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ON EXISTENCE OF TAME HARRISON MAP

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ABSTRACT. We present here two new criteria for existence of a tame Harrison map of two formally real algebraic function fields over a fixed real closed field of constants. The first criterion (c.f. Theorem 2.5) shows that a square class group isomorphism is a tame Harrison map if it induces an isomorphism of the coproduct rings of residue Witt rings. The other result (c.f. Proposition 3.5) associates a tame Harrison map to an integral quaternion-symbol equivalence.

1. Introduction

The notion of Witt ring plays a central role in the algebraic theory of quadratic forms. It is natural to ask for criteria for the existence of an isomorphism of Witt rings. This subject has been studied by several authors for over 30 years (see e.g. [11], [2], [13], [14], [6], [5], [7]). One of the tools used here, called a *Harrison isomorphism*, is an isomorphism t of square class groups of the fields in question such that $t(-1) = -1$ and the element 1 is represented by a binary form $\langle f, g\rangle$ iff it is represented by $\langle tf, tg\rangle$. Any such Harrison map induces an isomorphism of the Witt rings of the fields involved (see [9, Theorem XII.1.8]).

Take now a fixed real closed field $\Bbbk$ and let K, L be two formally real algebraic function fields over $\Bbbk$. Denote $\Omega(K)$, $\Omega(L)$ the sets of points of K, L trivial on $\Bbbk$. Among all the points of K (resp. L) we select those having the residue field isomorphic to $\Bbbk$. Following [4], we call such points *real* and denote the set of all real points γ^K (resp. γ^L). It is a real curve over $\Bbbk$. Fix an orientation (see [4, §5]) of γ^K, γ^L. With a point $\mathfrak{p} \in \gamma^K$ we associate two orderings of K, consisting of all elements of K (treated as functions on γ^K), positive in right/left neighbourhood of $\mathfrak{p}$. We denote those ordering $P_+(\mathfrak{p})$ and $P_-(\mathfrak{p})$ respectively (see [6, §2]).

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Recall that a Harrison isomorphism $t\colon \dot K/\dot K^2 \to \dot L/\dot L^2$ is called *tame* (see [6, Definition 2.18]) if it maps 1-pt fans onto 1-pt fans. The tame Harrison map canonically induces a bijection $T\colon \gamma^K \to \gamma^L$ of the sets of real points of K and L. Namely, let $\mathfrak{p} \in \gamma^K$ be a real point of K and $P_+(\mathfrak{p})$, $P_-(\mathfrak{p})$ be the two orderings of K compatible with $\mathfrak{p}$ (for the notion of orderings compatible with valuation consult [8]), if t is tame, then it maps the fan $P_+(\mathfrak{p}) \cap P_-(\mathfrak{p})$ onto a 1-pt fan of L. Denote $\mathfrak{q} \in \gamma^L$ the point of L compatible with $t(P_+(\mathfrak{p}) \cap P_-(\mathfrak{p}))$. The bijection is then given by $T(\mathfrak{p}) := \mathfrak{q}$. It was shown in [6, Proposition 3.1, Lemma 3.6] that T is a homeomorphism with respect to Euclidean topologies of γ^K, γ^L. It is, thus, natural to ask for criteria for the existence of a tame Harrison isomorphism. One such a criterion was given already in [6, Theorem 3.8]. It was shown there that any homeomorphism $\gamma^K \to \gamma^L$ gives rise to an appropriate tame Harrison map. In particular, if γ^K and γ^L have the same number of semi-algebraically connected components then such a map does exist.

In this paper we present two more conditions for an existence of a tame Harrison map: Theorem 2.5 and Proposition 3.5. To this end we need to utilise the notion of a quaternion-symbol equivalence. Recall (see [6], [5]) that a quaternion-symbol equivalence of fields K, L with respect to (γ^K, γ^L) is the pair of maps (t, T) such that $t\colon \dot K/\dot K^2 \to \dot L/\dot L^2$ is an isomorphism and $T\colon \gamma^K \to \gamma^L$ a bijection and such that a local quaternion algebra $\left(\frac{f,g}{K_\mathfrak{p}}\right)$ splits if and only if the local quaternion algebra $\left(\frac{tf,tg}{L_{T\mathfrak{p}}}\right)$ splits for all square classes $f, g \in \dot K/\dot K^2$ and every point $\mathfrak{p} \in \gamma^K$. In general a quaternion-symbol equivalence does not preserve -1 but it is easy to show (see [6, Proposition 2.6]) that there exists a quaternion-symbol equivalence iff there exists one that maps $-1 \in \dot K/\dot K^2$ to $-1 \in \dot L/\dot L^2$. In this paper we consider only those quaternion symbol equivalences that preserve -1. Moreover, we implicitly assume a quaternion-symbol equivalence to be taken always with respect to (γ^K, γ^L). Hence in what follows, unless stated otherwise, the phrase 'a quaternion-symbol equivalence' actually means 'a quaternion-symbol equivalence (with respect to the sets of real points) that preserves -1'. It was shown in [7, Theorem 3.1] that any quaternion-symbol equivalence preserves the parity of a valuation in the sense that

$$\operatorname{ord}_\mathfrak{p} f \equiv \operatorname{ord}_{T\mathfrak{p}} tf \pmod 2 \qquad \text{for every } f \in \dot K/\dot K^2 \text{ and every } \mathfrak{p} \in \gamma^K.$$

A tame Harrison isomorphism together with the canonically induced bijection $T\colon \gamma^K \to \gamma^L$ is a quaternion-symbol equivalence (see [6, Proposition 3.1]). Conversely, if (t, T) is a quaternion-symbol equivalence (recall that we implicitly assume that t maps -1 to -1), then t is a tame Harrison map.

In Theorem 2.5 we prove that a Harrison map for which the diagram 2.6 commutes is tame. This result is a real counterpart of the analogous result proved for global fields in [14]. Next, in Proposition 3.4 we show that any tame

Harrison map induces an integral equivalence. The converse of this is generally false. However in Proposition 3.5 we show that the *existence* of an integral equivalence implies the *existence* of a tame Harrison map.

2. Isomorphism of a coproduct ring

Paper [14] presents a criterion for a Hilbert-symbol equivalence of global fields to be tame (recall, [11], [13], that a Hilbert-symbol equivalence is a predecessor of a quaternion-symbol equivalence, in particular those two terms coincide on global function fields). Theorem 2.5, that we present in this section, can be treated as a certain analogue of that result.

First we need the following lemma. Here, for a non-empty set I, we denote $\mathbb{Z}^{(I)}$ a coproduct of card(I) copies of $\mathbb{Z}$. Obviously, $\mathbb{Z}^{(I)}$ is a group but we can augment it with a ring structure (without a unit!) by considering a componentwise multiplication. In particular, if we denote $\delta_i \in \mathbb{Z}^{(I)}$ a 'Kronecker delta' (i.e. an element having 1 on i-th coordinate and zeros everywhere else), then we have

$$\delta_i \cdot \delta_j = \begin{cases} \delta_i, & \text{if } i = j \\ 0, & \text{if } i \neq j. \end{cases} \tag{2.1}$$

Lemma 2.2. *If $\Phi\colon \mathbb{Z}^{(I)} \to \mathbb{Z}^{(I)}$ is a ring automorphism of $\mathbb{Z}^{(I)}$, then there exists such a permutation σ of the set I that*

$$\Phi\big((n_i)_{i\in I}\big) = \big(n_{\sigma(i)}\big)_{i\in I}.$$

Proof. Fix $i \in I$. The element δ_i is then a unit of a subring $\mathbb{Z}_i$ of the ring $\mathbb{Z}^{(I)}$, defined by $\mathbb{Z}_i := \big\{(x_j)_{j\in I} : \ x_j = 0 \text{ for } j \neq i\big\} \cong \mathbb{Z}$. Moreover $\mathbb{Z}_i = \delta_i \cdot \mathbb{Z}^{(I)}$, hence

$$\Phi(\mathbb{Z}_i) = \Phi(\delta_i)\Phi(\mathbb{Z}^{(I)}) = \Phi(\delta_i) \cdot \mathbb{Z}^{(I)}. \tag{2.3}$$

Thus, we need only to show that there is $j \in I$ such that $\Phi(\delta_i) = \delta_j$. Let $\Phi(\delta_i) = \beta_1 + \cdots + \beta_n$ where $\beta_k \in \mathbb{Z}_{i_k} < \mathbb{Z}^{(I)}$ are the all nonzero coordinates of $\Phi(\delta_i)$. Now $\delta_i^2 = \delta_i$ and so

$$\beta_1 + \cdots + \beta_n = \Phi(\delta_i^2) = \Phi(\delta_i)^2 = (\beta_1 + \cdots + \beta_n)^2 = \beta_1^2 + \cdots + \beta_n^2.$$

Here the last equality follows from (2.1). Consequently $\beta_k^2 = \beta_k \in \mathbb{Z}_{i_k} \cong \mathbb{Z}$, hence $\beta_k = \delta_{i_k}$.

Now $\mathbb{Z}_i$ is a free $\mathbb{Z}$-module of rank 1 and so is its image $\Phi(\mathbb{Z}_i)$. On the other hand

$$\Phi(\mathbb{Z}_i) = (\delta_{i_1} + \cdots + \delta_{i_n}) \cdot \mathbb{Z}^{(I)} = \mathbb{Z}_{i_1} \oplus \cdots \oplus \mathbb{Z}_{i_n}$$

is a free $\mathbb{Z}$-module of rank n. Therefore, $n = 1$ and $\Phi(\delta_i) = \delta_{i_1}$. □

Now, if instead of a single ring $\mathbb{Z}^{(I)}$ we consider two such rings, then the above lemma transcribes to:

Corollary 2.4. *Let A, B be two non-empty sets of the same cardinality. If $\Phi\colon \mathbb{Z}^{(A)} \to \mathbb{Z}^{(B)}$ is a ring isomorphism, then there exists a bijection $T\colon A \to B$ such that*

$$\Phi\big((n_i)_{i\in A}\big) = \big(n_{Ti}\big)_{i\in A}.$$

We are now ready to state our first main result. Recall that any Harrison map $t\colon \dot K/\dot K^2 \to \dot L/\dot L^2$ induces the isomorphism of Witt rings $WK \to WL$ sending $\langle f_1,\dots,f_n\rangle$ to $\langle tf_1,\dots,tf_n\rangle$. Such an isomorphism is called a *strong* Witt isomorphism associated to t.

Theorem 2.5. *Let $t\colon \dot K/\dot K^2 \to \dot L/\dot L^2$ be a Harrison map and let $i_t\colon WK \to WL$ denote a strong Witt isomorphism associated with t. If the diagram*

$$\begin{array}{ccc} WK & \xrightarrow{\partial_K} & \bigoplus_{\mathfrak p\in\gamma^K} WK(\mathfrak p) \\ {\scriptstyle i}\big\downarrow & & \big\downarrow{\scriptstyle \Phi} \\ WL & \xrightarrow[\partial_L]{} & \bigoplus_{\mathfrak q\in\gamma^L} WL(\mathfrak q) \end{array} \tag{2.6}$$

commutes, where the vertical arrows are ring isomorphisms, then t is tame.

P r o o f. For every point $\mathfrak p\in\gamma^K$ we have $K(\mathfrak p)\cong \Bbbk$, likewise for every point $\mathfrak q\in\gamma^L$. Hence $\bigoplus_{\mathfrak p\in\gamma^K} WK(\mathfrak p)\cong \mathbb{Z}^{(\gamma^K)}$ and $\bigoplus_{\mathfrak q\in\gamma^L} WL(\mathfrak q)\cong \mathbb{Z}^{(\gamma^L)}$. By the previous corollary the isomorphism Φ induces the bijection $T\colon \gamma^K\to\gamma^L$. Thanks to [6, Theorem 3.2] and [7, Theorem 3.1], all we need to do is to prove that (t,T) is a quaternion-symbol equivalence.

We claim that the pair (t,T) preserves a parity of a valuation in the sense that $\operatorname{ord}_{\mathfrak p} f \equiv \operatorname{ord}_{T\mathfrak p} tf \pmod 2$ for every $f\in \dot K/\dot K^2$ and every $\mathfrak p\in\gamma^K$. Indeed, take a point $\mathfrak p\in\gamma^K$, fix its uniformizer p and let $q := tp$. Consider the second residue homomorphism $\partial_{\mathfrak p}\colon WK_{\mathfrak p}\to WK(\mathfrak p)\cong\mathbb{Z}$. We have $\partial_{\mathfrak p}\langle p\rangle = 1$, so using the commutativity of (2.6) we obtain

$$1 = \big(\Phi\,|_{\mathbb{Z}_{\mathfrak p}}\circ\partial_K\big)(\langle p\rangle) = \big(\pi_{T\mathfrak p}\circ\partial_L\big)(\langle tp\rangle) = \partial_{T\mathfrak p}(\langle q\rangle),$$

here $\pi_{T\mathfrak p}\colon \mathbb{Z}^{(\gamma^K)}\to\mathbb{Z}_{T\mathfrak p}$ denotes the projection. Thus q is a uniformizer of $T\mathfrak p$. Similarly $-p$ is mapped to $-q$ and this proves our claim.

In particular this implies that t factors through $\dot K^2_{\mathfrak p}$ for every point $\mathfrak p\in\gamma^K$. Indeed, take a point $\mathfrak p\in\gamma^K$ and such a square class $f\in\dot K/\dot K^2$ that $f\in\dot K^2_{\mathfrak p}$

We then have $\partial_{\mathfrak{p}}\langle fp\rangle = 1$ and so the commutativity of (2.6) implies that also

$$\partial_{T\mathfrak{p}}(\langle tf \cdot q\rangle) = \left(\Phi\,\big|_{\mathbb{Z}_{\mathfrak{p}}} \circ \partial_K\right) = 1,$$

thus $tf \in L^2_{T\mathfrak{p}}$.

Take now two square classes $f, g \in \dot{K}/\dot{K}^2$ of K and a point $\mathfrak{p} \in \gamma^K$. Assume that a quaternion algebra $\left(\frac{f,g}{K_{\mathfrak{p}}}\right)$ splits. This is possible only if at least one of the elements: f, g, fg is a square in the completion $K_{\mathfrak{p}}$. As we have already noted, t preserves local squares, so tf, tg or $tftg$ must be a square in $L_{T\mathfrak{p}}$, which means that a quaternion algebra $\left(\frac{tf,tg}{L_{T\mathfrak{p}}}\right)$ splits. All in all, [7, Theorem 3.1] implies that (t, T) is tame in every point of γ^K and so [6, Theorem 3.2] implies that t is a tame Harrison map. □

3. Integral equivalence

Let $R(K)$ (respectively $R(L)$) denote the ring of regular functions on γ^K (resp. γ^L), for details see [1]. It is a Dedekind domain (see [12, §III.2]) and can be explicitly written as

$$R(K) = \{f \in K : \ \mathrm{ord}_{\mathfrak{p}} f \geq 0 \text{ for all } \mathfrak{p} \in \gamma^K\}.$$

By [10, Corollary IV.3.3] and [4, Theorem 11.2] the following sequence is exact:

$$0 \to WR(K) \to WK \to \bigoplus_{\mathfrak{p}\in\gamma^K} WK(\mathfrak{p}) \to \mathbb{Z}^M \to 0, \tag{3.1}$$

where M is the number of semi-algebraically connected components of γ^K. Of course we can build a similar sequence for the field L, as well:

$$0 \to WR(L) \to WL \to \bigoplus_{\mathfrak{q}\in\gamma^L} WL(\mathfrak{q}) \to \mathbb{Z}^N \to 0. \tag{3.2}$$

Following the terminology of [2], [7] we shall say that a quaternion-symbol equivalence (t, T) is *integral* if the induced strong isomorphism of Witt rings $WK \to WL$ maps $WR(K)$ onto $WR(L)$. Here, as in the rest of this paper, we identify $WR(K)$ with its image in WK under (3.1). First let us note down an immediate observation.

Observation 3.3. *If the sequences* (3.1) *and* (3.2) *are isomorphic, then there exists a tame Harrison map* $\dot{K}/\dot{K}^2 \to \dot{L}/\dot{L}^2$.

Indeed, if (3.1) and (3.2) are isomorphic, then $M = N$, so γ^K and γ^L both have the same number of semi-algebraically connected components. Hence, [6, Corollary 3.9] implies the assertion.

Proposition 3.4. *Let $t\colon \dot K/\dot K^2 \to \dot L/\dot L^2$ be a tame Harrison map and let $T\colon \gamma^K \to \gamma^L$ be the associated bijection, then (t,T) is an integral quaternion-symbol equivalence.*

Proof. Fix a quadratic form φ over K and assume that $\varphi \in WR(K) \subset WK$. It follows from the exactness of (3.1) that $\partial_{\mathfrak p}\varphi = 0$ for every point $\mathfrak p \in \gamma^K$. Let $\varphi = \langle f_1,\dots,f_k\rangle + \langle p\rangle\langle f_{k+1},\dots,f_n\rangle$ with $\operatorname{ord}_{\mathfrak p} p \equiv 1 \pmod 2$ and $\operatorname{ord}_{\mathfrak p} f_i \equiv 0 \pmod 2$ for $1 \le i \le n$. Then $0 = \partial_{\mathfrak p}\varphi = \operatorname{sgn}\langle f_{k+1}(\mathfrak p),\dots,f_n(\mathfrak p)\rangle$, now t being tame preserves local signs (see [6, Lemma 3.3]), hence

$$0 = \big\langle tf_{k+1}(T\mathfrak p),\dots,tf_n(T\mathfrak p)\big\rangle = \partial_{T\mathfrak p} i_t(\varphi).$$

Thus, exactness of (3.2) implies that $i_t\varphi \in WR(L)$. □

It is natural to ask whether the opposite implication is also true: whether integrality implies tameness. Unfortunately, in general the answer is negative. To see this consider a bijection $T\colon \mathbb P^1(\mathbb R)\setminus\{\pm1\} \to \mathbb P^1(\mathbb R)\setminus\{\pm1\}$ of a projective line $\mathbb P^1(\mathbb R)$ with points ±1 excluded, which inverts the interval $(-1,1)$. Namely,

$$T\,\big|_{(-1,1)} = -\operatorname{id}, \qquad T\,\big|_{\mathbb P^1(\mathbb R)\setminus[-1,1]} = \operatorname{id}.$$

Now [6, §4] implies that T gives rise to a Harrison automorphism t of $\mathbb R(\dot X)/\mathbb R(\dot X)^2$. It is straightforward to check that (t,T) is integral but t maps

$$t\big(P_-(-1)\big) = P_-(-1) \qquad t\big(P_+(-1)\big) = P_-(1)$$
$$t\big(P_-(1)\big) = P_+(-1) \qquad t\big(P_+(1)\big) = P_+(1),$$

hence, it does not preserve 1-pt fans and so it is not tame.

Nevertheless, although we cannot expect an integral equivalence to be tame, the following existential result does hold.

Proposition 3.5. *If there exists an integral quaternion-symbol equivalence of K and L, then there exists a tame Harrison map $\dot K/\dot K^2 \to \dot L/\dot L^2$.*

Before we proceed with the proof, let us first make a simple observation. Denote

$$\mathbb E(K) := \big\{ f \in \dot K/\dot K^2 : \operatorname{ord}_{\mathfrak p} f \equiv 0 \pmod 2 \text{ for every } \mathfrak p \in \gamma^K \big\}.$$

Now it follows from the exactness of (3.1):

Observation 3.6. *Let $f \in \dot K/\dot K^2$ be a square class. Then $f \in \mathbb E(K)$ if and only if $\langle f\rangle \in WR(K)$.*

Now equipped with the above observation we are ready to prove 3.5.

P r o o f. Assume that the asserted Harrison map does not exists. Hence, by [6, Corollary 3.9], the real curves γ^K and γ^L have different numbers of semi-algebraically connected components. Let $\gamma_1^K, \dots, \gamma_M^K$ be the components of γ^K and $\gamma_1^L, \dots, \gamma_N^L$ be the components of γ^L. Without loss of generality we may assume that $M > N$. By [6, §4] we can find finite subsets $S \subset \gamma^K$, $S' \subset \gamma^L$ and a quaternion-symbol equivalence (t, T) of K, L *with respect to* $(\gamma^K \setminus S, \gamma^L \setminus S')$. (This is the only part of this paper, where we consider a quaternion-symbol equivalence with respect to anything else than (γ^K, γ^L)).) It is tame at every point of $\gamma^K \setminus S$ (see [7, Theorem 3.1]), hence in particular it preserves local signs at those points: $\operatorname{sgn} f(\mathfrak{p}) = \operatorname{sgn}(tf)(T\mathfrak{p})$ for every $f \in \dot{K}/\dot{K}^2$ and $\mathfrak{p} \in \gamma^K \setminus S$.

By the means of [4, Theorem 2.10], for every $1 \le i \le M$, we can find a function $g_i \in K$ such that g_i is regular on γ_i^K, positive definite on $\gamma^K \setminus \gamma_i^K$ and negative definite on γ_i^K. In particular, by the above observation, $\langle g_i \rangle \in WR(K)$. Hence the integrality implies $\langle tg_i \rangle \in WR(L)$. Consequently, using again the above observation, we have $tg_i \in \mathbb{E}(L)$, which means that it has a constant sign on every component of γ^L.

Now, since γ^K has more components than γ^L, thus at least one component of γ^K must be mapped into more than one component of γ^K. To express this precisely: we can find $1 \le j, k \le M$ and $1 \le l \le N$ such that both $T\gamma_j^K \cap \gamma_l^L$ and $T\gamma_k^K \cap \gamma_l^L$ are open and non-empty. Therefore, tg_j is positive definite on $T\gamma_k^K \cap \gamma_l^L$ and negative definite on $T\gamma_j^K \cap \gamma_l^L$, so it changes sign on γ_l^L a contradiction. □

REFERENCES

[1] BOCHNAK, J.—COSTE, M.—ROY, M.-F.: *Real algebraic geometry.* Ergeb. Math. Grenzgeb. (3), Vol. 36, Springer-Verlag, Berlin, 1998.

[2] CZOGAŁA, A.: *Równoważność Hilberta ciał globalnych.* Pr. Nauk. Uniw. Śl. Katow. 1969, Wydawnictwo Uniwersytetu Śląskiego, Katowice, 2001.

[3] KNEBUSCH, M.: *On algebraic curves over real closed fields I*, Math. Z. **150** (1976), 49 70.

[4] KNEBUSCH, M.: *On algebraic curves over real closed fields II*, Math. Z. **151** (1976), 189 205.

[5] KOPROWSKI, P.: *Local-global principle for Witt equivalence of function fields over global fields*, Colloq. Math. **91** (2002), 293 302.

[6] KOPROWSKI, P.: *Witt equivalence of algebraic function fields over real closed fields*, Math. Z. **242** (2002), 323 345.

[7] KOPROWSKI, P.: *Integral equivalence of real algebraic function fields*, Tatra Mt. Math. Publ. **32** (2005), 53 61.

[8] LAM, T. Y.: *Orderings, Valuations and Quadratic Forms.* CBMS Reg. Conf. Ser. Math. 52, Published for the Conference Board of the Mathematical Sciences, Washington, DC, 1983.

[9] LAM, T. Y.: *Introduction to Quadratic Forms Over Fields.* Grad. Stud. Math. 67, American Mathematical Society, Providence, RI, 2005.
[10] MILNOR, J.—HUSEMOLLER, D.: *Symmetric bilinear forms*, Springer-Verlag, New York, 1973.
[11] PERLIS, R.—SZYMICZEK, K.—CONNER, P. E.—LITHERLAND, R.: *Matching Witts with global fields.* In: Recent Advances in Real Algebraic Geometry and Quadratic Forms (Berkeley, CA, 1990/1991; San Francisco, CA, 1991). Contemp. Math. 155, Amer. Math. Soc., Providence, RI, 1994, pp. 365–387.
[12] STICHTENOTH, H.: *Algebraic function fields and codes.* Universitext, Springer-Verlag, Berlin, 1993.
[13] SZYMICZEK, K.: *Matching Witts locally and globally*, Math. Slovaca **41** (1991), 315–330.
[14] SZYMICZEK, K.: *A characterization of tame Hilbert-symbol equivalence*, Acta Math. Inform. Univ. Ostraviensis, **6** (1998), 191–201.

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