the cycling suit: a – a belt with LED text [2], b – a bicycle helmet with EL wire [3], c – a cycling sash with EL strips [4]

The prototype of cycling belt (Fig. 2) with pockets and light emissive elements has been developed within the framework of the present research. The principle of the belt – while the cyclist rides at a constant speed or is at rest state, the LEDs flash, but when the cyclist is braking the LEDs light up instantly (like brake lights), which are activated by a signal coming from the sensor (accelerometer), placed in the central back pocket (Fig. 3).

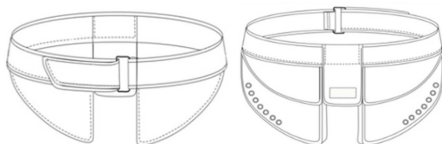


Fig. 2. Front and back of cycling belt

The approbation has proven that the sensor (placed on the back of the belt) does not provide the proper functioning of stop signals, due to the high level of additional movements of a cyclist during the riding. In this case, it is unacceptable.

The garment with a light signal indicating system has already been created; respectively, the jacket with turn direction identification signals that are activated by motion sensors and stop signals – activated by the accelerometer [5]. It is also placed in the lower back, like in the drawn up cycling belt.

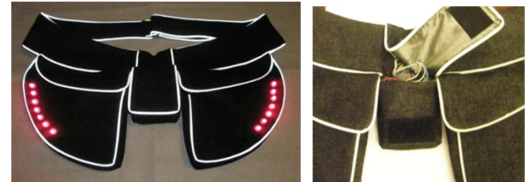


Fig. 3. Back of cycling belt prototype and central back pocket

The research of oscillation of the anthropometrical points on the back has been carried out to clarify the most appropriate placement of accelerometer for the design of cycling jacket (Fig.13). Within the framework of the research, bicycle exercise equipment for cycling imitation and Optical Active Motion Capture technology have been used [6].

Motion Capture technology consists of several types, therefore it has become quite popular in biomechanics [6]. The technology is used for bicycle fitting (e.g. distance between the saddle and the handlebar, the distance between the pedals) for the rider and also for optimization of positions of rider's body extremities, therefore improving riding technique, reaching better results and avoiding injuries of joints and muscles [7, 8].

Some studies include research of motion of separated body parts depending on their positions and conditions, e.g., pelvis motion or thorax during sustained cycling [9, 10].

II. EXPERIMENTS

A. Motion Capture

The goal of the research is to identify the least mobile point of the back during riding a bicycle at different speeds and in 2 positions of the bodice (Fig. 4). Position a – hands are on the lower part of the handlebars and position b – hands are on the upper part of the handlebars.

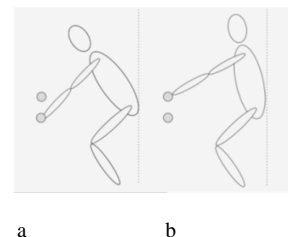


Fig.4. The slopping positions of bodice: a – hands are on the lower part of the handlebars; b – hands are on the upper part of the handlebars

The motion capture technology has been used in the study. The digital cameras of the installed system record the movement of anatomical points in 3 dimensions [11]. To record the motion, markers (small spheres, which are detected with infrared cameras) have been placed and attached to human anatomical points of the body (Table 1).

Six infrared light cameras send an infrared beam (120 Hz) and detect reflection of spherical markers (Fig. 5). The motion trajectories of the back points in 3 dimensions have been registered, and coordinates in time of reflective markers have been calculated.

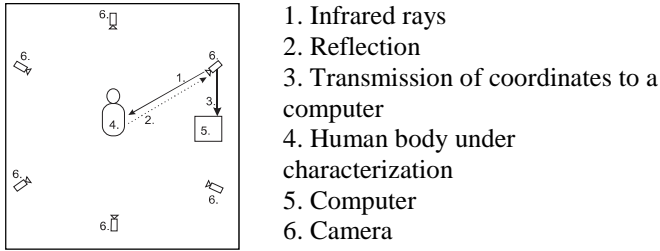


Fig.5. Placement of cameras according to the human body and principle of action of the system

B. Stages of Experiment

14 infrared ray reflective markers have been attached to definite points (Table I) of the back (Fig. 6). The points have been marked with numbers and letters according to the points, which are used in construction of clothing.

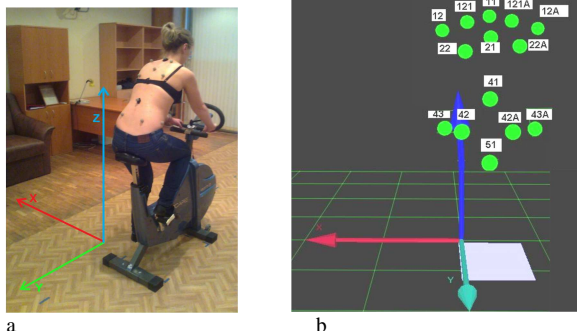


Fig.6. Placement of the markers; axis of coordinates and markers in real (a) and virtual (b) environment

TABLE I
MARKING AND EXPLANATION OF MARKERS

No.	Markers	Placement of the point
1.	12, 12A	Shoulder part of scapula
2.	121, 121A	Upper corner of scapula
3.	11	Cervical vertebra c7
4.	22, 22A	Lower edge of scapula
5.	21	Thoracic vertebra t3
6.	41	Lumbar vertebra l2
7.	43, 43A	Edge of ilium on the middle line of armpit
8.	42, 42A	Edge of Ilium on the line of scapula
9.	51	The middle point of sacrum

Cycling equipment has been prepared for the experiment: the height of the saddle and handlebars have been regulated

according to the parameters of the human body. The load of pedalling has been adjusted and test ‘rides’ have been made.

Eight experimental ‘rides’ have been made at different speeds and in two slopping positions (A and B) of the body. Each ‘ride’ lasted 10 seconds. Conditions of the experiment can be seen in Table II.

TABLE II
CONDITIONS OF THE EXPERIMENT WITH CYCLING EQUIPMENT

No.	Position	Speed, km/h	Time, s
1.	A	15	10
2.	A	20	10
3.	A	25	10
4.	A	increasing from 15 to 30	10
5.	B	15	10
6.	B	20	10
7.	B	25	10
8.	B	increasing from 15 to 30	10

Using special software and cameras, each coordinate in time of the markers has automatically been registered and calculated, and visualized on the monitor of the computer (Fig. 6, b).

C. Data Processing

During the experiment it has been noticed that markers 42, 43, 42A, 43A, placed on the lower part of the back, have greater amplitude of motion than other markers. Therefore, these points have been excluded from the further calculations.

Total amplitude of acceleration of each marker (2) has been clarified, when minimal and maximal values of total acceleration have been identified.

The component of acceleration (1) of motion point in the definite direction is the derivation of component of speed, or the second derivation of corresponding coordinate [12]:

$$\frac{d^2x}{dt^2} = a_x, \quad (1)$$

- where a_x –x component of the acceleration;
- a_y – y component of the acceleration;
- a_z – z component of the acceleration;
- t –time (s);
- v_x – x component of the velocity;
- v_y – y component of the velocity;
- v_z – z component of the velocity.

Absolute value of acceleration is:

$$a_{total} = \sqrt{a_x^2 + a_y^2 + a_z^2}, \quad (2)$$

where a_{total} – the module of total acceleration.

Table III presents the calculation of total acceleration of marker with code 12, increasing speed from 15 to 30 (km/h).

TABLE III
THE CALCULATION OF TOTAL ACCELERATION OF MARKER 12 (INCREASING SPEED FROM 15 TO 30 KM/H)

No.	x, cm	v _x , m/s	a _x , m/s ²	y, cm	v _y , m/s	a _y , m/s ²	z, cm	v _z , m/s	a _z , m/s ²	v, m/s	a _{total} , m/s ²
1.	20.79	0.31	-0.26	352.32	-0.03	-0.001	1397.75	0.09	0.01	0.32	0.26
...
2400.	5.27	-0.52	0.21	340.21	-0.25	0.04	1399.49	0.14	0.04	0.59	0.22
min			-0.90			-1.58			-1.41		0.002
max			0.92			1.58			1.24		2.14
min - max			1.82			3.16			2.65		2.14

III. RESULTS

The lowest amplitude of acceleration in position A (Fig. 7) at different speeds is characteristic of markers 22, 22A, 21, but the largest – of markers 121, 121A, 12A.

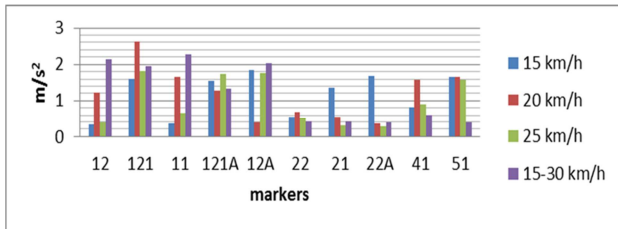


Fig. 7. Amplitude of total acceleration of markers in position A

The lowest amplitude of acceleration in position B (Fig. 8) at different speeds is characteristic of markers 11, 22, 22A, but the largest – of markers 12, 12A, 21, 51.

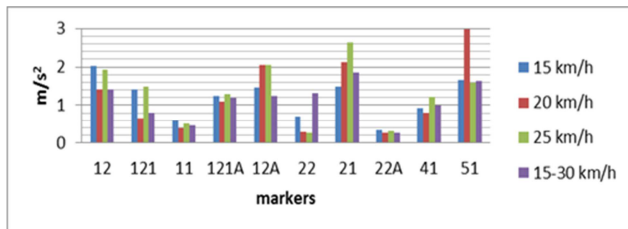


Fig. 8. Amplitude of total acceleration of markers in position B

Special attention has been paid to values of y axis coordinates and acceleration, as an axis with riding/braking direction. This data is important for programming and regulating the accelerometer. The lowest amplitude of acceleration in positions A and B at different speeds is characteristic of markers 22, 22A, 21 and 11 (Fig. 9, Fig. 10).

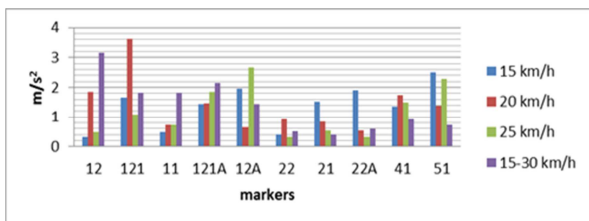


Fig. 9. Amplitude of total acceleration of axis y markers, in position A

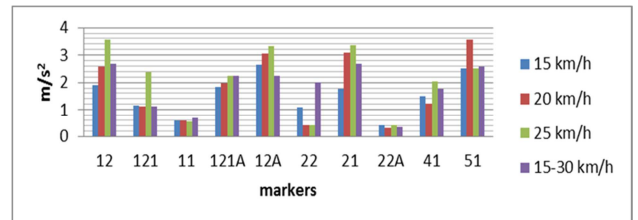


Fig. 10. Amplitude of total acceleration of axis y markers, in position B

IV. LIGHT EMISSIVE ELEMENTS

A. The Choice of Elements

Electroluminescent (EL) wire (Fig. 11) or optical wire has been designed to be integrated in the cycling jacket. Due to a small diameter and flexibility, these wires can be sewn up with a sewing machine or hand stitched. Despite these features, EL wire has been replaced with SMD (surface mount diode) strip. Firstly, it is better seen in the daytime and at night than the above-mentioned wire. A small difference is observed between switched on and switched off mode of EL wire in the daytime (Fig. 11). Secondly, the plain, flexible and isolated strip of surface mount diodes contains all necessary electronic components. Thirdly, connecting wires can be soldered to the ends of strip or in the middle part of strip. This process eases the integration of connecting wires in the construction seams of the jacket.



Fig. 11. Comparison of EL wire modes: in the daytime switched off (a) and switched on (b); at night switched on (c)

B. Integration of Light Emissive Elements

For the integration of SMD strip, special tunnels (Fig. 13, b, Fig. 12, c) of the lower and upper parts have been designed. The lower part – fabric of the jacket and the upper part – transparent, braided or weaved ribbon or ribbons of synthetic fibres with width of 3.5 cm, in red or yellow colour (Fig. 12, a, b).

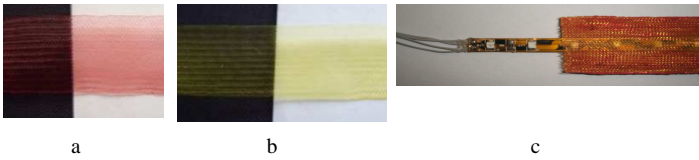


Fig. 12. Red (a) and yellow (b) braided ribbon; SMD strip placed in the special made tunnel of ribbons (c)

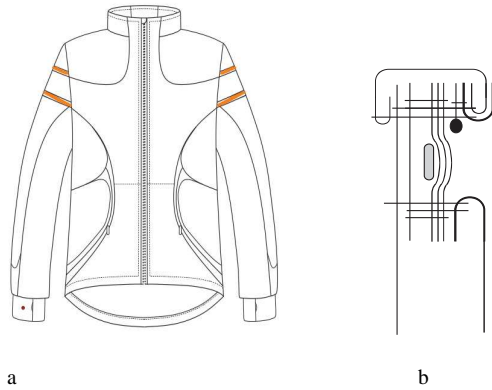


Fig. 13. Front of cycling jacket (a) and the designed tunnel with SMD strip integration in the jacket (b)

The main functions of the ribbons are the following: to be the component of tunnel and to disperse the light coming from the SMD strip inserted in the tunnel.

The goal of this part of the research has been to define the type and number of layers of ribbon for better light dispersion and for protection against the eyes to be dazed, using bright red and yellow SMD strips.

C. Experiment

To conduct the experiment, it has been necessary to use one red and one yellow SMD strip, three types of synthetic ribbons, dark (black) fabric for background and camera for taking photos.

The ribbons with code numbers shown in Table IV have been attached to the black background thereby making a tunnel, where a red or yellow SMD strip has been inserted and photos taken.

TABLE IV
CODING AND EXPLANATION OF RIBBONS

Code number of ribbon	Structure	Colour of ribbon
1	Braided	Red
2	Braided	Yellow
3	Weaved	Red

The tunnels have been made of single, double and triple layers of ribbons; for example, code number 1 means one layer of ribbon, 11 means two layers on the same ribbon. Table V shows the photos (without flash) taken in dark using the same configuration of settings of the camera.

Comparing the photos, it is obvious that the light is better dispersed using triple layered tunnels and corresponding colour. It means that the light is better dispersed, when yellow SMD strip light is covered with triple layers of yellow ribbon, and similarly when a red light is covered with red layers of ribbon.

SMD spot of lights, which are covered with three layers of braided ribbon, appears in square shape (see Table 5, row 3, 6). It is caused by the fact that the yarns of braided ribbon are positioned at an angle of 45 degrees to the horizontal. But those that are covered with weaved ribbon appear in the shape of circle (Table V, row 9, 10). The reason is that the yarns are positioned at an angle of 90 degrees to the horizontal.

TABLE V
CODING AND EXPLANATION OF RIBBONS

No.	Code of ribbon	SMD strip	
		Red	Yellow
1.	1		
2.	11		
3.	111		
4.	2		
5.	22		
6.	222		
7.	3		
8.	33		
9.	333		
10.	312		

DISCUSSION AND CONCLUSIONS

The goal of the study has been to detect the points of the back, whose periodical motions, during the pedalling, minimally influence the readouts of accelerometer and allow them, without disturbances, to define the changes in speed in the riding direction of bicycle. Experimental researches demonstrate that the motion dynamics of markers depends on the position of the bodice and riding speed. It's proved with marker 21 (amplitude of total acceleration and amplitude of total acceleration of axis y), small oscillations in position A, increased – in position B (Fig. 7, Fig. 8). Therefore, the most suitable place for accelerometer is the body point 21 or 11, or between them.

From the point of view of the clothing construction these points are acceptable, as they can be placed on the back central seam. The sensor can be easily integrated, placing it on seam allowances (sensor parameters 10 x 15 x 2 mm). The detail (-s) of clothing upper part of the back is less influenced by deformation (Fig. 14).

In terms of safety, considering anthropometric features, the sensor at this place (marker 21) is less influenced mechanically, as there is concavity between scapulae. For example, putting on a rucksack, the sensor will not be damaged.

Red and yellow SMD strips have been chosen for integration as light-emissive elements because of their brightness and flexibility of connection with wires.

To disperse bright light of diodes and facilitate the integration of light strips, special tunnels have been made with dispersion layers of ribbons. Triple layered tunnel disperse light better than double and single layered tunnels.

Depending on the density and position of yarns in the ribbons, the light disperses in the shape of a square or circle.

Fig. 14 demonstrates the draw up cycling jacket with yellow turn direction signals and red stop signals, activated by the accelerometer.



Fig. 14. Front and back of the cycling jacket

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Marianna Grecka, Ausma Viļumšone, Juris Blūms, Zane Pavāre. Kustību signalizēšanas risinājumi velobraucēja jakā

Līdz ar velosipēdistu skaita palielināšanos, rodas nepieciešamība palielināt drošību aktīvajā satiksmes plūsmā. To iespējams risināt, integrējot gaismu izstarojošos un atstarojošos elementus velobraucēja apģērbā. Iepriekšējos pētījumos tika izveidota josta ar LED, kas signalizē par velobraucēja apstāšanos, ko nodrošina mugurdaļā esošā sensora (akselometra) signāls. Aprobējot jostu, konstatēts, ka sensora darbību traucē muguras lejasdaļas kustības, kas rodas braucot ar velosipēdu. Projektējot velobraucēja jaku ar līdzīgām funkcijām, tika veikts velosipēdistu muguras punktu svārstību pētījums, lai noskaidrotu vismazkustīgāko muguras punktu braukšanas laikā. Izmantots velotrenažieris (braukšanas imitācijai) un motion capture tehnoloģija, ar kuru tika fiksētas un aprēķinātas uz muguras izvietoto marķieru koordinātes laikā. Nosakot sensora izvietošanas vietu, secināts, ka atzīmēto ķermeņa punktu kustības dinamika ir atkarīga no cilvēka stāva noliekšanās pozīcijas un braukšanas ātruma. Vismazākās svārstības raksturīgas muguras punktiem, kas atrodas lāpstiņu līmenī, līdz ar to paštrinājuma sensors velobraucēja jakā ir jāizvieto posmā no mugurkaula kakla septītā un krūšu trešā skriemeļa. Risinot gaismu izstarojošo elementu integrēšanas iespējas velobraucēja jakā, elektroluminiscento un optisko vadu vietā tika izmantots sarkanas un dzeltenas SMD (surface mount diode) gaismas joslas, jo tās ir spilgtākas un ērtāk savienojamas ar vadiem. Izstrādāts SMD joslu integrēšanas veids. Sākuma stadijas integrēšana paredz tekstilmateriāla tuneļa izgatavošanu, kas sastāv no apakšdaļas (pamatdrāna) un virsdaļas (caurspīdīga sarkana, dzeltena pīta vai austa lente). Lai noskaidrotu tuneļa virsdaļas materiāla izkliedes īpašības, izpētītas 3 veidu lenšu gaismas izkliedes īpašības, variējot slāņu skaitu, savstarpēju kombināciju. Noskaidrots, ka labāk gaisma tiek izkliedēta zem 3 lenšu slāņiem, uz gaismas avota novietojot tās pašas krāsas lentes (sarkana gaisma pārklāta ar sarkanām lentēm). Lentes pavedienu savstarpējs novietojums nosaka gaismas izkliedes formu – zem pītās lentes gaisma izkliedējas kvadrāta formā, zem austas – apla formā.

Марианна Грецка, Аусма Вилумшоне, Юрис Блумс, Зане Паваре. Решение сигнализации движений для куртки велосипедиста

С увеличением числа велосипедистов возникают вопросы их безопасности в активном потоке транспортного движения. Это возможно решить с помощью интегрирования светоизлучающих и светоотражающих элементов в одежду велосипедистов. В предыдущих исследованиях был создан пояс с LED элементами, сигнализирующими при торможении велосипеда. Эту функцию обеспечивает сигнал сзади находящегося сенсора (акселерометра). Во время апробации пояса констатировано, что движения нижней части спины во время езды на велосипеде создают помехи для действия сенсора. Проектируя куртку с похожими функциями, было исследовано колебание различных точек спины велосипедиста, с целью выяснить наименее подвижную точку на спине во время езды на велосипеде. Был использован велотренажер (для имитации езды) и технология *motion capture*, с помощью которой зафиксированы и произведены расчеты координат маркеров размещенных на спине. Определив расположение сенсора на спине, констатировали, что двигательная динамика отмеченных точек на спине зависит от наклона торса человека и скорости езды. Наименьшие колебания маркеров отмечались в точках на уровне лопаток. Следовательно, сенсор ускорения оптимально разместить между седьмым шейным и третьим грудным позвонками. Исследовав возможности интегрирования в куртку светоизлучающих элементов, вместо электrolуминесцирующего и оптического провода были использованы легко соединяемые с проводами и более яркие светодиодные полосы SMD (*surface mount diode*) красного и желтого цвета. Разработан способ интегрирования в одежду световых полос SMD. В начальной стадии интегрирования диодных полос предполагает создание туннеля из текстильных материалов. Нижней частью является основное полотно, а верхней - прозрачная красная, желтая плетеная или тканая лента. Чтобы выяснить рассеивание света сквозь материал верхней части туннеля, во время исследований были использованы 3 вида лент с различными свойствами рассеивания света, а также меняя количество слоев лент и их комбинацию. Выяснено, что самое оптимальное рассеивание света создают 3 слоя лент, идентичного с диодами цвета (красный свет под красными лентами). Форму рассеянного света определяет расположение нитей ленты. Под плетеной лентой рассеивается в форме квадрата, а под тканой – в форме круга.