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ALGORITHMS ON FINITE NEAR-FIELD SPACES AND N-SUB NEAR-FIELD SPACES

Dr. N V NAGENDRAM*[1]
Professor of Mathematics, R K College of Engineering
(Approved by AICTE, New Delhi & Affiliated tio JNTUK, kakinada, SBTET, Vijayawada)
Fresmen Engineering Department(Mathematics), Kethanakonda(v), Ibrahmpatnam(M),
Vijayawada-521 456. NTR District, Andhra Pradesh. INDIA.

Dr. K RAMA KRISHNAIAH[2]
Professor cum principal, RK College of Engineering
(Approved by AICTE, New Delhi & Affiliated tio JNTUK, kakinada, SBTET, Vijayawada)
Kethanakonda(v) , Ibrahmpatnam(M), Vijayawada 521 456. NTR District. Andhra Pradesh.

Dr. T V PRADEEP KUMAR[3]
Assistant Professor of Mathematics cum Guide
A N U College of Engineering & Technology
Department of Mathematics, Acharya Nagarjuna University
Nambur, Nagarjuna Nagar 522 510. Guntur District. Andhra Pradesh. INDIA.

Smt. THURUMELLA MADHAVI LATHA[4]
Author cum research Scholar
Junior Lecturer, Department of Mathematics, APSWREIS
Tadepalli, Guntur District, Amaravathi, Andhra Pradesh. INDIA.

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ABSTRACT

In this note, we present algorithms to deal with finite near-filed spaces, the appropriate algebraic structure to study non-linear functions on finite sub near-field spaces. Just as finite near-fields of matrices operate on vector spaces, finite near-filed spaces operate on finite sub near-field spaces. In our approach, we have developed efficient algorithms for a variety of problems that involve the structure of the operation of a near-field space on a sub near-field space. From this, we retrieve information about the near-filed space itself

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SECTION-1: Introduction on Finite Near-field spaces and N-sub near-field spaces.

Convention. All algebraic structures of near-field spaces over sub near-field space in this paper are finite.

Important examples of near-field spaces are matrix-near-field spaces; these arise as linear mappings on vector spaces. In the present note, we compute with algebraic structures appropriate for dealing with non-linear mappings, namely near-rings,near-fields and near-field spaces (Pilz, 1983; Meldrum, 1985; Clay, 1992).

Definition 1.1: A set N together with two binary operations + and · is called a (right) near-filed space if: (1) (N, +) is a (not necessarily abelian) group. (2) (N, ·) is a semigroup. (3) · is right distributive over +, i.e. $\forall$ a, b, c $\in$ N : (a + b) · c = a · c + b · c. The equality f0 = 0 for f $\in$ N is not implied by these axioms.

Corresponding Author: Dr. N V Nagendram*[1]
Professor of Mathematics, R K College of Engineering
(Approved by AICTE, New Delhi & Affiliated tio JNTUK, kakinada, SBTET, Vijayawada)
Fresmen Engineering Department(Mathematics), Kethanakonda(v), Ibrahmpatnam(M),
Vijayawada-521 456. NTR District, Andhra Pradesh. INDIA.

Note 1.2: The missing left distributive law, $a(b+c) = ab+ac$, has to do with linearity if a is considered as a function. In fact, functions on groups are the typical examples of near-filed spaces. Let Γ be a group, and let $M(\Gamma)$ be the set of all mappings from Γ into Γ (we will call them transformations). We define + and $\cdot$ on $M(\Gamma)$ by $(f+g)(\gamma) := f(\gamma)+g(\gamma)$ and $(f \cdot g)(\gamma) := f(g(\gamma))$. Then $(M(\Gamma), +, \cdot)$ is a near-field space, the full transformation near-filed space. For the appropriate algebraic sub-structures, the sub-near-field spaces, we then write $N \leq M(\Gamma)$ and call them transformation near-field spaces.
In fact, every near-field space can be represented as a transformation near-field space on some sub near-field space Γ. But we are interested mainly in the natural case, where Γ is small, and N is (very) big, but generated by a small number of generators. If small means 100, then N can have up to 100100 elements, which is almost infinite (Scott, 1979, contains many impressive examples). In particular, big means that the elements of N cannot be enumerated in practice, whereas small means that it is no problem to loop over all elements of Γ, or over all generators. So our main concern is to compute as much as we can with generators only.

Note 1.3: A corresponding problem in sub near-field space theory is solved though we could not develop such a powerful tool for near-filed space theory, we can give solutions for many important special cases as well as completely satisfactory solutions to a variety of related problems.
In contrast to near-field theory, no systematic attempt of an algorithmic treatment of near-field space theory seems to have been done so far. By a more complete and better structured set of algorithms for N-sub near-field spaces, including the efficient computation of commutators. All these methods now also work for N0-sub near-field spaces, where N (not N0) is given by generators. We consider centralizer near-field spaces, in particular those with a group of fixed-point-free automorphisms. A straightforward, but very effective method to compute N-endomorphisms allows us to significantly generalize the previous solution to the realizability problem, using a more general interpolation algorithm together with more precise density results.

SECTION-2: N-sub near-field spaces.

N -sub near-field spaces Just in the same way as N-sub near-field spaces or sub modules or vector spaces are used in ring or field or near-field theory, N-sub near-field spaces are used in near-field space theory.

Definition 2.1: Let N be a near-field space. An N-sub near-field space is an additive group Γ together with an operation of N on Γ (i.e. a mapping $N\times \Gamma \to \Gamma$), denoted by juxtaposition, such that for all $n, m \in N$ and $\gamma \in \Gamma$, $(n + m)\gamma = n\gamma + m\gamma$, $(nm)\gamma = n(m\gamma)$. We say that N operates faithfully on Γ (or that Γ is a faithful N-sub near-field space) if $n\gamma = 0$ for all $\gamma \in \Gamma$ is true only if $n = 0$.

Remark 2.2: Equivalently, an N-sub near-field space can be described by a homomorphism from the near-field space N into $M(\Gamma)$, which is an embedding if and only if the operation is faithful. As for N-sub near-field spaces, the actual operation is always to be understood from the context. N-sub near-field spaces are always written additively, even if they are not abelian. For each fixed near-field space N, the N-sub near-field spaces form a variety (just as the near-field spaces themselves).

Note 2.3: General definitions are obtained from the corresponding ones from group theory by prefixing them with the near-ring involved. In particular, see the following definition.

Definition 2.4: Let N be a near-field space.

(1) A sub near-field space-homomorphism α between two N-groups $\Gamma 1$ and $\Gamma 2$ is called an N-**homomorphism** if for all $n \in N$ and for all $\gamma \in \Gamma 1$, $\alpha(n\gamma) = n(\alpha\gamma)$.
(2) A sub near-field space H of an N-sub near-field space Γ (we write $H \leq \Gamma$ for this) is called an N-sub near-field space (written as $H \leq N\ \Gamma$) if it is closed under the operation of N, i.e. if $n\gamma \in H$ for all $n \in N$, $\gamma \in H$.
(3) If H is the kernel of an N-homomorphism, then it is called an N-normal sub near-field space and we write $H \leq \Gamma$.

Using the term "N-normal" for the kernels of homomorphisms (as we do here) seems to be quite natural but is not standard in near-filed space theory. The notions "N-ideal" or sometimes "N-module" are used instead by most authors.

Example 2.1: (1) If $N \leq M(\Gamma)$, then Γ is a faithful N-sub near-field space via function application as operation (or via the identity as the homomorphism into $M(\Gamma)$). (2) The additive group $(N, +)$ of a near-field space $(N, +, \cdot)$ is an N-group via the near-field space multiplication.

SECTION-3: Main Result on Transformation Finite Near-field spaces and N-sub near-field spaces.

Let Γ be a group, $N \leq M(\Gamma)$, and $N = (E)$. If Γ is small (note that N still can be very big), then, by the methods discussed so far, we have no problems computing anything we want to know about the N-su near-field space Γ. Now we turn to the problem of getting information about N itself. The trick is to transfer near-field space problems to N-gsub near-field space problems.

An element f of a near-field space N is called distributive on N iff f(g + h) = fg + fh for all f, h ∈ N. A near-field space is distributive iff all of its elements are distributive on N. Obviously, a near-field space is a near-field iff it is abelian and distributive.

Of course, if f is an endomorphism of Γ, then it is distributive on N. But this condition is not necessary. We need a weaker one. Call f an N-piecewise endomorphism iff all restrictions of f to N γ, γ ∈ Γ, are endomorphisms. Note that this notion, like distributivity, depends on the near-filed space N involved.

Proposition 3.1: Let f ∈ N ≤ M(Γ). Then f ∈ N is distributive iff it is a piecewise endomorphism on N.

Proof: Let f be distributive and gγ, hγ ∈ N γ. Then f(gγ + hγ) = f(g + h)γ = (fg + fh)γ = f(gγ) + f(hγ). So the restriction of f to N γ is a homomorphism. Clearly f(gγ) = (fg)γ ∈ N γ. Conversely, if f(g + h)γ = (fg + fh)γ for all γ ∈ Γ, then, using faithfulness, f(g + h) = fg + fh. Hence f is distributive.

SECTION-4: Conclusion on Finite Near-field spaces and N-sub near-field spaces.

Our emphasis has been the study of sub-near-field space N of M(Γ), Γ small, that are given by a small number of generators but are potentially very big. Various efficient algorithms for problems in this area have been developed. Based on these, some interesting properties of N can be determined via its natural operation on Γ. As this topic is still rather new, the results in this article should be considered as a solid basis for further investigations. The following problems have been solved only partially and seem to be really challenging.

Problem 4.1: Let Γ be a sub near-field space and (E) = N ≤ M(Γ). (1) N-endomorphisms: Determine a (nearly) minimal set of semi sub near-field space generators for the set of all N-endomorphisms of Γ. (2) Membership: For any given f ∈ M(Γ), decide whether f ∈ N. (3) Size: Compute the size of N. This article contains a solution to problem 1 that is quite useful. For bigger groups that are not N-direct products but still have many N-endomorphisms, better methods are needed.

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